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 2: Asphalt production and construction

Ashiel Rampersad
CSIR, South Africa

KEY FINDINGS

This technical note focusses on the quality assurance of asphalt production and construction done by the CSIR at the University of Pretoria's Engineering 4.0 facility for Heavy Vehicle Simulator testing for Case Study 3, where the project aimed to demonstrate the wet modification process of incorporating waste plastic in South African road construction. The modification of bitumen using waste plastic prior to the manufacture of the asphalt mix is known as thewet modification process. The objective of the study was aimed at establishing performance limits for the asphalt mix using the "wet modification method" and the technology was refined to meet local standards and specifications.

This technical note covers details and highlights from the asphalt manufacturing and construction (Phase 2) before Heavy Vehicle Simulator performance testing was carried out in Phase 3. The layer works construction for Case Study 3 was completed in July 2022 and constitute Phase 1 of the project. AECI Much Asphalt produced the asphalt mix, while BSS (Pty) Ltd and Dow Southern Africa (Pty) Ltd supplied the modified bitumen for the demonstration. The asphalt layer was paved by Roadspan Surfaces (Pty) Ltd.

INTRODUCTION

The South African road construction industry is governed by several national standards and specifications to ensure the material, physical, mechanical, performance, and application requirements of road surfaces and pavements (which refers to the load bearing layers of the road below the surface).

These standards and specifications ensure performance and durability towards safe application and use. Any new or alternative materials, such as new plastic-modified materials entering the industry, must strictly comply with these specification requirements and regulations before they can be adopted for use in road construction applications.

This construction Technical Note follows the following format:

- Project context
- Pre-construction of asphalt sections
- Construction of asphalt sections
- Post-construction of asphalt sections
- Conclusions and next steps

PROJECT CONTEXT

The modification of bitumen using waste plastic prior to the manufacture of the asphalt mix is known as the "wet modification process". The project aimed to establish the performance limits for the asphalt mix using the wet modification process. It included the design and construction of Heavy Vehicle Simulator (HVS) test sections that comprised of a control asphalt pavement structure and a waste plastic modified asphalt.

The aim was to facilitate the implementation of this technology in South Africa in conjunction with national and international partners.

SCOPE

A test section for demonstrating the use of waste plastic through the wet modification process was identified for HVS testing to establish the long-term performance of the technology. This technical note focusses on the quality assurance of asphalt production and construction at the Accelerated Pavement Testing (APT) track at the University of Pretoria's Engineering 4.0 facility.

PRE-CONSTRUCTION OF ASPHALT SECTIONS

Mix Design

The design of the pavement structures was done according to COTO (material specifications), TRH 4 (initial structure design) and TRH 16 (traffic loading). An ES30 pavement design was used for the project which supports 10 million to 30 million Equivalent Standard Axles (ESALs) per lane and is classified as a Category A road used on major freeways and roads.

Two sections were constructed at the APT track. The first section consisted of blended waste plastic incorporated into the binder (70/100 penetration grade modified bitumen) for the construction of a 50 mm thick continuously graded coarse asphalt mix. The second section, served as the control section and consisted of a 50 mm continuously graded coarse asphalt mix with no waste plastic and an unmodified 50/70 penetration grade binder. Each section was 50 m in length, and both asphalt sections had the same layer works (Refer to Mokoena, 2024 for the technical note on construction of earthworks and pavement layers). Table 1 highlights the asphalt mix and paving details.

