Permanent deformation of asphalt concrete modified with waste plastic

ABSTRACT: Permanent deformation or rutting is one of the most common forms of road pavement distress. It is typically associated with hot weather and heavy trafficking. According to the recent Stern Report, global climate change will have significant effect on temperature, and so improved understanding of how asphalts behave under different temperature conditions will continue to be an important aspect of mixture design and development. This paper compares two methods of assessing permanent deformation of asphalt concrete modified with waste plastic at a range of test temperatures. Analysis found that both methods gave similar ranking of performance and that the mixtures modified with waste plastic had better resistance to permanent deformation over the temperature range evaluated.

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1 Introduction

Asphalt concrete is used around the world but can suffer from extremes of temperature. Polymer additives can improve properties such as temperature susceptibility, resistance to permanent deformation and fatigue life. However, the use of such additives is expensive and limits its potential to improve the life of asphalts. This led to the investigation of low cost materials that could provide an alternative. The use of shredded waste plastic milk bottles offered a possible solution. This paper considers the assessment of permanent deformation of asphalt concrete mixtures modified with waste plastic at a range of temperatures. The repeated load axial test[1] and the wheel tracking test[2] were chosen for this comparison which had two main objectives:

- To determine whether waste plastic could improve the permanent deformation characteristics of asphalt concrete at a range of test temperatures
- To determine the degree of correlation between the two methods of assessment. This would be of benefit in situations where the relatively expensive equipment required to determine permanent strain characteristics could be replaced by the cheaper wheel tracking equipment.

2 Materials and preparation

The asphalt concrete mixture was made using a basalt aggregate and paving grade bitumen having a penetration between 60 and 70. The plastic milk containers were collected from household waste and cut into small pieces approximately 2 x 2mm in size. The bitumen was heated to 160–170°C and the plastic added slowly for about five minutes. The bitumen/plastic blend was then mixed at high speed for one hour using a mechanical stirrer. Marshall mix design procedures were used to optimise the bitumen and modifier content of the asphalt concrete mix. This was found to be 6% bitumen modified with 1.5% waste plastic.

3 Permanent deformation assessment

Two methods were used to determine the permanent deformation characteristics of the mixture. These were the repeated load axial test (RLAT) using the Nottingham Asphalt Tester and the wheel tracking test using a UK standard small dry wheel tracking machine. The test specimens were assessed over a range of increasing test temperatures to determine the effect of the plastic waste addition. Comparison of both test methods would also determine whether one value could be predicted from the other.

3.1 Repeated load axial tests

The RLAT test specimens were prepared using Marshall compaction (50 blows). A Nottingham Asphalt Tester was used to assess the asphalt concrete mixtures at 20, 30 and 40°C for permanent deformation. The RLAT data is summarised in *Figure 1*.

This shows that the permanent strain using the waste plastic modified bitu-

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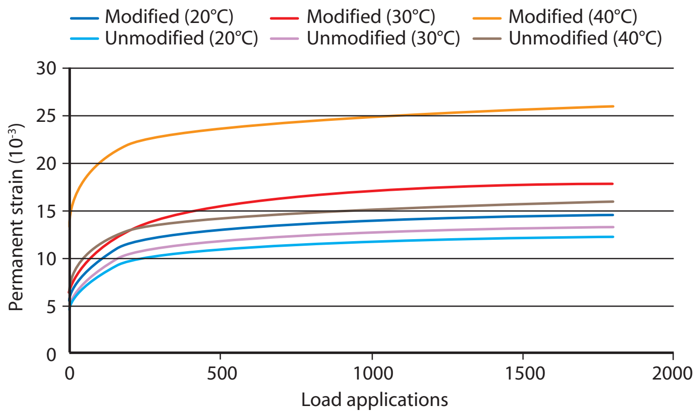

