Comparison of Thermal Stress Restrained Specimen Test (TSRST) Results with Bending Beam Rheometer (BBR) Results to Evaluate the Thermal Cracking Properties of Bituminous Materials

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ABSTRACT

Thermal cracking of bituminous pavement is a common type of degradation observed in northern countries. In order to ensure good low-temperature performance of bituminous materials, it is important to have a test that is well adapted. However, in North America, the thermal cracking resistance is mostly based on the low temperature of the bitumen performance grade (PG). This paper presents the results of an extensive testing program on different bitumen and different asphalt mixes in order to link the low-temperature performance grade of the bitumen obtain thru Bending Beam Rheometer (BBR) tests with the thermal cracking resistance evaluated with the thermal stress restrained specimen test (TSRST). The results show that using BBR test method is not always reliable to predict the low temperature cracking of asphalt mixes.

Keywords: TSRST, BBR, Low-temperature performance, Thermal cracking

1. INTRODUCTION

Asphalt mixtures can suffer from different types of cracking distresses during their service life such as fatigue cracking, low-temperature cracking, and reflective cracking. In cold regions, low-temperature cracking is one of the major causes of distress for asphalt pavement structures [1-2]. Mixture contraction produces tensile stress that continually increases as the temperature drops. When the tensile stress equals the tensile strength of asphalt materials, cracks initiates and propagates through the mix to relieve the stress [3]. Road transportation agencies in cold areas spend a lot of time and money to rehabilitate pavements that suffer from low-temperature cracking [4]. Therefore, it is very important to analyze the mechanical properties of different asphalt mixes exposed to thermally induced stresses.

There are a great number of field investigation and laboratory techniques that have been used to analyzed low temperature cracking of asphalt mixtures. Among them, TSRST and BBR tests are very common. The thermal stress restraint specimen test (TSRST) is used to characterize the low temperature cracking of asphalt mixes, and the Bending Beam Rheometer test (BBR) is conducted to characterize the rheological behavior of asphalt binder. However, the current methods and laboratory tests have not sufficiently solved this kind of distress due to its complexity. While the BBR test gives a good understanding of the low-temperature properties of asphalt binder, it usually does not fully represent the resistant of the mix to thermal cracking. The characteristics of other components (aggregates, air voids, and additives), adhesion properties of aggregate-binder, presence of water in the pores and characteristics of additives used in the mix can change the thermal coefficient of asphalt mixes.

This paper summarizes the laboratory's experience of an extensive testing program on different bitumen and different asphalt mixes with the TSRST and BBR tests highlighting the effectiveness of the BBR and the Superpave performance binder grading system. Tests were performed on straight run and polymer-modified bitumen, and on mixes with different binder content, gradation, nominal maximum aggregate size and air voids content.

2. MATERIALS AND EXPERIMENTAL RROGRAM

Asphalt mixes using different percentage of air voids and binders, polymer modified asphalt, fiber additive, recycled glass materials, RAP conditioning, and also different environmental conditioning were tested through BBR and TSRST tests.

2.1 Binder

The characteristics of the binders used in this study are classified according to the Superpave performance binder grading system. Based on the specifications described by AASHTO, BBR low temperature is defined as the lowest temperature at which slope of log time curve and log stiffness M (t_{60} sec) ≥ 0.3 and flexural stiffness S (t_{60} sec) ≤ 300 MPa.

2.2 Mixtures

Mix design tests were conducted according to the LC method of mix design. LC Method of Mix Design presents the mix design method that developed by the pavement laboratory (*Laboratoire des Chaussées*) at the ministry of transportation of Quebec (MTQ). After mix design tests and analysis, slabs were compacted with the French laboratory slab compactor according to Quebec Standard (Ministry of Transportation of Quebec, MTQ standard). Cylindrical specimens were cored in the direction of the compaction of the slabs after a 2-week rest period at room temperature and then trimmed [5].

2.3 Experimental procedures

TSRST tests were carried out on cylindrical asphalt specimens with a diameter of 60 mm and 250 mm in height. The process began with the gluing of aluminum helmets using epoxy. Extensometers were placed on the cylindrical surface of the specimen to measure and control its deformation. Three thermocouples were also attached on the surface of the specimen to record the temperature on the surface during the test. The force required to prevent the specimen from contracting was measured by a cell at the base of the system. Cooling takes place at a constant rate of 10 ˚C / h. The thermo-mechanical tests were realized using a servo-hydraulic press (MTS press), with an electronic monitoring system at the LCMB laboratory at ÉTS. An environmental chamber was used for thermal conditioning of the specimens.

