ABSTRACT: Currently in Malaysia, the common mode of pavement failures at high stressed area are due to bituminous layer undergoing aging and subjected to extreme long loading times by the slow moving heavy commercial vehicles. This scenario causes major structural deteriorations and permanent deformation of the bituminous road surfacing. In order to fix this problem, the use of Polymer Modified Bitumen (PMB) in asphalt mixture to form Polymer Modified Asphalt (PMA) mixtures was chosen as an alternative method to increase the durability and lifespan of the pavement. The PMA mix design was developed using the latest Malaysia Public Work Department Specification namely the Standard Specification for Road Works: Flexible Pavement (JKR/SPJ/2008-S4). The objective of this paper is to highlight the ability of PMA to increase the performance and subsequently increase the life span of bituminous pavement layers. This paper highlights the performance of Polymer Modified Asphalt (PMA) as one of the methods to reduce the development of permanent deformation on bituminous pavement layers. The real site condition was monitored using PMA and conventional bitumen of Grade 80-100 with same aggregate grading from the beginning of the construction. The monitoring and testing were carried out almost for two years. The performance indexes that were monitored were cracking, rutting and surface roughness.

KEY WORDS: Polymer, modified, asphalt, road, durability, flexible

1. INTRODUCTION

The total extent of Malaysia roads network is approximately total of 137,220 kilometers with 111,378 kilometers of paved road and 25,842 kilometers of paved roads [1]. Most of the paved roads in Malaysia are flexible pavement. The flexible pavement structures in Malaysia consist typically of bituminous surfacing, granular road base, drainage sub base and the formation subgrade. The pavement structure is designed in accordance to The Arahan Teknik (Jalan) 5/85 [2] which is adapted from the AASHO (American Association of State Highway Officials) Road Test. Recently in early 2013, the standard was reviewed and the new references for the pavement structures design was published as Arahan Teknik (Jalan) 5/85 (Pindaan 2013) Manual for the Structural Design of Flexible Pavement [3]. The design approach recommended in this Manual combines improved design development data and mechanistic methods of analysis into a single tool that is presented in the form of a catalogue of pre-design pavement structures.

Asphalt concrete mix was introduced as a bituminous surfacing in the 80’s, both as the wearing course and binder course. Design using the Marshall Method, asphaltic concrete is preferred over the bituminous Macadam surfacing, road base layer or stabilized base layer as the latter exhibited several unacceptable distress patterns such as raveling and early development of cracks.

The asphaltic layers play a very important role in road pavement construction. i.e providing a hard and impermeable layer to the road pavement. The hard layer prevents undue deformation in the unbound layer when subject to the traffic loading. The impermeable asphalt bound layer also prevents water from reaching the lower layer of the pavement structure thereby weakening the layers. Reference by the Public Institute Malaysia (IKRAM) has show that asphaltic concrete roads failed predominantly through cracking while reflection crack normally occurs on roads where resurfacing was done directly on top of a previously cracked road. The introduction of asphaltic concrete in Malaysia has brought with the problem of the extensive quality control...
testing that is required to produce such mixes to the required Marshall tolerances. Even when these materials are produced to specification, there are often inappropriate in areas of high traffic stresses, such as climbing lanes and main junctions, as is evident by the rapid permanent deformation along the wheel paths throughout the country. This type of deformation was called rutting is hazardous to the road users as it allows surface water to accumulate, thus increasing the risk of water infiltration into the pavement structure.

The objective of this paper is to highlight the performance of the using polymer asphalt mix at the high stress area comparing with the normal asphaltic concrete mixes (ACW14). The aims of this research are as followed:

i. To determine the performance of polymer modified asphalt to prolong the life of pavement surface compared to conventional mix using 80/100 penetration bitumen grade.

ii. To identify the effectiveness of polymer modified asphalt concrete to prevent the presence of cracks on the pavement surface.

2. MODES OF PAVEMENT DISTRESS IN MALAYSIA

2.1 Top – down cracking
Bituminous surfacing in Malaysia use primarily the conventional 80/100 penetration grade bitumen as a binder. For the production of asphaltic concrete, the 80/100 bitumen is normally blended with hot aggregate at a mixing temperature of 150 – 170°C. Research work by the JKR and other research institution overseas have shown that bitumen tend to harden while at the early stage of handling, in storage, during mixing and in service. Chemical reaction between bitumen and oxygen has been determined to be the main cause of bitumen hardening during these stages [4]. It is accepted facts that 80/100 pen grade bitumen loses at least a grade after undergoing hot mixing process at the asphalt producing plant. During service, exposure of the bitumen film to ultra – violet radiation exacerbated the oxidation of the bituminous binder. The thin bitumen film in the top layer of the road surfacing soon becomes brittle and causes an increase in the stiffness moduli of asphaltic mixes, but at the same time reduces the strain required to induce cracking.

