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COLOURED ASPHALT BUS RAPID TRANSIT LANES IN THE REGIONAL MUNICIPALITY OF YORK: INTEGRATING LABORATORY PERFORMANCE TESTING INTO SUSTAINABLE PAVEMENT ASSET MANAGEMENT

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ABSTRACT

Located north of Toronto, Ontario, The Regional Municipality of York, the sixth largest municipality in Canada, is a thriving community and home to a well-established service sector. York Region's population is expected to grow from 1.1 million in 2013 to 1.8 million in 2041. With more people coming to the Region every year, Rapid Transit projects provide significant benefits. Bus Rapid Transit (BRT) lanes are built or being built along the three most heavily travelled roads in York Region: Yonge Street, Highway 7 and Davis Drive. To improve the level of safety through enhanced visibility and help residents and motorists easily understand this new transit system and follow the right-of-way, York Region uses coloured asphalt pavement design for its dedicated BRT lanes.

York Region and Metrolinx, an agency of the Government of Ontario created to improve the coordination and integration of all modes of transportation in the Greater Toronto and Hamilton Area, retained the Centre for Pavement and Transportation Technology (CPATT), located at the University of Waterloo, to identify innovative and sustainable future preservation and maintenance solutions to ensure durability and high performance throughout the material's life cycle.

This paper highlights information on how coloured asphalt can be used to achieve technical and social benefits in a number of transportation applications. This paper also looks at pavement performance results obtained from conducting material testing at the state-of-the-art pavement laboratory at CPATT. These results provide insight into the level of resistance the pavement structure will exhibit to loss of surficial colour and friction due to inevitable wear and tear. These results are used to compliment performance prediction models describing the expected path of deterioration over time. Materials under evaluation included those collected during paving operations and those produced under controlled laboratory conditions.

1. INTRODUCTION

As the home of a well-established service sector including engineering, information technology (IT), finance and insurance, York Region in Ontario has the fastest growing population in Canada. Located north of Toronto, it is a thriving community and proactive in promoting efficient transportation. To meet its rapidly increasing need for public transit, York Region has used a combination of coloured aggregate and red pigment as surface course for its dedicated Bus Rapid Transit (BRT) lanes (Figure 1). The initial BRT lanes are located along the three most heavily travelled roads in the Region: Yonge Street, Highway 7 and Davis Drive.



Figure 1: A section of Highway 7 BRT lane, York Region, Ontario

Denoting dedicated bus lanes in the right-of-way (ROW) has been implemented globally and allows buses to move out of congestion, enabling travellers to get around the busiest corridors faster by using transit. This solution is known as Bus Rapid Transit (BRT) and endeavours to create a more vibrant, livable and sustainable urban development by providing a pedestrian and transit oriented real estate development. Many metropolitan areas around the world have included coloured pavements in their infrastructure to denote dedicated lanes for buses and bicycles. These cities, such as New York, London, Ottawa, Sydney and Auckland, all have colouring applied to all or portions of their dedicated bus lanes (SDT, 2011). Transit benefits of these installations are well documented in terms of vehicle violation of the lanes, however structural and functional performance has not been investigated systematically and data are scarcer.

Developing a BRT system easily understood by ROW users is necessary in order to maintain a high level of safety. This is traditionally accomplished through signage and lane markings, however the most effective solution is through using a different surface colour for designated lanes. Lane colouring can be accomplished through one of three methods: painting, applying a coloured thermoplastic or laying a thin wearing course of Coloured Hot Mix Asphalt (CHMA).

In collaboration with the University of North Carolina Highway Safety Research Center (UNCHSRC), the City of Portland investigated colour options for bike lane identification in the 1990s and their analysis provides a broad analysis of material durability. In brief, their research expected that the most durable solution would be a dyed asphalt wearing course, however this was not tested due to the high cost of implementation. Portland installed test sections of painted and thermoplastic colours and found that while the painted material wore away after the first winter, the thermoplastic proved to still be in good condition after one year (Birk et al., 1999).