An example of test results are presented in Figure 1 and explained hereafter as a typical sample for a TSRST test results. Failure strength (S_f) defines as the highest level of stress where the stress reaches its highest value before failure. The temperature at which failure occurs is defined as the failure temperature (T_f). Slope 1 indicates the rate of stress evolution as a function of temperature of the bitumen at the beginning of the test. The glass transition temperature (T_g) represents the time at which the asphalt starts to have a fragile behavior following the relaxation period of the asphalt during the test. Slope 2 indicates the rate of stress evolution as a function of temperature of the asphalt for temperatures below (T_g).

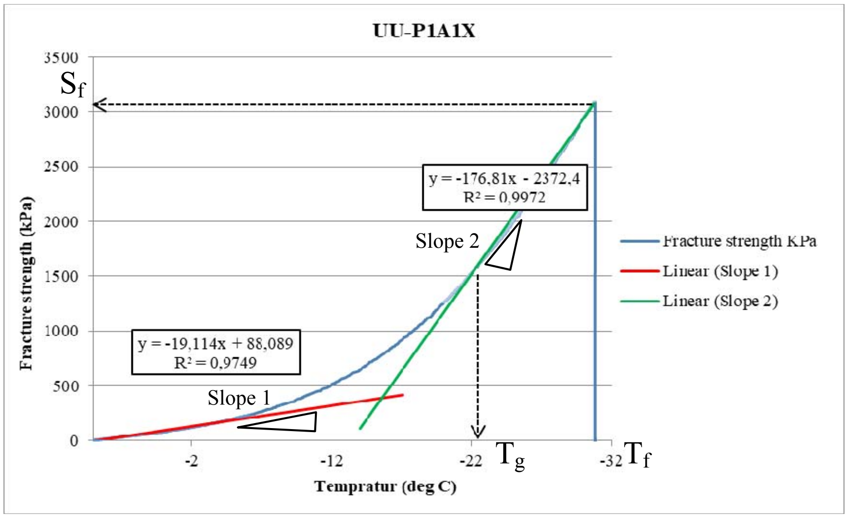

FIGURE 1 Example of TSRST results

3. TEST RESULTS

3.1 General TSRST results for all specimens

This paper presents the results of more than 50 TSRST tests in the LCMB laboratory. Three repetitions on three different specimens have been performed for all tested materials. The general variations of stress in function of temperature were analyzed for each TSRST test. In order to compare the results for all performed tests, it is possible to compare the values gained from TSRST curves. The relationship between the failure temperature and failure strength in this study is indicated in Figure 2. The scatter plot indicates that the mix properties change the values obtained in TSRST test for the same type of binders, which is due to the different characteristics of the mixes. For instance, the addition of aramid fiber in GB20 mix (used for the base course) decreased the fracture strength and temperature. Consequently, Figure 2 shows scattered points for all of the PG grades. It was also seen that the environmental conditions (e.g., freeze-thaw cycles) substantially decreased the fracture strength and increase the fracture temperature of the GB20 (base-course) mix. The durability of the base-course asphalt mix under the environmental freeze-thaw cycles was explained in previous research [6].

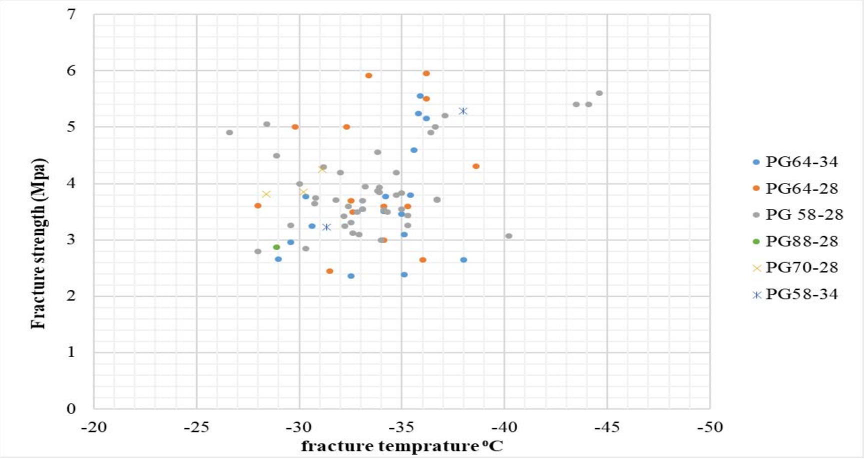

FIGURE 2 Scatter plot of failure temperature and failure strength

The relationship between the transition and fracture temperature is shown in Figure 3 with considering all type of mixes. Based on Figure 3 it is clear that the relationship is linear and also there is a good relationship for most of the mixes. Same results have been found in previous studies [2-7-8].