Brittle bitumen tend to crack due to shrinkage stresses cause by the diurnal temperature change or by traffic induced stresses caused by the diurnal temperature change, or by traffic induced stresses, or by combination of both. Surface crack allows the hardening process to take place deeper into the body of the mix resulting in the propagation of surface crack downwards, a phenomenon referred to as top-down cracking.

Top-down cracking occur prematurely compared to the normal design life of road pavement (seven to ten years). This is due to the thin bitumen film thickness (typically 5 – 10 micron) prevalent in the mix. The hardening process due to oxidation is exacerbated by the presence of high voids content (5 – 8%) in the mix due to inadequate compaction or improper mix design. Exposure to the ultra violet radiation and moisture accelerate further the deterioration rate of asphaltic concrete mix.

2.2 Reflection crack
Reflective cracks are a major concern to the pavement surface because it can significantly reduce the service life of asphalt layer pavement structure. When the asphaltic concrete mix was are placed over the severely cracked pavement surface, the cracks in the existing pavement can reflect to the surface in a short period of time. These cracks allow water to penetrate the underlying layers causing further damage to the pavement structure by destroying the bond between the existing pavement and overlay, causing moisture damage in the asphaltic concrete layers, as well as weakening unbound layers, and result in a loss of ride quality or smoothness.

Research by Mutalif et.al. [5]. On the effectiveness of 40mm thick asphaltic concrete overlays, showed that crack in the existing surface reflected through the new asphaltic concrete overlay in a relatively short period. The rate at which the crack reflect depended on the type of the cracking and the magnitude of the pavement deflection prior to overlay, and the cumulative flow of commercial vehicles after the construction. It was show that the use of 40 mm asphaltic concrete overlays to rehabilitate roads with interconnected cracks is ineffective.
2.3 Rutting
The introduction of asphaltic concrete in Malaysia has brought with it the problem of the extensive quality control testing that is required to produce such mixes to the required Marshall tolerances. Even when these materials are produced to specification, they are often inappropriate in areas of high traffic stresses, such as climbing lanes and main junctions as it evident by the rapid permanent deformation along the wheel paths throughout the country. This type of surface distress allows surface water to accumulate, thus increasing the risk of skidding and aquaplaning which is hazardous to the road user especially during wet condition because ruts tend to pull a vehicle towards the rut path as it is steered across the rut. If it allowed deteriorating, it can lead to longitudinal cracking of the surface and subsequently permit the ingress of water. As the deformation causes a reduction in driving comfort and effects safety, the road has to be inevitably rehabilitated now and then.

2.4 Lack of macrotexture
Besides cracking and rutting, asphalt concrete road surfacing in Malaysia lack the desirable macrotexture for skidding resistance at high speeds. Johari et. al. [6] observed that the average texture depth (sand patch) on asphaltic concrete surfacing is 0.35mm. Research work by the TRL suggested that the risk to accidents increases when the microtexture falls below 0.7mm.

Skidding resistance is the term used to describe friction between the road and the tire. It is generally considered that a dry road normally provides adequate grip, but in wet condition (about 25 percent of the time in Malaysia), friction falls and there is a greatly increased risk of skidding. For this reason, the term skidding resistance is normally assumed to refer to wet roads. Although tire characteristics are important, the main contribution to skidding resistance comes from the road itself [7]. Two components determine the skidding resistance of a road surface: microtexture and macrotexture. Microtexture depends on the surface roughness of aggregate and varies with aggregate types.

It is frequently described as either rough or smooth. Macrotexture is formed by the aggregate arrangement at the road surface. Macrotexture can be obtained by aggregate protrusion at the surface (e.g. Hot Rolled Asphalt with chippings rolled on top) or aggregate inversion (in the case of porous asphalt). At speeds greater than 50 km/hr, coarse macrotexture is required for channelisation of water trapped between tyres and road surface thereby evading aquaplaning. In Malaysia, the average yearly rainfall ranges between 1700 mm and 2000 mm hence the importance of macrotexture cannot be overemphasized.

