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Durability assessment of asphalt binder

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HIGHLIGHTS

- AASHTO M 320 lacks sensitivity and passes many binders of low durability.
- DENT testing separates binders with a high degree of sensitivity in ductile failure.
- Grade losses due to extended PAV aging are correlated with losses in the extended BBR.
- Limiting EBBR grades are highly correlated with limiting phase angle temperatures.

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ABSTRACT

Test results are presented for 24 asphalt binders with the aim to compare various measures of durability. Surprisingly high correlations were found between disparate measures of durability but practical considerations make certain tests preferable. A comparison is provided between AASHTO M 320 grades, critical crack tip opening displacements, extended bending beam rheometer grades and grade losses, differences in limiting temperatures (ΔT_c), and simple limiting phase angle temperatures ($T(\delta)$), on aged residues. The limiting phase angle temperature appears to be a convenient surrogate property that accurately predicts thermoreversible aging tendencies. Several binders performed poorly, likely because they contained unwarranted reclaimed asphalt.

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1. Introduction

Shortly after the implementation of the Superpave® specifications in the late 1990s, the Ministry of Transportation of Ontario (MTO) became concerned that roads were aging prematurely at significant cost to taxpayers. In 2003, MTO commissioned a pavement trial on Highway 655, north of Timmins, to validate the various test methods that were being proposed to improve the performance grading of asphalt [1]. The 3.5 km trial was built late in the season with binders of nearly identical low-temperature (−34 °C to −36 °C) Superpave grades from six different suppliers. In early 2004, the air temperature reached a record −48 °C, and the pavement surface reached the low design of −34 °C twice. (In 2005, it dropped below −30 °C on six additional days.) In spring 2005, the pavement had cracked to moderate degrees in four sections. As of 2011, section 1 remained largely free of distress with only few cracks (mostly through core holes) because it was made with a durable binder from Lloydminster [1]. The worst performer, section 4, was riddled with cracks and many potholes. Fig. 1 provides representative crack maps and photographs for both sections. Performance as seen in section 1 is rare today while the state represented by section 4 is rather common. The other four sections showed performance somewhere in between these two extremes. In 2014, as measured by MTO's Automated Road Analyzer, section 1 had remained largely free of thermal cracking distress, five sections had about 1000 m of cracks each, while the worst performer, section 4, had 2160 m of cracks, many potholes, and will soon be in need of significant end-of-life care (MTO,

Abbreviations: BBR, bending beam rheometer; CTOD, critical crack tip opening displacement; DCM, dichloromethylene; DENT, double-edge-notched tension; DSR, dynamic shear rheometer; FHWA ALF, Federal Highway Administration accelerated loading facility; LS, laboratory standard; MTO, Ministry of Transportation of Ontario; PAV, pressure aging vessel; PPA or P31, polyphosphoric acid; PG, performance grade; RAP, reclaimed asphalt pavement; REOB, recycled engine oil bottoms; RTFO, rolling thin film oven; SHRP, Strategic Highway Research Program.

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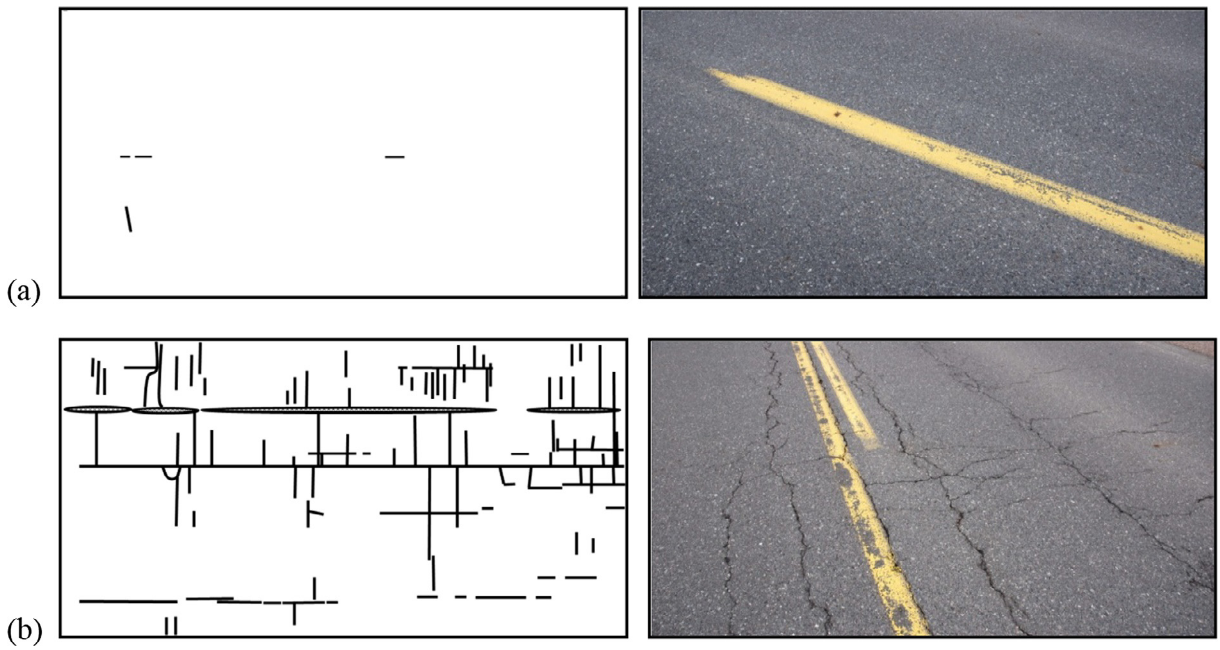