Table 1: Asphalt mix and paving details

Parameter	Plastic Waste Mix	Asphalt Reference Mix
Surfacing	50 mm continuously graded coarse asphalt	
Binder	70/100 modified	50/70 unmodified
Plastic waste	Yes	No
Density	2 598 kg/m^3	2 594 kg/m^3
Field Compaction	93 ± 0.5 %	
Width	4.2m	
Category	Road Category A: Major freeways and roads	
Design	ES30: Supporting 10 million - 30 million standard axles / lane	

Laboratory Verification

Prior to upscaling, the CSIR verified the bituminous material at the Advanced Material Testing Laboratories (AMTL). The Technical Guideline (TG1) on The Use of Modified Bituminous Binders in Road Construction (SABITA, 2015) classification criteria were introduced prior to performance grading as per SATS 3208 (2021). Two grades were to be used for classifying the modified products: the current A-P1 grade for waste plastic modified binders exhibiting both rutting and fatigue properties, and a new A-P2 grade for less trafficked roads (e.g. rural roads) where improved rutting properties are needed, without compromising fatigue properties.

Different binders and emulsions were verified with percentages of plastic and polymers. This was done to identify the combination of binder, plastic and polymer to meet the standard. Properties such as softening point, elastic recovery, dynamic viscosity, storage stability and flash point were tested. Ageing of the binders (which includes mass changes and stress sensitivity) as well as strain tolerances were also tested. The optimized blend was identified, and the compaction temperature viscosities were calculated.

Blending and Upscaling

The blending procedure of plastic waste and binder was developed at the CSIR'S AMTL laboratory. However, upscaling of the procedure was required for construction, where BSS (Pty) Ltd aided in this regard.

The binder properties of a 1 litre sample were established before construction. The mass change was done with one sample, the elastic recovery snapped at 200 mm (original) and 135 mm (after RFTO ageing). the required criteria were met for softening point, elastic recovery, dynamic viscosity, storage stability (after 17.5 hours) and flash point. RFTO ageing criteria were met apart from softening point.

The day before construction, the CSIR team visited the BSS (Pty) Ltd site to verify the procedure used during upscaling and ensure that the plastic waste material was fully blended (Figure 1). A modified blending procedure from that described in Sabita's TG1 was adopted.

The directions, as per lessons from the laboratory-scale trials, include technical specification on the following:

- Bitumen heating temperature
- High shear stirrer speeds
- Wait times for additions of the plastic
- Changes in speeds and blending times
- Visual inspection of the blend

Figure 1: Blending of waste plastic with bituminous binder (upscaling)

CONSTRUCTION OF ASPHALT SECTIONS

Asphalt Verification

Upscaling of the asphalt plastic mix was conducted at AECI Much Asphalt in Roodeport, including supply of the reference mix. The asphalt mix contained 4.8 % binder, with the reference mix designed by AECI Much Asphalt.

The binder used for the plastic mix was a 70/100 penetration grade bitumen incorporating waste plastic and polymer. A 50/70 penetration grade bitumen was used for the reference mix. The methodology was designed to investigate the performance of a lower grade binder (utilizing plastic waste) to a higher-grade reference mix.

Two trucks of each asphalt mix were dispatched where dispatch records captured the binder content (verification) dispatch temperature, temperature on site and asphalt weight.

Mix design trials were completed at the asphalt plant to verify the mixes. These included the mix grading, binder content achieved, workability (air voids in mix), compaction temperature, mix density, moisture resistance and rutting resistance

Site Quality Control

General instructions and best practices were provided and adopted by the paving consultant. The instructions included level control, paving practices, rolling practices, control measures, workmanship and health and safety. Observations noted on site include:

- Paving practices: Paving was conducted at a constant speed. The paver was fed with a constant supply of material. Paving thicknesses were checked regularly. A dip rod was used to check the paving thickness (Figure 2).
- Rolling practices: The rolling pattern on site was adequate for the uniform compaction of the paved width (Figure 3).
- Level control: Level control equipment was utilized on site. Sensors and beams were used on site. The level control was further verified with measurement of core thicknesses.
- Control measures: Mechanically sound rollers were on site to carry out the compaction correctly. Tandem (drum) rollers were used and were free from backlash when reversing. The vibrating rollers are recommended for asphalt compaction.
- Visual assessment: The test section had a visually homogeneous surface texture without areas of segregation or fattening. The appearance and finish as well as dimensional acceptance control were assessed. The constructed asphalt layer complied with level, layer thickness, grade, width, cross section and surface regularity.
- Workmanship: Workmanship complied with level tolerances (all samples met the H_{max} criteria).

