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Performance grading of extracted and recovered asphalt cements

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HIGHLIGHTS

- Current pavement designs based on regular BBR grades fail to provide control of cold temperature cracking.
- It is imperative to test extracted and recovered asphalt cement for specification grading.
- Extended BBR grades for 3–5 year old pavements showed deficits ranging from 3 °C to 17.3 °C.
- Extended BBR grades correlate well with limiting phase angle temperatures.

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ABSTRACT

Binder extracted and recovered from pavement core samples at two different locations from 18 contracts showed small differences within contracts, well within the minor borderline acceptance criteria. Serious discrepancies were found between original tank sampled asphalt binder and material recovered from pavement cores. Regular BBR grades for recovered materials were on average 2.7 °C in deficit, which is considered high for 3–5 years of service. EBBR grades were on average 7.6 °C in deficit (range 3 °C to 17.3 °C). Equilibrium grades, after 72 h of conditioning, correlated well with temperatures where the phase angle reached 30° after minimal conditioning, suggesting that a limit on phase angle may provide a practical quality assurance measure.

1. Introduction

The replacement cost for all municipal roads in Canada is estimated at $330 billion, of which $48 billion-worth (15%) is considered to be in poor or very poor condition, and an additional $73 billion-worth (22%) in fair condition [24]. Pavement life expectancy can decrease due to increased traffic, anomalous weather (weakened polar vortex with more frequent extreme temperatures, both in summer and winter), reduced durability of the asphalt binder, the increased use of recycled materials, and perhaps other unknown factors.

Improved test methods for asphalt binder have been investigated for a considerable length of time as part of collaborations between the MTO, Queen's University, the FHWA, and other agencies ([8,9,47,10,73,74,40,11,41–43,38,44,65,34,56,60], others). This long term effort is aimed at reducing asphalt pavement cracking and improving pavement life expectancy.

Two of the products from the research are the DENT test [54,4] and EBBR test [55,5]. The methods have shown to be practical and

Abbreviations: AASHTO, American Association of State and Highway Transportation Officials; AC, asphalt cement; ASTM, American Society for Testing and Materials; ATSDR, Agency for Toxic Substances and Disease Registry; BBR, bending beam rheometer; CTOD, critical crack tip opening displacement; DCM, dichloromethylene; DENT, double-edge-notched tension; EBBR, extended bending beam rheometer; EPA, Environmental Protection Agency; ESEM, environmental scanning electron microscope; FHWA, United States Federal Highway Administration; II, intermediate temperature AASHTO M320 grade; LS, laboratory standard; MTO, Ministry of Transportation of Ontario; PAV, pressure aging vessel; PG, performance grade; QA, quality assurance; RAP, reclaimed asphalt pavement; RAS, recycled asphalt shingles; REOB, recycled engine oil bottoms; RTFO, rolling thin film oven; TCE, trichloroethylene; TP, test protocol; XX, high temperature AASHTO M320 grade; YY, low temperature AASHTO M320 grade.

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have been validated on a large number of pavement trial sections and full-scale contracts [47,73,74,41,42,44].

Both the DENT and EBBR were developed as binder tests. Their corresponding mixture equivalents were also explored at the time, but were not found to be as reproducible [9,66]. Reproducible DENT results for asphalt mixtures are hard to obtain due to alignment issues and the inherent variability in aggregate, mastic and binder structure around notches [9]. Reversible aging tests on asphalt mixtures are also significantly more complicated than those on binder due to the confounding effects of microcracking and gradual stiffening [66]. Geometries other than the DENT have been investigated but experience with those is lacking and they invariably lead to a degree of empiricism with unknown consequences.

Both DENT and EBBR were used for acceptance of the asphalt binder on selected MTO contracts in 2008–2010. Since 2011, the methods and associated acceptance criteria have been included on a significant number of highway rehabilitation and reconstruction contracts in Ontario. For the acceptance of the binder, tests are performed on samples supplied from the tank feeding the mix during production. These contracts are being monitored to collect information for contractors to determine how to build pavements that will meet cracking performance acceptance criteria. Eighteen contracts from 2011 to 2013 were investigated in this study, sampled in two different locations for each contract. Alternative and potentially more practical test methods to the DENT and EBBR are also being investigated on a continuing basis.

It was recognized early on that it is important to develop protocols that can appropriately account for changes in performance due to the presence of recycled asphalt, contamination and overheating during production of the asphalt mix. Testing the recovered asphalt binder from loose mix is one way of assuring that in service properties of the mix are matched to design performance. Hence, in this investigation, extracted and recovered asphalt binders were evaluated for various performance-based attributes. The properties obtained for asphalt binder from core samples are compared with those for the virgin material sampled from the supply tank during mix production.

