Modified Asphalt Binder To Improve Travel Characteristics

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Abstract

When dense graded asphalt cools the ability to compact the mix decreases, resulting in high in-situ air voids. High in-situ air voids could mean an increase in the potential for asphalt deformation, a reduction in its fatigue life and an increased rate of oxidation of the bitumen. This is the problem Main Roads Western Australia is facing as the asphalt is often made in Perth or regional centres and carted for a long distance to sites, thus a drop in temperature of the asphalt mix is unavoidable. An emerging new technology named Warm Mix Asphalt (WMA) may be able to address this problem. It introduces a wax product (Sasobit®) to modify the behaviour of the bitumen binder in the asphalt. According to Sasol Wax (2007), Sasobit® is a synthetic paraffin wax which reduces the viscosity of the binder at mixing and compaction temperatures. In this project laboratory and field testing were conducted on both Sasobit® modified and unmodified asphalt specimens compacted at varying temperatures. The study has demonstrated that Sasobit® modified asphalt has reduced air voids at lower compaction temperatures. Other tests were performed, including resilient modulus, flow and stability, beam fatigue and wheel tracking test to characterise the stiffness and deformation properties of asphalt specimens. The results obtained for Sasobit® modified asphalt complied with relevant Main Roads W.A. specifications.

1.0 INTRODUCTION

As stated by Rebbechi et al (2002), in Australian and New Zealand heavily trafficked roads, and in urban areas, hot-mix asphalt (HMA) is commonly used for its resistance to trafficking effects, durability and smooth riding surface. The manufacture of hot-mix asphalt, involves heating aggregates and binder to high temperatures (typically to around 160^{0}C) prior to compaction. The focus of this study was on dense graded asphalt, which consists of a dense, continuously graded mixture of coarse and fine graded aggregates, mineral filler and bituminous binder.

Asphalt is carted in W.A mostly by a truck and trailer configuration. For most applications asphalt is dumped directly from trucks into the front hopper of a paver. For long distance haulage, asphalt is carted on road train and then stockpiled on site to be later transported by smaller trucks to the paver. This is usually the case for remote rural road constructions, as the asphalt plant may be located at a considerable distance away from the construction site, and would require bulk asphalt transportation to be made. Dean and Skinner (1991) have stated that the average temperature reduction during normal asphalt haulage is around 10-20°C, subject to many different factors. There can be significant temperature reductions for long distance haulage, cool weather or windy conditions. Time delays will also add to further temperature drops in the asphalt mix.

Warm Mix Asphalt (WMA) allows a reduction in the viscosity of the asphalt binder at any given temperature. This in turn allows mixing, transporting and lay-down process to take place at significantly lower temperatures. Using a WMA process, it has been documented by Jones (2 that successful compaction can be achieved at temperatures as much as 37^{0}C lower than cu requirements. The other potential benefits of WMA that are usually publicised in literature are the emission reductions and reduced energy consumption during production.

Hurley and Prowell (2005) states that the three most widely used technologies in Europe for producing WMA are Asphalt-Min®, WAM-Foam and Sasobit®, the latter of which is the focus of this study. Sasobit® is a product of Sasol Wax, South Africa, a long-chained aliphatic hydrocarbon derived from coal gasification. At temperatures below its melting point (100°C), Sasobit forms a lattice structure in the asphalt binder that is the basis for the reported stability of asphalts that contain Sasobit. At service temperatures, Sasobit modified asphalts are reported to display an increased resistance to rutting. In addition Sasol Wax (2007) reports improved "compactibility" with an increase in the degree of compaction for the same roller loading as unmodified asphalt.

2. METHODS AND PROCEDURES

This project composed of two testing procedures, i) laboratory testing component which involved purely laboratory testing, ii) field testing component which involved carrying out tests on asphalt slab specimens prepared under field conditions. Figure 1 shows the experimental program carried out for laboratory testing, and Figure 2 for field testing.

