TECHNICAL NOTE

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THE USE OF PLASTIC WASTE IN ROAD CONSTRUCTION IN SOUTH AFRICA
Case study 3: Demonstration section of the wet modification process
Phase 3: Heavy Vehicle Simulator testing

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KEY FINDINGS

A Heavy Vehicle Simulator (HVS) test was conducted on two pavement structures with asphalt surfacing, namely a control (reference) asphalt mix as well as an asphalt mix that contains waste plastic through the wet modification process. Based on the initial study, the following findings were made:

- The waste plastic modified mix had a final total average surface rut measurement of 7.2 mm and a maximum rut depth of 8mm after 2.9 million E80s (using a damage coefficient of 4.2).
- The reference mix the final total average surface rut measurement of 10.4 mm and a maximum ruth depth of 12 mm after 2.9 million E80s (using a damage coefficient of 4.2).

This validation study through the accelerated long-term performance simulation showed waste plastic modified asphalt could potentially be used to enhance rutting resistance due to the stress-resilient stiffening effect with a relatively softer bitumen under high pavement temperature conditions.

INTRODUCTION

Accelerated Pavement Testing (APT) is the controlled application of wheel loading to pavement structures to simulate the effects of long-term, in-service and realistic loading conditions in a reduced time interval (Hugo and Martin, 2004).

The HVS (See Figure 1) is a mobile APT device that assists pavement engineers to understand the mechanisms of traffic-associated road failures and pavement distresses in a short period of time. Through HVS simulations, it is possible to obtain relatively quick results related to the damage caused by the equivalent of 20 years projected traffic in a period of three to six months. The mechanisms of failure and the influence of various controlled environmental factors on the behaviour and performance of various pavement structures can therefore be investigated (Verhaeghe *et al*., 2010).

RELEVANCE OF HVS TESTING IN THE CONTEXT OF THE USE OF PLASTIC WASTE IN ROAD CONSTRUCTION

Determining the engineering properties of road construction materials for traffic loading and climatic conditions require establishing the performance history (or in this case the performance projection over the future commissioning period) of the material and can assist in performance-based classifications.

Figure 1: HVS

The modification of bitumen using waste plastic prior to the asphalt mix manufacturing is also known as the “wet modification” process and Case Study 3 was aimed at establishing performance limits for an asphalt mix using this modification method. The “dry modification” process was also demonstrated during Case Study 2 in 2021 and included a detailed performance evaluation of two asphalt sections through APT with the HVS.

SCOPE

The scope of this technical note is to provide level 1 HVS test analysis of Case Study 3 and is aimed at comparing the performance of a waste plastic modified asphalt mix to a control standard asphalt mix (reference) based on an ES30 pavement design, i.e. 10 million to 30 million Equivalent Standard Axles (ESALs). Please note that the construction of the demonstration section is discussed in the accompanying technical notes (Mokoena, 2024; Rampersad, 2024).

HVS TEST PROGRAM

The following HVS dual wheel load applications were applied to both the reference mix and the waste plastic modified asphalt mix simultaneously, using a constant tyre pressure of 780 kPa. As shown by Figure 2 and Figure 3 the testing protocol was as follows:

- From start to about 71 857 repetitions a 40 kN dual wheel load (simulating a standard 80 kN axle load) was used.
- From 71 857 to about 89 461 repetitions the dual wheel was increase to 60 kN (simulating a 120kN axle load).
- And finally, from 89 461 to 124 856 repetitions (or test completion) the dual wheel load was increased to 80 kN (simulating a 160 kN axle load).

The total number of HVS repetitions applied to HVS Section 477A4 is 286 174. This equated to approximately 2.9 million ESALs under channelized trafficking or 5.2 million ESALs using equivalent comparable wandering traffic (Steyn, 2012).

It should be noted that this HVS test was conducted at temperatures higher than the ambient air temperatures using heaters to simulate maximum temperature conditions bituminous binders are exposed to in certain regions in the country.

Several HVS-associated instruments and sensors (both embedded and non-embedded) were used to monitor the structural behaviour and environmental conditions during this test, these include:

- CSIR Multi-Depth Deflectometer's (MDD's) – embedded at four locations.
- Standard straightedge – non-embedded.
- Thermocouples (k-type) – embedded at two different depths within the asphalt layer, at 8 locations along the test section.
- Temperature buttons – embedded at 6 locations along the test section.
- CSIR Road Surface Deflectometer (RSD) – non embedded.
- Weather Station – non-embedded.