The objective of the current research is to investigate the feasibility of acceptance testing of recovered asphalt binder and to compare properties so obtained with those from regular quality assurance tests on tank sampled materials. The results obtained can guide producers and user agencies in making the appropriate adjustments to deal with sampling and/or overheating issues, as well as specification test inadequacies. Once materials are more accurately graded for thermal and fatigue cracking it is anticipated that major savings can be realized throughout Ontario and beyond.

2. Background

The decline in pavement lifecycles due to premature cracking distress has been an issue of concern to MTO and other user agencies in Ontario for at least 10–15 years [14,41]. Shortly after the Superpave® asphalt binder specifications were fully implemented in the late 1990s, a number of highways in Eastern and Northeastern Ontario exhibited extensive premature cracking. Roads that were designed not to crack due to oxidative and other forms of aging for at least 8–10 years, were showing major thermal distress within the first few years of service [41].

The approach to addressing this problem has been to develop a set of improved asphalt binder tests—largely based on Superpave principles but better at detecting the poor-performing materials. The tests that were settled on were the DENT and the EBBR. The DENT test is best described as a somewhat improved ductility test while the EBBR simply extends the conditioning time for the regular BBR protocol from one hour to 72 h. The combined implementation of both methods with associated acceptance criteria will provide an improved control on future pavement performance. A third and final test method was developed to improve the process used to model the oxidative aging that occurs to the asphalt binder in service [33]. The modified PAV protocol conditions samples for longer or in thinner films, and is awaiting initial implementation trials [53].

It has also been recognized that with the increased usage of RAP in hot mix asphalt, it is imperative to develop methods for the testing of extracted and recovered asphalt binder to ensure modification is not negatively impacting the mix performance in service.

2.1. Double-Edge-Notched Tension (DENT) test

The work on a failure test for asphalt binder was inspired by the original development of the asphalt ductility test [30]. Dow [31] described that he first did the pulling by hand. Binders that performed to satisfaction in service would flow well prior to failing while binders with lesser performance failed rather abruptly. He recognized that air blown (oxidized) binders and those that were unstable performed rather poorly in both the ductility test and in service.

The DENT test is an improved ductility test as it has a more fundamental basis in mechanics [21,28]. The test protocol was developed with the objective of providing a fundamental measure of strain tolerance for asphalt binder in the ductile state close to the ductile-to-brittle transition [8]. The test measures the total energy to failure, W (J), as the area under the force-displacement curves for three samples, each with a different ligament length, L (mm). Typical ligaments include 5, 10 and 15 mm. The notches are introduced in order to localize the failure to varying degrees. Extrapolation of the specific total work of failure, w_t (J/m^2), to a zero ligament length allows for the determination of the specific essential work of failure, w_e (J/m^2). The essential work of failure is divided by the average peak stress in the net section, $\sigma_{net,\ tensile}$ (N/m$_2$), to obtain an approximate critical crack tip opening displacement, CTOD (mm).

The CTOD provides a measure of strain tolerance in the ductile state and represents the amount by which a tiny fibre (fibril) of asphalt binder can be stretched before it fails. As such, it provides a measure of how much the pavement can flex before the binder breaks. Higher CTOD values should provide more resistance to fatigue cracking, but then of course this only holds until the mastic detaches from the coarse aggregate's interface.

Fig. 1 shows the samples before the DENT test is run while Fig. 2 is an illustration of samples that have just been pulled apart. The

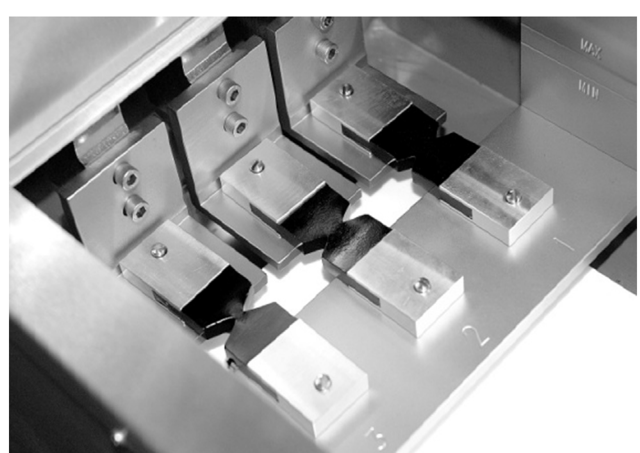

Fig. 1. Three DENT samples with ligaments of 5 mm (bottom), 10 mm (middle) and 15 mm (top) just before testing. Note: The water has been drained from the bath to improve the clarity of the image.