Fig. 1. Representative 2011 crack maps and photographs from 2003 Highway 655 pavement trial: (a) section 1 and (b) section 4. *Note:* Both crack maps are for randomly selected 50 m stretches of pavement. Photographs were not necessarily taken in areas where cracks were mapped.

Unpublished Data, 2014). Hence, this trial has shown rather starkly that the current AASHTO M 320 specification lacks accuracy and needs to be improved to provide a more correct measure of durability.

The term durability is defined by the Oxford Online dictionary as follows: "The quality of being durable. Capability of withstanding decay or wear." [2]. In the context of asphalt science and technology this means the ability to retain certain design properties that allow a flexible pavement to remain without significant distress for at least the design life and preferably longer. It is well documented in the literature that pavements of ostensibly the same design, subgrade, climate and traffic can show a wide range of lifespans. This is often due to differences in durability of material properties that are overlooked by current specification protocols [1]. An ideal durability test for asphalt binder can be defined as one that measures properties showing a high degree of correlation with performance in old age. It might be added that for practical reasons, the test should be easy to conduct on a small amount of material and be highly reproducible. An accurate test with a high degree of reproducibility lessens the risk for both users and producers of asphalt binder.

Certain asphalts high in naphthene aromatics, and low in paraffin and asphaltenes, can accommodate a significant amount of additional asphaltenes from oxidation and harden slightly over time [3]. California Valley crude produces such binder since it is largely naphthenic and its residue is low in asphaltenes. Binders produced from aromatic crudes can be oxidized for long times without much hardening. Many Western Canadian naphthenic crudes can produce material that is highly resistant to aging [4]. In contrast, inferior paraffinic crudes typically produce materials that are sensitive to both thermoreversible (wax crystallization, asphaltenes and resins precipitation, phase separation, collectively known as paraffinic demixing) and irreversible (oxidative) hardening [5–7]. Western Texas Intermediate and certain Argentinian crudes are examples that produce hardening-susceptible binders [8].

Air blown binders are another group of materials that lack durability. While they provide impressive grades in the laboratory, their performance in service has consistently been disappointing [9–11]. The air blown (oxidized) residues lack colloidal stability since additional asphaltenes introduced through the air blowing process are poorly accommodated and form gel-type structures that hinder stress relaxation during winter and spring. However, these binders do well in the grading process since the structure that forms the gel network takes time to consolidate when cold, and is therefore not captured in most current specification tests that prescribe only minimal conditioning.

Finally, the recent "greening" of the asphalt industry through the increased use of reclaimed asphalt pavement (RAP), recycled engine oil bottoms (REOB), asphalt shingle waste, and other unknowns has introduced performance challenges. Added to the problem is the increased use of wax-based warm asphalt technologies that facilitate compaction. Early pavement failures have become quite common and the causes for these can nearly always be traced back to deficient materials and processes. The incorrect and irresponsible use of certain recycled materials is costing user agencies more for less performance than in years past [12].

Our long-term vision is that paved roads last the lifespan expected from quality Western Canadian asphalt instead of the significantly reduced lifespans currently obtained in Ontario and elsewhere [11–13]. Longer-lasting roads with less need for repair cause less congestion, delay and danger for users. To achieve this, we will develop more comprehensive, theoretically-sophisticated tests to assess durability in asphalt. Our test methods will be available to producers and user agencies in Ontario and beyond. Our short-term objective is to develop a practical test protocol that can be done in a reproducible manner, in a short amount of time, with little material. Placing a minimum durability requirement in asphalt binder specifications will prevent premature failures in terms of fatigue, low temperature cracking and moisture damage.

2. Background

The two types of aging that are most relevant for long-term pavement performance are oxidative, or non-reversible aging, and thermoreversible aging. In the literature there are a great number of studies related to oxidative aging. This is likely because

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