Coloured surface treatments for bus lanes were investigated by the New York City Department of Transportation (NYDOT) in collaboration with Penn State University in 2010, as part of a study to improve the durability and cost-effectiveness of colouring treatments. NYDOT has implemented red bus lanes since 2008. Figure 2 shows one of the major bus corridors outfitted with red bus lanes. This study focused on long-term field observation and laboratory testing of various colouring treatments with a minimum durability and skid-resistance target of three years, which were selected to be applied on different road surfaces such as: (1) existing asphalt, (2) new asphalt, (3) existing concrete and (4) new concrete (Carry, 2012).



Figure 2: Red bus lane on 1st Avenue in Midtown, Manhattan, United States (Carry, 2012)

Overall, their work found that epoxy street paints produced the most durable solution, while hot mixed asphalt (HMA)-based micro surfaces were promising and required further investigation (Carry, 2012). Moreover, the study concluded that regardless of age/condition of the asphalt road surface, treatments experience intense wear at bus stops. This wearing was suggested to be due to factors such as: (1) friction caused by buses stopping and starting and (2) prolonged heat exposure from bus engines.

Laboratory evaluation of HMA overlays incorporating coloured synthetic binders for use in bus lanes have been studied in Seoul, South Korea. This work focused on an unnamed synthetic resin binder and performed number of laboratory tests to evaluate the strength and moisture susceptibility of the overlays. The results showed the designed overlay was of higher strength and lower moisture susceptibility than traditional HMA mixtures, indicating the technical potential of coloured HMA overlay and structure solutions (Lee & Kim, 2007).

The friction, thermal and UV characteristics of coloured asphalt pavement surfaces have been studied to some extent. Friction is of high importance due to the minimum requirements for safe vehicle operation, and adding paints and polymers to the roadway surface increases the risk of making a driving surface too smooth (Carry, 2012). Coloured asphalt reduces the amount of thermal energy absorbed compared to black asphalt and this can reduce the urban heat island effect which has major benefits for cities.

One challenge is finding scientific literature on the usage of colouring pigment in HMA, as all major chemical suppliers have their own proprietary products. The products tend to be either synthetic binders or pigment solutions. In addition, the usage of these materials in Canada has been limited. All additives may have a direct impact on the structural, functional and environmental performance of the pavement surface, so when selecting the ideal pigmentation option for a given region, it is important to identify the best options and perform thorough laboratory and field testing before implementation.

2. RESEARCH OBJECTIVES AND SCOPES

A key to proper management of BRT lanes is identifying timely and cost-effective preservation and maintenance strategies. This may be difficult without a good understanding of the in-situ materials' performance and its long-term behaviour. To assist decision makers, an array of materials are being systematically evaluated at the state-of-the-art pavement laboratory, located at Centre for Pavement and Transportation Technologies (CPATT), to gather performance testing results to develop performance prediction models describing the expected path of deterioration

over time. Materials under evaluation include those collected during paving operations and materials produced under controlled laboratory conditions.

Laboratory performance results are integrated with field observations and semi-automated distress surveys of existing road sections. The distress survey is conducted using a semi-automated road analyzer equipped with an extensive set of sensors and video cameras, continuously recording type, extent and intensity of different types of surface cracks. By using the semi-automated road analyzer equipment, accurate and cost-effective data is collected and will effectively compliment management decisions.

3. LABORATORY TESTING AND RESULTS

3.1 Materials and Sample Fabrication

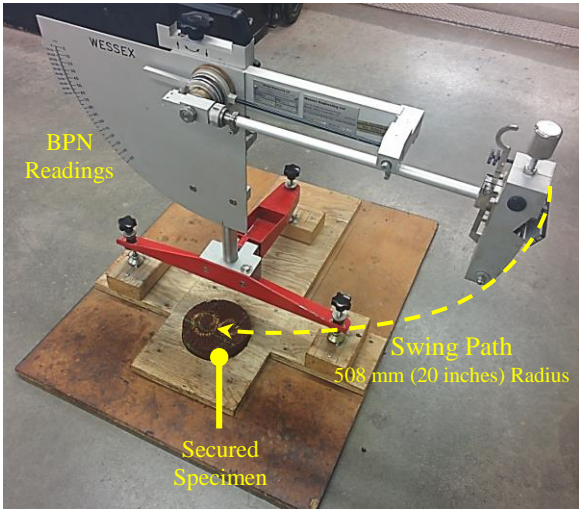
Plant-produced red asphalt mixture was collected from production plant and consisted of a red aggregate blend, red proprietary pigment and polymer modified asphalt binder. The aggregate blend consisted of 12.5 mm coarse aggregate, and crusher fines (washed, and unwashed) to meet physical requirements of Superpave 12.5 Friction Course type 2 (FC2) mixture type for use in Traffic Category 'D' as per Ontario Provincial Standard Specification (OPSS). This type of mixture is intended to provide superior rutting resistance and skid resistance for a 20 year Equivalent Single Axle Loads (ESALs) level of 10 to 30 million. The CPATT Superpave Gyratory Compactor (SGC) was used to fabricate compacted specimens, which can be used for further testing. The specimens measuring 152 mm (6 inches) in diameter and approximately 180 mm (7 inches) in height were compacted at pressure of 600 kPa in accordance with AASHTO PP 060-13, "*Standard Practice for Preparation of Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC)*" (AASHTO, 2013).