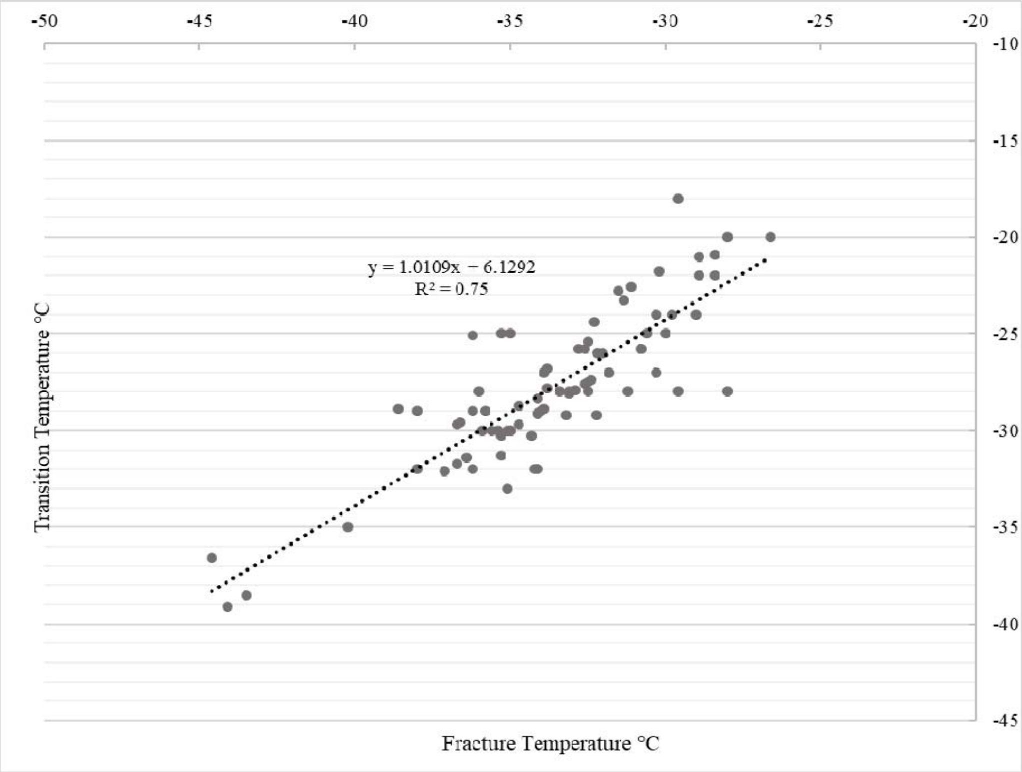

FIGURE 3 Relationship between the transition and fracture temperature

3.2 Correlation between the BBR and TSRST test

Figure 4 illustrates the comparison between the BBR and TSRST results. BBR and TSRST results are closed for the reference mixes with lower BBR values compared to TSRST. The coefficient of thermal contraction of the asphalt mixture reflects the response of each of its component (asphalt cement, aggregates and additives). For the asphalt cement, the coefficient of thermal contraction is much higher than the aggregates, so the contraction of an asphalt mix associated with low-temperature is an impression of the response of the asphalt cement binder [9]. The addition of Aramid fiber (KEVLAR) additives had a positive effect on the TSRST results and increased the ductility of the GB20 mix. Aramid fiber decreased the fracture strength while maintaining the fracture and transition temperatures. The addition of shingle waste material has been analyzed to improve the durability of the base mix in cold regions. Shingles had no influence on the TSRST values. BBR values also changed with the same PG grade but from different sources. The results show that the percentage of air voids is not a major factor affecting TSRST values comparing with additives effect. The outcome of the tests showed that using recycled asphalt pavement (RAP) in small quantity had a little influence on the value of TSRTS.

The coefficient of variation (COV) is the deviation factor which is used to determine the comparison of two variables. In this study, it is described as the ratio of TSRST value/BBR values. The results of COV for each tested materials are shown in Figure 6. In general, COV data shows that there is a very good relationship between the TSRST and BBR tests, especially for the reference mixes.