Figure 1 – Permanent strain data at different test temperatures

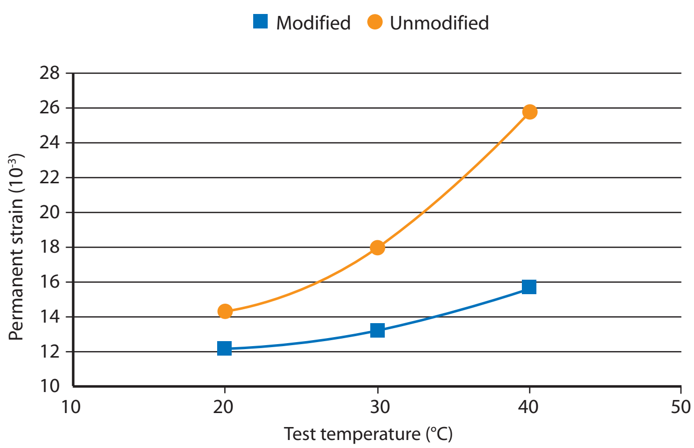

Figure 2 – Effect of temperature on RLAT data

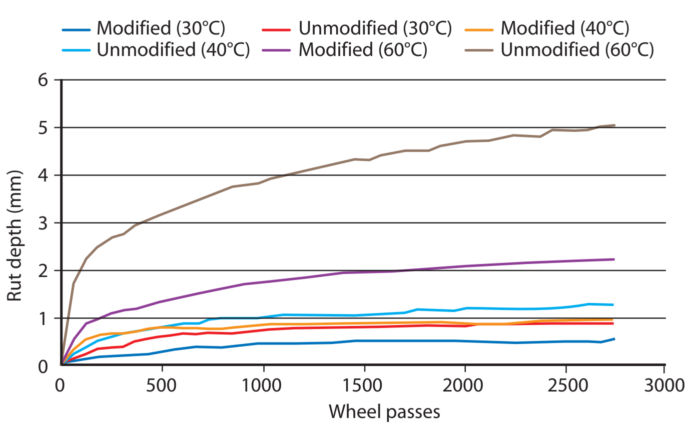

Figure 3 – Rut depth data at different test temperatures

men was smaller than for the standard unmodified bitumen, ie the waste plastic improved resistance to permanent deformation.

Figure 2 shows that temperature significantly affects deformation performance, particularly at the higher temperatures. However, the addition of waste plastic reduced the deformation by about 40% at 40°C.

3.2 Wheel tracking tests

The wheel tracking test specimens were 150mm in diameter and 50mm thick, manufactured using gyratory compaction to obtain, by trial and error, the same density as the Marshall test samples. A Wessex wheel tracking machine assessed the specimens at 30, 40 and 60°C for a period of 45 minutes.

Figure 3 shows that the rut depth of asphalt concrete containing waste plastic in the bitumen was lower than for standard unmodified mixtures. It can be clearly seen that a significant improvement in rutting resistance can be achieved by adding waste plastic to the bitumen. *Figure 4* shows that at 60°C the addition of 1.5% waste plastic gave an improvement of 55%.

4. Comparison of test methods

Both test methods for assessing permanent deformation performance were compared. Rut rate was calculated in accordance with BS 598-110:1998 and strain rate as the average in the linear phase. *Figure 5* plots rut depth against permanent strain. *Figure 6* plots rut rate against the rate of permanent strain. Both plots show good correlation between the test data, ie it could be reasonable to use either method to determine resistance of permanent deformation.

Table 1 summarises the test data from both types of assessment and provides a simple ranking. This clearly shows that the addition of waste plastic improves both sets of data and that both test methods provide the same ranking.

5. Conclusions

This investigation has provided the following conclusions:

- The addition of waste plastic to bitumen was found to significantly reduce the permanent deformation of asphalt concrete, particularly when tested at higher temperatures.
- A good relationship was found between RLAT and wheel tracking test methods.
- Both test methods ranked the asphalt concrete mixtures in the same order.