3.2 Effect of Colouring on Surface Friction

Effect of colouring pigment on the surface frictional properties was measured in a laboratory by using the British Pendulum Skid Resistance Tester in accordance with the ASTM E 303-93, "*Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester*" (ASTM, 2013). The British Pendulum Skid Tester in the CPATT setup shown in Figure 3-2 (a) was used to capture the effect of pigment on the friction response due to micro-texture modification.

The testing procedure involved using a dynamic pendulum impact-type tester (also called "British Pendulum") to swing a rubber slider over a contact path marked on the surface of a specimen, as shown in Figure 3-2 (b). The surface friction was then measured as the amount of energy loss during the contact between the slider and the test surface. A drag pointer on the British Pendulum as shown in Figure 3-2 (a) was used to indicate the energy loss in terms of a British Pendulum Number (BPN). The greater the friction between the slider and the test surface, the more the swing is reduced and the larger the BPN reading.

Specimens were prepared by using the CPATT Superpave Gyratory Compactor, each measuring 150 mm (6 inches) in diameter. Specimens were compacted to a targeted air void content of 4 ± 0.5 per cent to represent the field condition. Five swings of the pendulum were made for each test dry surface conditioned at five different temperatures (0, 4, 21, 37 and 54 degree Celsius) to obtain BPNs. Conditioning was performed by using the environmental chamber located at CPATT. Furthermore, the testing was performed on a wet surface for each testing temperature. To wet the test surface, approximately 45 mL of distilled water was sprayed across the specimen in the beginning of each set of data collection and 5 mL of water was sprayed on the specimen surface to replace the lost water between swings. The average results for the measured skid resistance are shown in Figure 3-2.