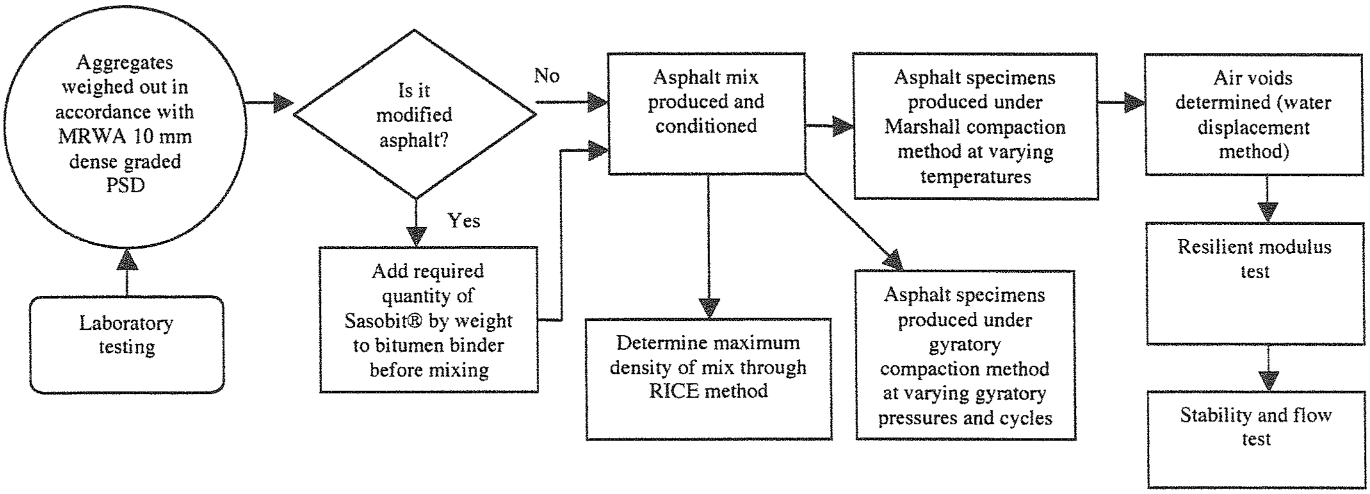


Figure 1. Flow chart for laboratory testing program

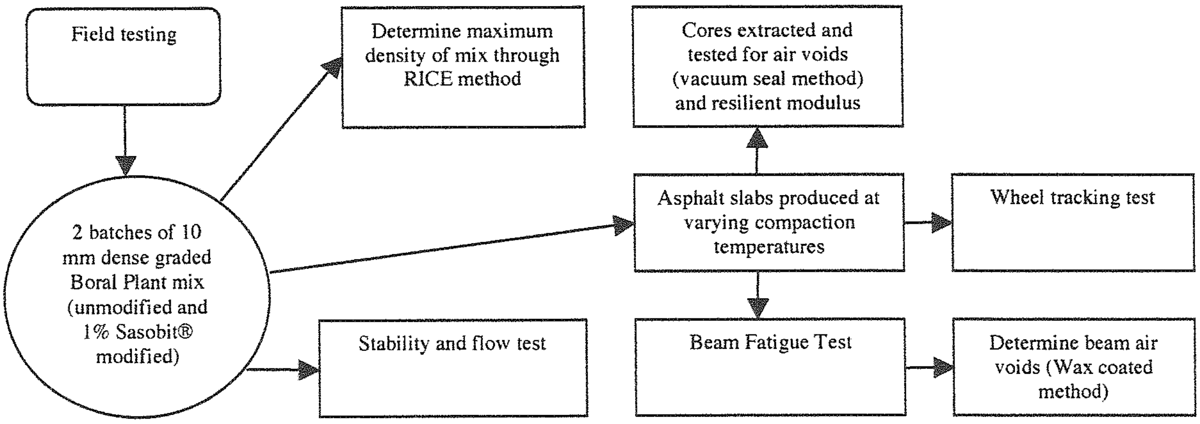


Figure 2. Flow chart for field testing program

All aggregates were obtained form Boral Asphalt plant and laboratory in Welshpool, Western Australia and quarried locally at the Boral Orange Grove quarry in Orange Grove. These aggregates were primarily composed of granite. Hydrated lime was used as the added mineral filler. Bitumen Class 320 viscosity grade was used as a binder for all samples associated with the testing for this project. All mix preparations for modified asphalt involved Sasobit® as the bitumen modifier.

The main objective of this project is to study the level of compaction achieved by modified and unmodified asphalt at varying temperatures, through measuring percentage air voids. The effect of compaction level on the deformation characteristics were also studied including stiffness, fatigue strength, and permanent deformation resistance through such tests as defined by the following testing standards:

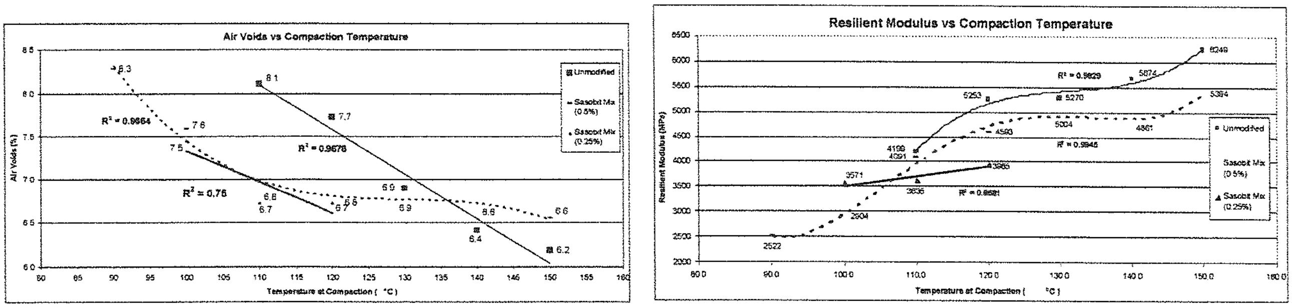
- Marshall specimens were produced in accordance with MRWA Specification 731.1.
- Rice Method is carried out in accordance with MRWA Specification 732.2.
- Air voids determined in accordance with MRWA Specification 7331.1.
- Resilient Modulus test was carried out in accordance with AS 2891.13.1 – 1995.
- Marshall Stability and Flow test were carried out in accordance with MRWA Specification 731.1.
- Wheel tracking test was carried out in accordance with Austroads Test Method AG:PT/T231.
- Beam fatigue testing was carried out in accordance with Austroads Test Method AG:PT/T233.

3. RESULTS AND DISCUSSION

3.1 Laboratory testing results

Fig 3(a) is a graph of air voids versus compaction temperature. It can be clearly seen that for unmodified asphalt there is a strong linear relationship for air voids against compaction temperature. The trend shows that for every 20°C increase in compaction temperature there is a 1% drop in the level of air voids. The general trend for 0.5% modified asphalt also shows that as the compaction temperature increases then the air voids decrease, however not linearly. At compaction temperature range between 90°C and 110°C the air voids decrease exponentially, and at temperature range between 110°C and 150°C the air voids plateau. At the temperature range between 110°C and 120°C modified asphalt air voids are significantly less than unmodified asphalt. The level of compaction achieved in this range has effectively reduced the air voids to an acceptable level that is similar to the compaction achieved at the standard specified temperature of 150°C± 5°C. It also appears that a close to maximum compaction level can be achieved for temperatures between 110°C and 120°C. There is a significant reduction in air voids between unmodified and modified asphalt at 120°C equal to 0.9%. At higher compaction temperature range of 140°C to 150°C modified asphalt air voids were slightly greater than unmodified asphalt. It is believed that this is as a result of the reduced viscosity of the Sasobit® modified bitumen causing it to become very fluid and fill up the asphalt voids.

Figure 3(b) is a graph of resilient modulus versus air voids. The general trend shows that as the air voids increase, the resilient modulus and hence stiffness of the asphalt decreases. Majority of the modified and unmodified asphalt specimens have satisfied MRWA standard specification which states that the resilient modulus shall be in the range of 3000MPa to 6000MPa, with the exception of modified asphalt compacted at 100°C or less which gave results that were outside this range. It can be seen that modified asphalt has less resilient modulus than unmodified asphalt at a given air void level. It is believed that the addition of wax may cause a lubricating effect which reduces the interlocking ability of aggregates, thus resulting in reduced stiffness for modified asphalt. MRWA standard specification states that the minimum stability requirement is 8kN. The results from the stability test show that only modified specimens compacted at 100°C or less did not comply with the specification. The stability of modified asphalt is also slightly greater than unmodified asphalt at lower air voids. MRWA standard specification for flow states that it must be in the range of 2mm to 4 mm. The results from the flow test show that all specimens satisfied MRWA standard specification. 0.5% Sasobit® Modified asphalt showed slightly less flow than unmodified asphalt at a given air voids.



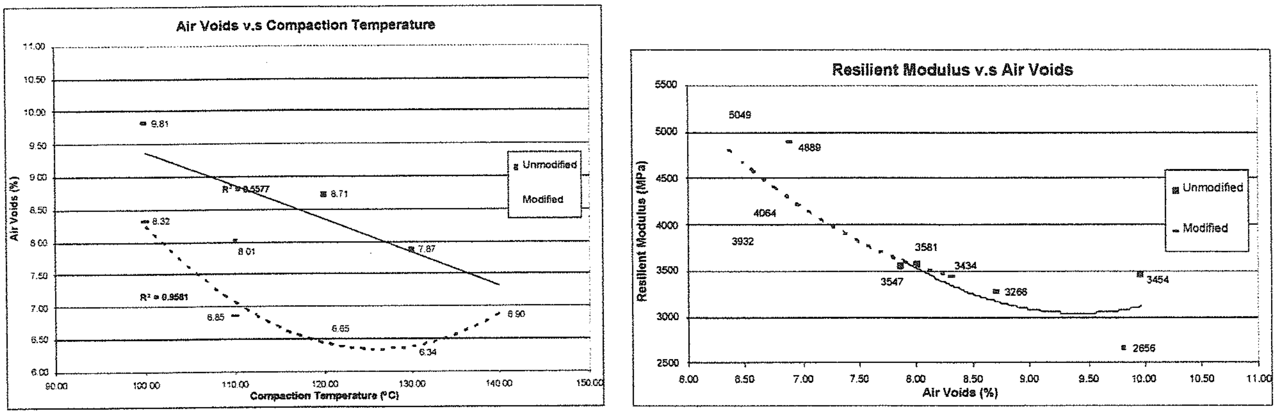
(a) (b)

