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Effect of aircraft traffic on the structure and response of asphalt

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ABSTRACT

As part of a broader investigation into distress in the asphalt surface layer at a major Australian airport, significant testing was performed on cores taken from both trafficked and un-trafficked zones within two different asphalt mixes. Samples were compared for aggregate orientation, relative density, resilient modulus, wheel tracking, interface shear resistance and cyclic shear creep. There was a significant difference between the results from the trafficked and un-trafficked samples. It appeared that the changes to the asphalt caused by 'straight-through' aircraft trafficking increased the asphalt surface's resistance to the severe shear forces induced by heavy braking and cornering of aircraft. It is suggested that where operationally practical, the surface should be exposed to frequent and heavy straight-through traffic for as long as possible prior to allowing harsh braking and turning operations. This would reduce the risk of early life horizontal deformations occurring in the heavy braking zones.

Introduction

As part of a broader investigation into distress in the asphalt surface layer at a major Australian airport, significant testing was performed on cores taken from the trafficked and un-trafficked portions of two different asphalt mixes. The two asphalts were of the same approximate age, binder and mix specification, with the source of the fine aggregate (dust) being the only substantial difference. The two dust sources are referred to as Quarry T and Quarry M. The surface was generally 50–60 mm thick and comprised airport-quality asphalt. At the time of coring and testing, the surface was approximately two years old. Both mixes were manufactured using M1000 Multigrade binder complying with the requirements of Australian Standard (AS) 2008, Australia's standard specification for non-polymer modified binders for asphalt paving. One asphalt mix was observed to be performing well while the other was suffering from multiple areas of isolated horizontal deformation, characterised by curving of the sawn grooves in the heavy aircraft braking zones. Table 1 shows the key characteristics and mix design parameters for the two materials.

A significant difference was noticed in forensic test results from areas of the pavement that were frequently trafficked by aircraft and those that were not. This prompted a specific assessment of the effect of aircraft traffic on the internal structure and response of the surface layer.

The samples were recovered from the two runways at the airport. The airport was found to accommodate in the order of 220,000 aircraft movements per annum, reasonably evenly distributed across the two runways. As a major international airport, the regular operating traffic included B737, B767, A330, B747, B777 and A380 aircraft. These aircraft generally have tire pressures in the order of 1.4 to 1.5 MPa on wheel loads of 20 to 25 tonnes. Cores were recovered from trafficked portions along both runways at 3–4 m (trafficked) and 8–10 m (un-trafficked) offsets from the runway centre lines.

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Table 1
Key asphalt parameters.

Parameter	Asphalt mix	
Dust source	Quarry T	Quarry M
Observed performance	Sound	Horizontally deforming
Methyl blue value for dust source (%)	4	8
Multigrade binder content (%)	5.8	5.8
Hydrated lime content (%)	1	1
Maximum nominal size (mm)	14	14
Passing 75 μm sieve (%)	6.1	6.5
Marshal stability (kN)	15.3	17.5
Marshal flow (mm)	3.3	3.1

The aim of this research was to compare various properties and responses of trafficked and un-trafficked asphalt. Firstly existing knowledge is summarised, covering asphalt structure characterisation, the structural factors affecting asphalt performance, interface shear and cyclic shear resistance, as well as previous investigations that considered the impact of traffic. The adopted research methods are then described and the results from each of the test methods are presented and compared using statistical analysis techniques. Finally, conclusions are made and the implications for future work are described. The cause of the Quarry M dust asphalt's poor performance is specifically excluded from this work.

Background

Asphalt is a material of very complex mechanical behaviour. Asphalt's internal composition is the agglomeration of binder, active filler, fine and coarse aggregate. The mastic exhibits plastic, elastic and viscous properties which are inherently temperature dependent (Drescher et al., 2010). While the mastic dominates many mix properties, both the mastic and the aggregate skeleton are important to asphalt performance (Hassan et al., 2012). In fact, by mass, aggregate comprises some 95% of asphalt's structure and can therefore have a significant impact on the mechanical properties of a surface layer (Chen et al., 2005).

Characterisation of aggregate skeleton

The aggregate skeleton within asphalt can be measured directly through microstructure assessment or via bulk material characteristics using macrostructure measurements (Chen et al., 2005). For microstructure assessment two main approaches are commonly adopted:

- *X-ray Computer Tomography (XCT).* XCT provides an accurate 3D assessment of an aggregate structure. XCT is able to differentiate between a broad range of engineering materials with an accuracy of up to 5 μm (Tashman et al., 2007). Due to its non-destructive nature, XCT can be used to assess the same sample before, during and after wheel tracking or other performance test. It also offers the advantage of being able to measure air void distribution (Masad et al., 1999a).
- *Digital image analysis.* Digital image analysis is well established within the study of geomechanics of materials such as clays (Masad and Button, 2000). Digital image processing includes three major steps; image acquisition, image processing and image analysis (Tashman et al., 2007). Common software can rapidly calculate the number of contact points, aggregate orientation distribution and aggregate segregation measures (Coenen et al., 2012). Requiring only a digital camera and software, digital image analysis offers an economical and rapid assessment of the aggregate skeleton, but only on a 2D basis.

Significant research has been conducted on the structure of asphalt skeletons using both techniques. Image analysis was used by Hamzah et al. (2013) to compare the aggregate skeletons produced by different compaction methods. Lv et al. (2011) analysed the voids, aggregate orientation and segregation of numerous asphalt mixes using similar techniques. In contrast, Masad et al. (1999a) used XCT to assess the air voids distribution and segregation of various asphalt mixtures prepared with various compaction methods. The effect of different compaction methods on asphalt structure was also investigated by Kutay et al. (2010) using XCT. Tashman et al. (2005) used XCT to characterise the aggregate structure, but only as a means of verifying a viscoplastic model for asphalt deformation.

Structural factors affecting performance

Research has shown asphalt performance to be affected by variation in the orientation and spatial distribution of coarse aggregate particles (Coenen et al., 2012). The number and length of contact points is known to influence asphalt's shear strength (Masad et al., 1999b) as does the distribution of the air voids within the sample (Masad et al., 1998). Coarse and fine aggregate angularity provides an indication of aggregate internal friction and deformation resistance (Holleran et al., 2008). For asphalt samples of identical mix design and construction process, changes in the orientation of the particles within the aggregate skeleton can explain differences in performance (Chen et al., 2005).

Aggregate orientation

Aggregate orientation cannot be expressed as a single value or described by a single parameter (Hunter et al., 2004). Many researchers have used a combination of average angle of inclination ($\hat{\theta}$) and vector magnitude (Δ) Masad et al., 1998; Hamzah et al., 2013; Tashman et al., 2007; Bessa et al., 2012; Chen et al., 2005; Reyes and Zanzotto, 2007; Lv et al., 2011. These concepts were advanced to their current form by Curray (1956) and are defined in Eqs. (1) and (2).

$$\Delta\ (\%) = \frac{100}{n}\sqrt{\left(\sum \sin 2\theta_k\right)^2 + \left(\sum \cos 2\theta_k\right)^2} \tag{1}$$

$$\hat{\theta}\ (^\circ) = \frac{\sum |\theta_k|}{n} \tag{2}$$