Test Temp (°C)	Mixture Composition	RLAT Permanent Strain µstrain	RLAT Strain Rate µstrain/cycle	Rank	Wheel tracking Rut Depth mm	Wheel tracking Rut Rate mm/wheel pass	Rank
20	Unmodified	14.374	0.011	2	—	—	—
	Modified	12.197	0.010	1	—	—	—
30	Unmodified	17.920	0.015	2	0.81	0.252	2
	Modified	13.223	0.012	1	0.46	0.072	1
40	Unmodified	25.776	0.027	2	1.21	0.408	2
	Modified	15.650	0.016	1	0.88	0.168	1
60	Unmodified	—	—	—	5.03	2.148	2
	Modified	—	—	—	2.20	0.852	1

Table 1 – Ranking of test method data

- The deformation performance of asphalt concrete mixtures prepared using waste plastic (as obtained from shredded milk bottles) was better than conventional mixtures at the range of temperature assessed.

References

[1] **British Standards Institution**
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[2] **British Standards Institution**
Sampling and examination of bituminous mixtures for roads and other paved areas, Method of test for the determination of wheel tracking rate and depth, BS 598-110:1998
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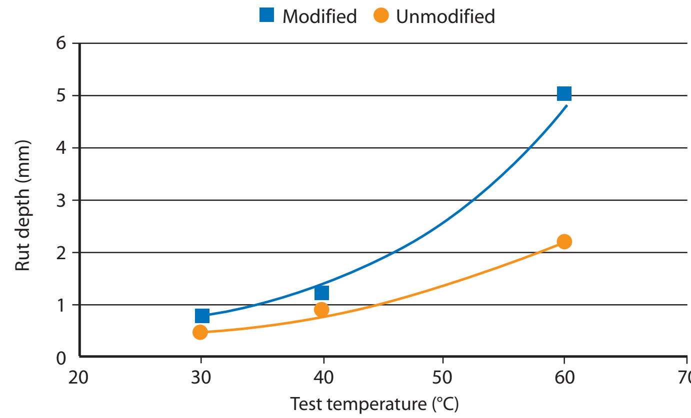

Figure 4 – Effect of test temperature on wheel tracking data

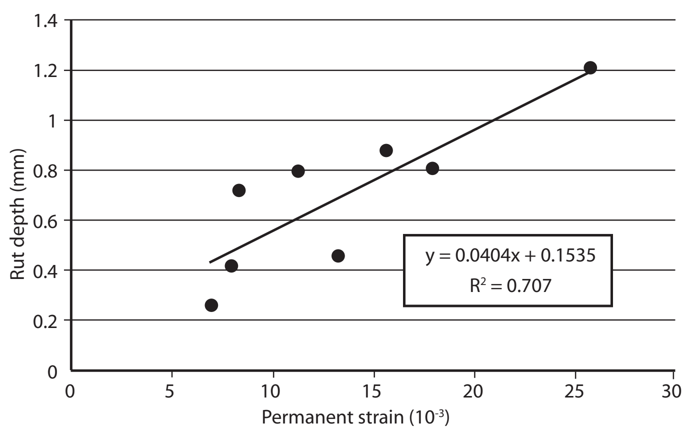

Figure 5 – Rut depth versus permanent strain

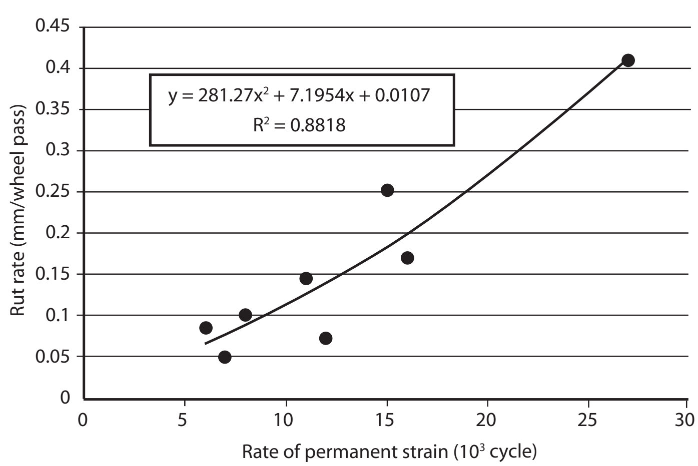

Figure 6 – Rut rate versus rate of permanent strain