(a) Wessex British Pendulum and CPATT test setup



(b) Close-up view of contact path

Figure 3-1: CPATT British Pendulum Test Setup

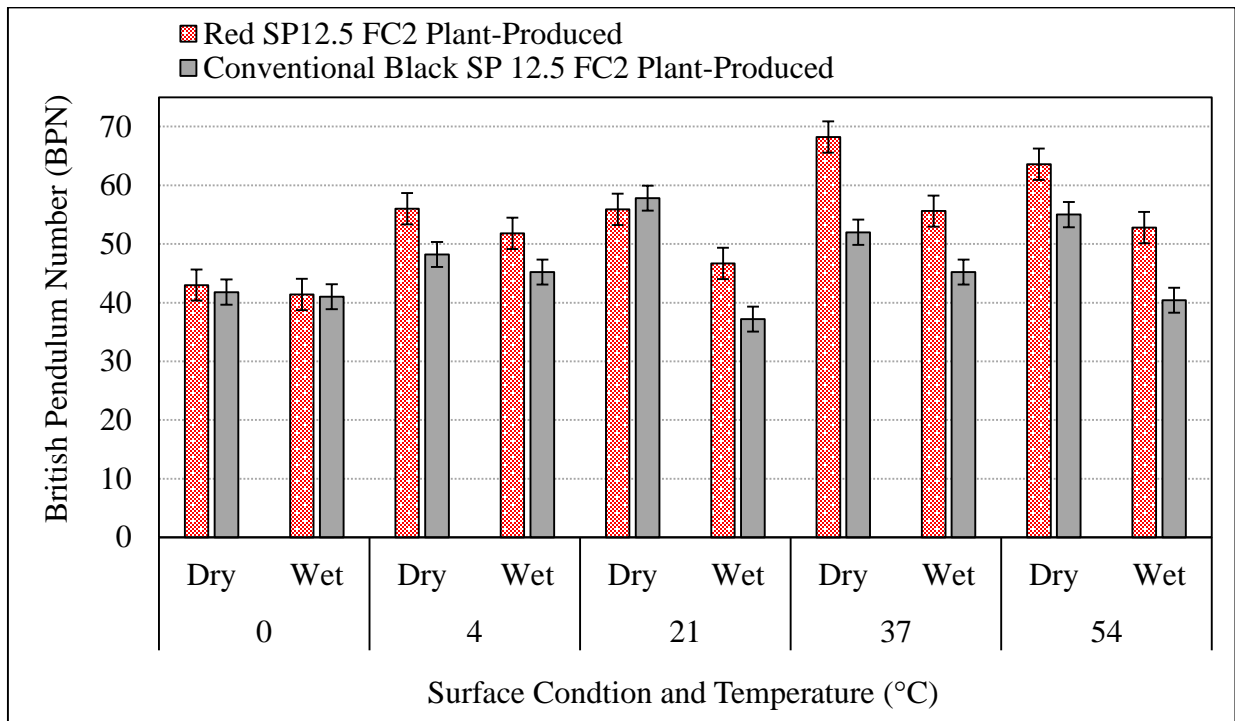


Figure 3-2: British Pendulum Number Laboratory Results

The results of laboratory friction testing suggests pigmented plant-produced mixture exhibited a higher number of BPN in both dry and wet conditions at different temperatures, suggesting a higher level of friction and safety.

3.3 Colour and Functional Performance

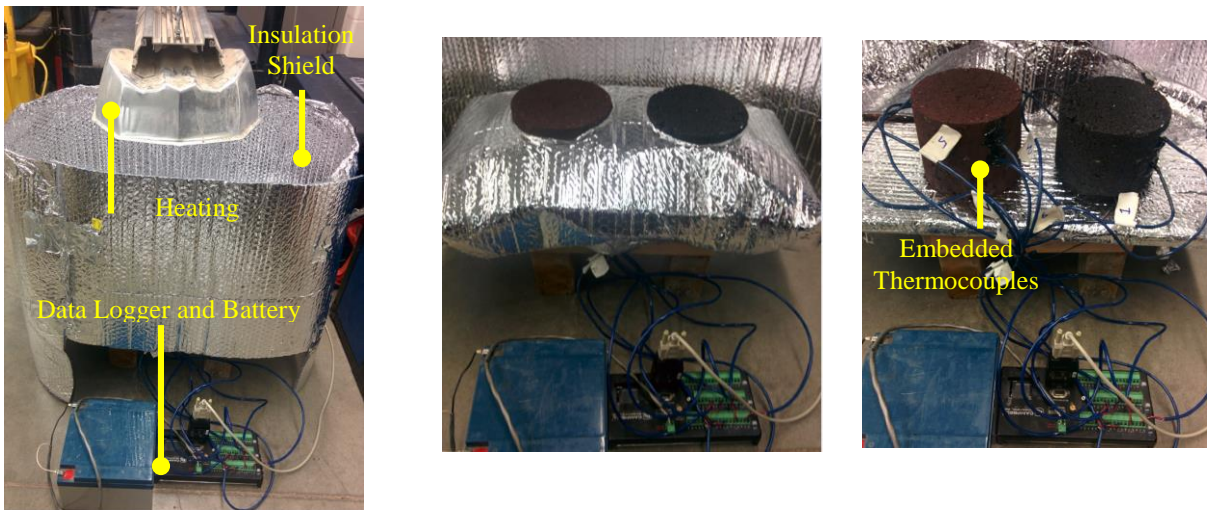
Literature review suggested the colour of material exposed to sunlight affects its thermal properties due to solar radiation absorption. Darker colours relatively absorb more solar radiation, which cause temperature increase; while lighter colours absorb less radiation, leading to cooler temperatures. This theory has been evaluated by many researchers on pavements with lighter surface colours compared with so called “black topped” asphalt pavements.