Non-conformance as well as health and safety on site are also critical components of any construction project. Non-conformance does not automatically imply that the constructed layer needs to be reconstructed by removal and replacement. Each instance is judged on the principles of "fit for purpose". Such judgements require a high level of engineering knowledge and experience, based on known and acceptable levels of risk and cost implications. No major irregularities were noted, and the construction was deemed as "fit for purpose".

The contractor implemented a health and safety management system for utilization on site, in line with ISO 45001/OHSAS 18001 requirements, for work construction. This was approved by the facility manager at the University of Pretoria. During the construction, there were no irregularities noted.

Figure 2: Paving of asphalt test section

Figure 3: Asphalt compaction and adequate rolling practice

Figure 4: Temperature verification of asphalt mix

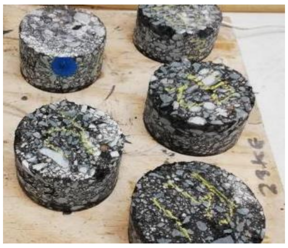

Figure 5: Asphalt cores taken for verification

POST-CONSTRUCTION OF ASPHALT SECTIONS

Sampling and Testing

Asphalt samples were taken using hot boxes from the paver for testing. The hot boxes were in good condition and material loss as well as contamination were deemed unlikely. The asphalt samples were acquired in accordance with TMH5 (MB7). Asphalt cores were also taken for verification. The preparation and test methods conducted on the asphalt samples include:

- Gyratory compaction (AASHTO T312)
- Binder content & sieve analysis (SANS 3001 AS20)
- Modified Lottman (ASTM D4867M)
- Hamburg Wheel Track Test (AASHTO T324)
- Bulk density (SANS 3001 AS10 & ASTM D6752)
- Workability (AASHTO T312)
- Maximum Voidless Density (SANS 3001 AS11)
- Troxler density (TRH 8)

Table 2: Performance testing and verification of plastic and reference asphalt mixes

Test / Performance	Plastic Waste Mix	Asphalt Reference Mix
Core thickness (mm)	50.0	48.3
The average core thicknesses of the plastic and reference mixes are within the 2mm tolerance limit.		
Air Voids (%)	4.9 – 7.0	2.9 – 7.5
Density (kg/m^3)	2 423 – 2 475	2 440 – 2 475
Modified Lottman, Hamburg Tracking and Workability samples were used for the air voids and density.		
Binder content (%)	4.7 – 4.9	4.6 – 4.8
The binder content should be 4.8 ± 0.3, this specification is met (Sabita, 2014)		
Modified Lottman	0.93	0.96
The Tensile Strength Ratio between the reference and plastic mixes are similar, with the higher ratio showing better performance. The minimum required TSR is 0.80		
Hamburg Wheel Tracking Test (Rut depth @ 20 000 passes) (mm)	0.73	1.76
HWTT was conducted in accordance with AASHTO T324. Both mixes performed significantly well after 20 000 passes. It was noted that the plastic mix performed better than the reference mix.		
Workability (Compaction Temperature) (°C)	167	158
The workability of the mixes was assessed by using gyratory compaction according to AASHTO T312. The compaction curves for the mixes are plotted		

Plastic Modification Performance

The results of the plastic modified mix were compared to the reference mix. A description and analysis of the performance is also included in Table 2 with selected results. The results of the performance tests were critical in ensuring compliance of the asphalt mixes and the decision to move forward to HVS testing.

CONCLUSIONS AND NEXT STEPS

This technical note provides quality assurance results of asphalt production and construction for Heavy Vehicle Simulator testing of Case Study 3 that is summarized in Smit (2024). The author would also like to acknowledge the contracted parties including BSS (Pty) Ltd, AECI Much Asphalt and Roadspan Surfaces (Pty) Ltd for their high-quality work and professional conduct.

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