Figure 4 (a) Laboratory testing results of air voids versus compaction temperature, (b) Laboratory testing results of resilient modulus versus air voids.

3.2 Field Testing results

Field testing has been conducted on unmodified and 1% Sasobit® modified asphalt slab specimens. Figure 5(a) shows the graph of air voids versus compaction temperature of the asphalt slab specimens, made from plant produced mix and compacted under field conditions. The trend for unmodified and 1% Sasobit® modified asphalt clearly demonstrate compatibility to the laboratory testing results for unmodified and 0.5% Sasobit® modified asphalt. The maximum difference between the air voids for unmodified asphalt to modified asphalt also occurs at 120°C, with 23.6% less air voids for modified asphalt than unmodified asphalt.

Figure 6(b) shows the graph of resilient modulus versus air voids for the field prepared asphalt slabs. It demonstrates that modified asphalt produced greater stiffness and better compaction than unmodified asphalt. This is attributed to greater compaction achieved for modified asphalt, resulting in less air voids, as compared with unmodified asphalt. For both modified and unmodified asphalt the resilient modulus is within the standard specification requirements. The stability for both modified and unmodified plant produced mixes were well above the minimum requirement, and although the results for flow are in the upper range of the limit, they are also considered to be acceptable. For flexural stiffness testing the general trend for both modified and unmodified asphalt beams indicate that as the air voids increase then it results in a decrease in flexural stiffness. Modified asphalt beams had the least air voids, and therefore produced greater flexural stiffness. From the change in flexural stiffness results it showed that modified asphalt has a mean change in flexural stiffness of 23.88% and unmodified asphalt has a mean change of 19.01%. MRWA standard specification states that the maximum change in flexural stiffness to failure is at 50%. Therefore, even though modified asphalt stiffer and undergoes greater fatigue than unmodified asphalt, the results show that they are still well within the requirements. standard specification for wheel tracking test states maximum rut depth of 15 mm. From the wheel tracking test results it showed that on average, unmodified asphalt produced 20 % less rut than the standard specification, as compared to the much superior performance of modified asphalt which produced on average 64% less rut. Therefore, this demonstrates that modified asphalt has a greater potential for rut resistance than unmodified asphalt.



(a) (b)

Figure 5 (a) Field testing results of air voids versus compaction temperature, (b) Field testing results of resilient modulus versus air voids.

4. CONCLUSIONS

Based on the laboratory and field testing results, Sasobit® modified asphalt can produce effective compaction and hence lower air voids at lower compaction temperatures than unmodified asphalt. It can achieve a similar level of compaction at a temperature range of 110 °C to 120 °C that would require a compaction temperature of 140 °C to 160 °C for unmodified asphalt. The deformation characteristics as investigated through the stability and flow test, resilient modulus test, beam fatigue testing and wheel tracking test all achieved the minimum standard requirements. There was a noticeable reduction in stiffness and stability for specimens compacted at temperatures less than 100 °C. Therefore, as a safety factor, the minimum workable temperature for Sasobit® modified asphalt to achieve effective compaction shall be set to 120 °C. This will provide some allowance for any temperature drops in the field, due to the handling and laying down processes, while still achieving effective compaction.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Dean, T., Skinner, R. 1991. Hot mix asphalt paving handbook. Washington, D.C.: U.S. Army Cops of Engineers

Hurley, G. and Prowell, B. 2005. Evaluation of Sasobit® for use in warm mix asphalt. Auburn: Auburn University

Jones, W., 2004. Warm mix asphalt: Technology of the future, Asphalt Institute. Available from: www.asphaltinstitute.org/Upload/2004_Fall_Mag_Warm_Mix_Asphalt_Pavements.pdf

Rebbechi, J., Morrison, R. and Youdale, G. 2002. AAPA asphalt guide. Sydney: Austroads Incorporated

Sasol Wax 2007, Applications: Sasobit® Technology. Available from:

<http://www.sasolwax.com/Sasobit_Technology.html>[29 April 2007]