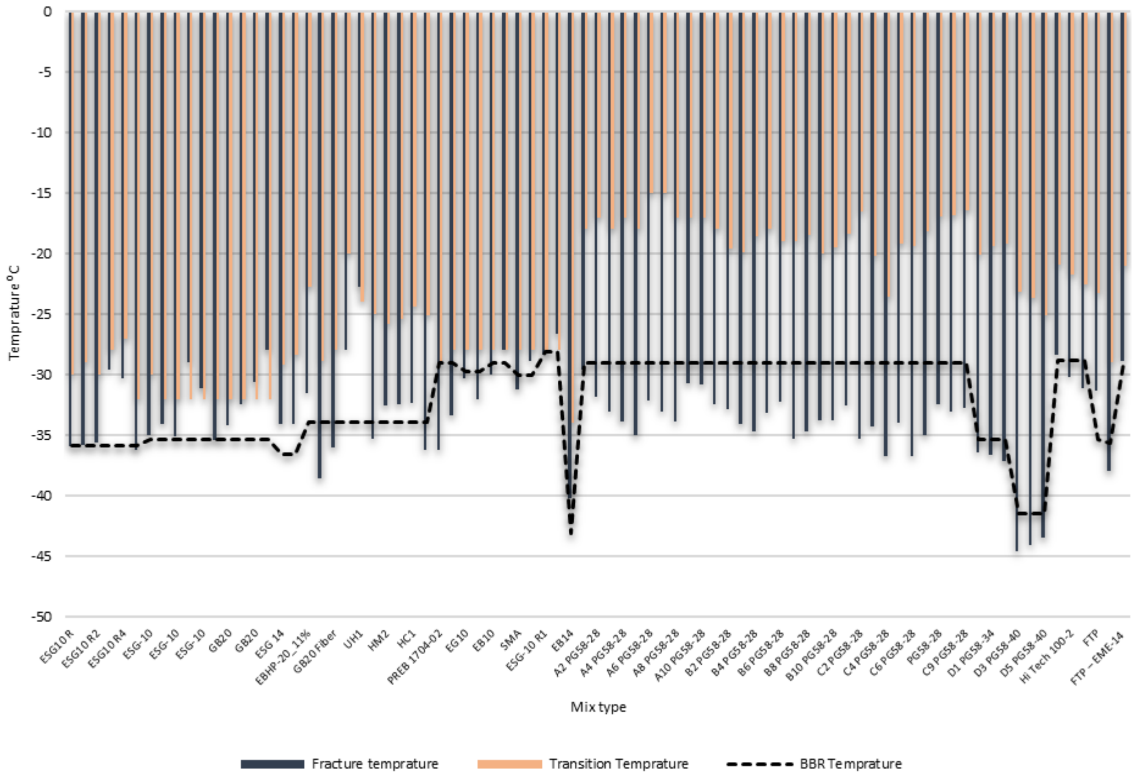

FIGURE 4 Comparison between the BBR and TSRST results

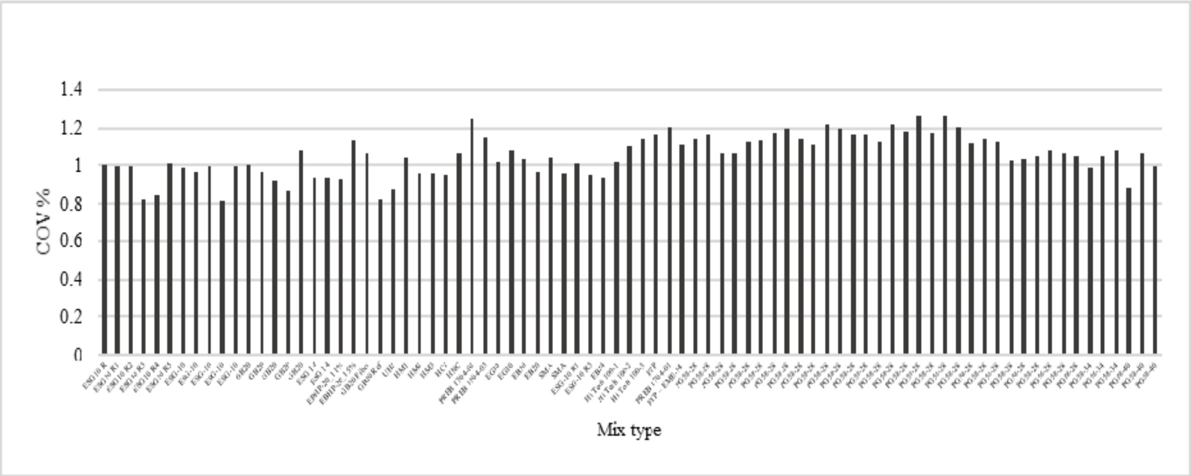

FIGURE 6 COV values between BBR, TSRST and air voids

4. CONCLUSIONS

This paper presents the results of 40 testing program on different bitumen and different asphalt mixes in order to link the low-temperature performance grade of the bitumen obtain thru

Bending Beam Rheometer (BBR) tests with the thermal cracking resistance evaluated with the thermal stress restrained specimen test (TSRST).

The results show a clear link between the results from the BBR and the TSRST especially for the reference mixes, but with the BBR results under predicting the cracking temperature for the mix having fiber and RAP additives. It was also shown that the PG grade is by far the most important factor, compared to additives, mix design, etc, dictating the cracking temperature of a bituminous mix.

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