Lighter surface colour pavements are commonly referred to as “cool pavements”, which has been demonstrated by many researchers to provide major benefits for cities by reducing heat absorption and ultimately reducing the possible impact of black surfaced pavements on urban heat island generation (Synnefa, 2009).

In addition to environmental benefits, lighter colour pavements may provide economic benefits as reduction in heat absorption rate may lead to a reduction in the in-service temperatures through different seasons. This allows for usage of less expensive Performance Grade (PG) binders. Moreover, surface layers within the pavement structure may not experience as high a temperature which causes damages such as rutting and bleeding. This might lead to a more durable and longer lasting road, which might require less maintenance.

A laboratory setup shown in Figure 3-3 (a) was used to evaluate the effect of colour change due to pigmentation on the rate of heat absorption. This test was performed on two laboratory-produced cylindrical specimens at the same time: (1) pigmented and (2) non-pigmented asphalt specimen. Specimens were prepared using the CPATT Superpave Gyrotatory Compactor compacted to similar level of in-field compaction level (4% Air or 96% G_{mm}).

Specimens were instrumented with thermocouples connected to an automated data collection unit (also referred to as “data logger”) capable of collecting data every two minutes. Thermocouples were installed at various depths of specimen by drilling holes extended 75 mm (2 inches) into the specimen. The holes were then backfilled with the same PG grade asphalt binder used in producing the specimens. Instrumented specimen are shown in Figure 3-3 (c).



(a) UV heating laboratory setup (b) Inside view of insulation shield (c) Instrumented Specimens

Figure 3-3: UV heat absorption laboratory setup

Figure 3-4 illustrates measurements collected during one heat-cycle performed in 210 minutes, which indicates coloured asphalt absorbed less heat resulting in roughly 2°C of reduction in temperature at 20 mm below the surface. Similar trend was also observed for the depth of 40 mm. This temperature reduction might be significant in field, which might suggest lowered level of oxidation and colour degradation compared to conventional black asphalt.

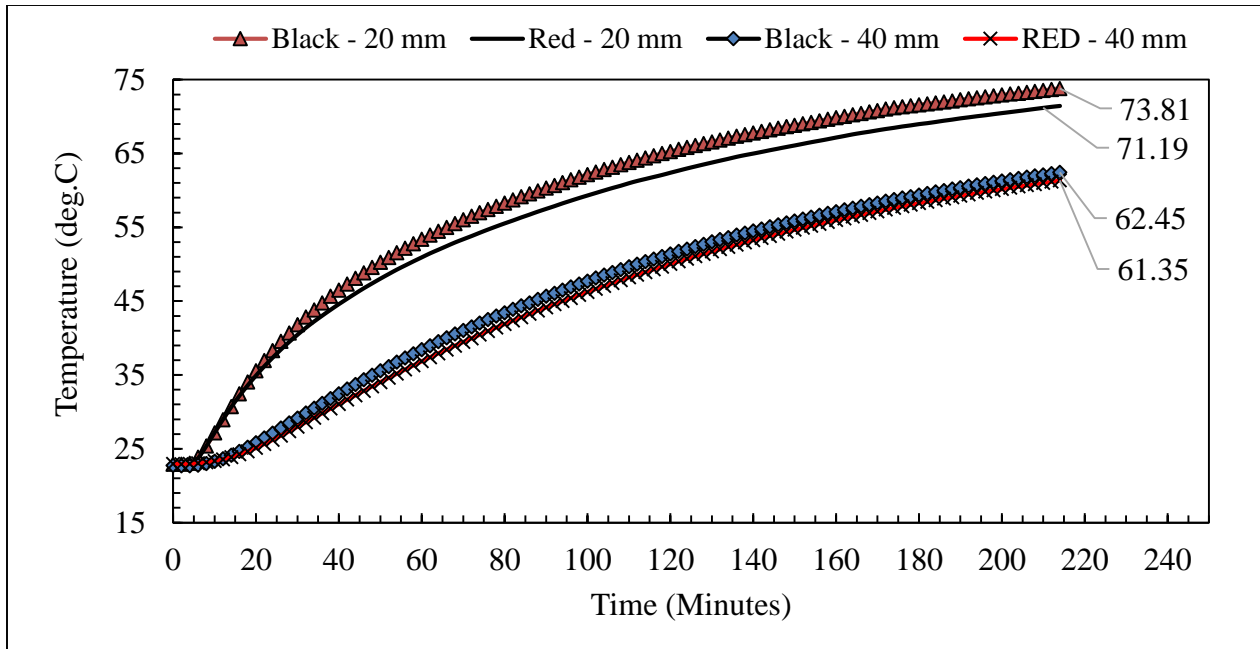
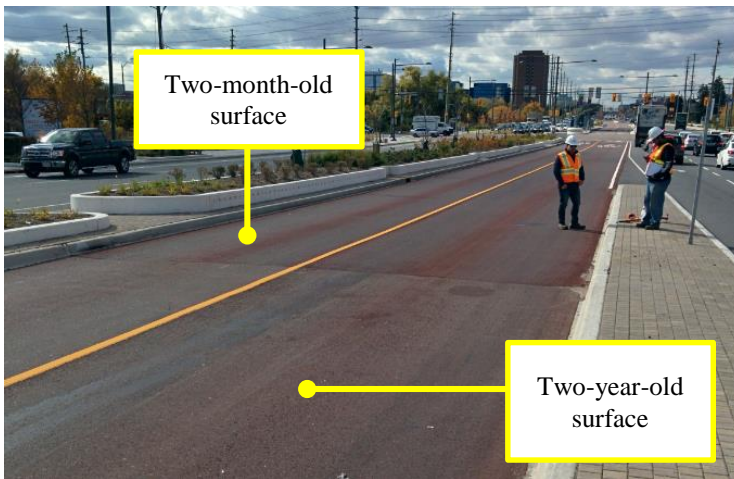
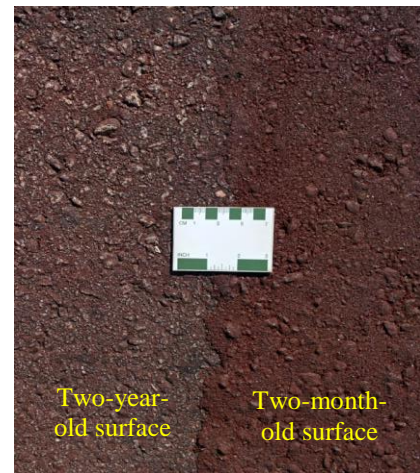