RESULTS

The average RSD and MDD deflections of the waste plastic modified mix and the reference mix did not differ significantly during the first two phases of testing. After 161 318 repetitions when the trafficking load changed to 80 kN, the waste plastic modified mix showed a higher RSD and MDD deflection compared to the reference mix (Figure 2). The difference observed between the plastic modified and control section was found to be within expected limits and can be ascribed to the inherent variability from construction and the natural variation found in construction materials.

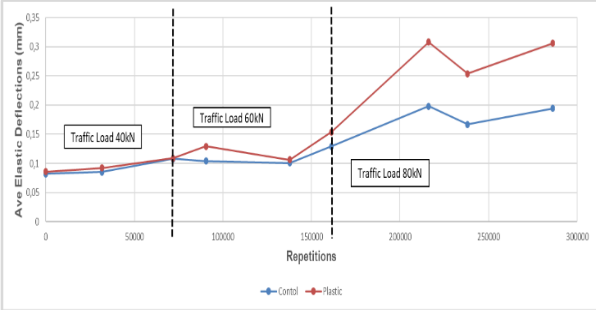

Figure 2: Average RSD Deflections at 40kN testing wheel load after repetitions at different trafficking wheel load

The surface permanent deformation (total rut depths) as measured with the traditional straight edge are shown in Figure 3.

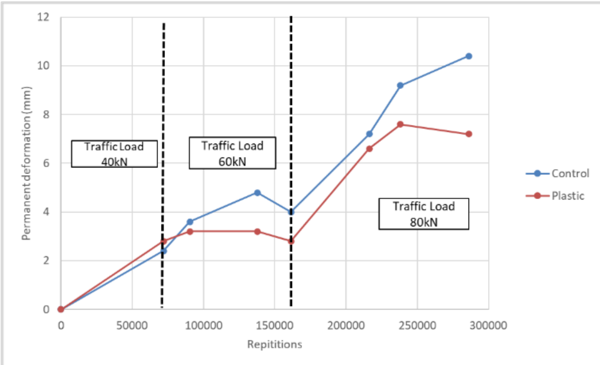

Figure 3: Average surface permanent deformation (total rut depth) vs HVS repetitions

The reference mix had a final total average surface rut measurement of 10.4 mm after approximately 2.9 million E80s (using a damage coefficient of 4.2) under channelised trafficking or 5.2 million E80s using equivalent comparable wandering traffic (Figure 2). The maximum rut depth at a single point was 12 mm. Using linear extrapolation (R^2 = 0.90) a terminal rut of 20 mm will be reached after 5.9 million E80s (using a damage coefficient of 4.2) under channelised trafficking or 10.7 million E80s using equivalent comparable wandering traffic.

The waste plastic modified mix had a final total average surface rut measurement of 7.2 mm after approximately 2.9 million E80s (using a damage coefficient of 4.2) under channelised trafficking or 5.2 million E80s using equivalent comparable wandering traffic (Figure 2). The maximum rut depth was 8 mm. Using liner extrapolation (R^2 = 0.81) a terminal rut of 20 mm will be reached after 9.0 million E80s (using a damage coefficient of 4.2) under channelised trafficking or 16.2 million E80s using equivalent comparable wandering traffic.

CONCLUSION

Accelerated long-term performance simulation with the HVS study demonstrated the potential for using waste plastic in asphalt mixes to enhance rutting resistance (Figure 4) due to the stress-resilient stiffening effect that it imparted on a relatively softer bitumen under high pavement temperature conditions.

It is recommended that future research work includes the following:

- The development of a design guideline based on the results from the testing.
- Fatigue and durability testing of the waste plastic modified mixes on LTPP sections to ensure that the outcomes from this HVS evaluation are complete.

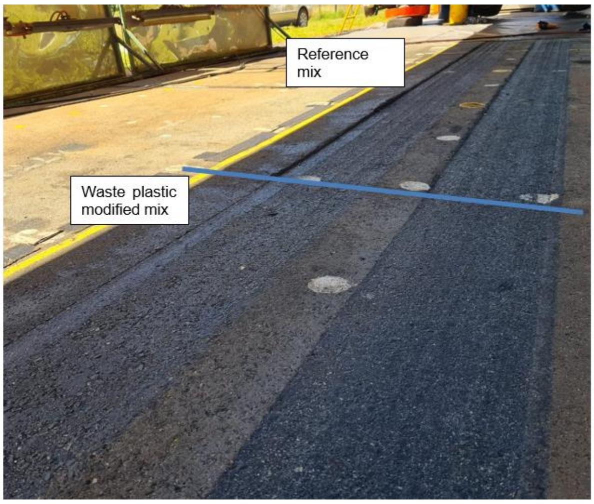

Figure 4: Photo of asphalt on the waste plastic modified mix side

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