Figure 3-4: Heat absorption comparison of red and black asphalt after one heating cycle

The UV properties of a coloured surface are important as UV radiation will degrade the colour over time and may make it less effective for lane designation. This was observed during the field test conducted on October 26, 2015. During this visit, the image in Figure 3-5 was taken from a section of BRT lanes located near the Highway 7 and Woodbine Avenue intersection, which consisted of two sub-sections paved with coloured asphalt two years apart. The UV properties of a coloured surface are important as UV radiation will degrade the colour overtime and make it less effective for lane designation. While these factors have been widely analyzed, it is important to test these factors for any potential new installation in a new environment to ensure compatibility.



(a) New and old coloured surface



(b) Close-up view of new and old coloured asphalt texture

Figure 3-5: Surface colour change over two-year period

4. CONCLUSIONS

To effectively manage its red coloured pavements on BRT lanes, York Region is interested in understanding the in-situ materials' performance and its long-term behaviour. The field and laboratory performance results assist York Region to develop performance prediction models describing the expected path of deterioration over time. Additionally, the performance data triggers the best timing to apply innovative and sustainable solutions, which can be effectively used as a means of ensuring durability and high performance throughout the red pavement life cycle. Research results indicated pigmented plant-produced mixture exhibited the higher level of friction and less heat absorption compare to conventional black plant-produced asphalt.

5. FUTURE STEPS AND EXPECTED CONTRIBUTIONS

This research is intended to advance the state-of-the-art and knowledge of using coloured asphalt mixtures in Canada. It will focus on evaluation methods to characterize the long-term structural, colour and functional performance of the mixture. Moreover, this research is intended to identify effective maintenance and rehabilitation options to maintain the structural, colour and functional performance of the in-situ mixture throughout the material's lifecycle. The integration of this knowledge gained from both laboratory and field experiments will provide a greater understanding of the material. This information can then be used by municipalities and agencies to implement the most suitable asphalt mixture for their region.

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