3. DEVELOPMENT OF POLYMER MODIFIED ASPHALT IN MALAYSIA

Polymer Modified Asphalt (PMA) concrete is an option to prolong the life or enhance the performance of bituminous pavement layers. It is a mixture of continuously graded aggregate and polymer modified binder. The binder is produced by incorporating an appropriate quantity of synthetic polymer to conventional bitumen. The main objective of using modified binders in asphaltic mix is to provide a cost effective solution in improving the resistance to permanent deformation of the surfacing materials at high temperature and under extreme loading condition. This is achieved by stiffening the binder so that the viscous response of the asphaltic mix is reduced resulting in a corresponding reduction in permanent strain. Alternatively, the elastic component of the binder is increased, thereby reducing the viscous component, which again results in a reduction in permanent strain. Secondary benefits in terms of resistance to fatigue cracking, better load spreading ability and resistance to aging may also be gained with some of the additives.

Construction of polymer modified asphalts in Malaysia began in the late eighties, initially as full scale trials and subsequently in major rehabilitation projects. Various polymers had been used and these include the Polybilt 101, XCS 503, Chemcrete, Gilsonite and synthetic rubber. Proprietary polymer modified bitumens
(PMBs) have also been used in asphalt construction and these include Multigrade, Carbit-Plus, Cariphalte-DM, Asphapol 2000, Novophalt, Sealoften and Flexipave.

The trial on 1994 involving Chemcrete, and Caribit-Plus modifiers, the PMAs showed marked improvements in rutting resistance. However, cracks started to develop 6 months after construction in the Caribit-Plus and Chemcrete sections. Visual inspection of cores taken from the affected areas showed that the cracks originated from the top and had propagated down by no more than 20 mm. The control section for this trial had unexpectedly performed better with minimal rutting and no cracks after approximately 16 months. Subsequent tests on the mix composition showed that the binder content was 5.27%, much less than the design value of 5.95%. The improved performance could be due to the reduction of the binder content [8].

In another trial on using of PMA's in 1992 was done at Bukit Tinggi on the Kuala Lumpur – Karak Highway. The climbing lane had a grade of 8 percent and the average speed of the commercial vehicles using it was uniform and measured at 15km/hr. In an experiment comparing the relative performance of a control asphaltic concrete with similar material modified with Polybilt 101 polymers, Hizam [9] reported that polymer modified asphalt performed better than the control section, reducing the rate of deformation by a factor of over 2.

In year 1996, the construction of Kuala Lumpur International Airport Runway and taxiway pavement was applying the largest amount of polymer modified asphalt. The design of bituminous binder was done using the Strategic Highway Research Program (SHRP) performance grading.

4. ADVANTAGES OF POLYMER MODIFIED ASPHALT

At high temperatures and long loading times conventional bitumen behaves in a viscous manner, allowing the mix to deform under traffic. The subsequent reduction in air voids decreases the materials resistance to deformation as the fine aggregates occupy more of the voids thus reducing the mechanical interlock between the course aggregates [10]. This eventually results in structural instability and the surfacing shears under trafficking.

5. EXPERIMENTAL DESIGN

Public Work Department was carried out the study on the performance of PMA in the maintenance project for the maintenance cost saving. The trial site selected for the study was a 400 meters length at Bentong on Federal Route 2, Kuala Lumpur - Kuantan, Pahang. The trial site was flat and highly traffic loaded. The trial was designed to compare the relative performance of a control 14mm asphaltic concrete wearing course (AC14) made with 80/100 pen bitumen with the similar material modified with Stryrene Butadiene Styrene (SBS). The 2 kilometers length project site was one of the periodically rehabilitation project using mill and replace method. The existing asphalt layer was removed and replace with the new AC14 wearing course layer.

The test section were each 200 metres in length and test points were marked out at 10 meters intervals, at which International Roughness Index (IRI), modulus strength and surface condition survey were taken periodically.

5.1 Control Section

The 200 meters of control section was constructed to the normal contractual procedures using 14 mm (AC14) wearing course material without any modifier. The premix of AC14 was laid at 45mm thickness while the existing layer was milled out.

5.2 Polymer Modified Asphalt (PMA) Section

The 80/100 penetration grade bitumen was modified using Stryrene Butadiene Styrene (SBS) to produced Shell Chariphalte PG76 product. The SBS in Chariphalte ensure the formation of a 3 dimensional network within the bitumen thus reducing temperature susceptibility whilst increasing stiffness modulus at high
temperature as well as substantially increasing elasticity. As same as the control section, the existing layer was remove and the premix of PMA AC14 was laid at 45mm thickness.

5.3. Aggregate Gradation
The aggregate gradation was designed using AC14 gradation limit as stated in Public Works Department’s (JKR) Standard Specification for Road Works JKR/SPJ/2008-S4. The grading for design and extracted gradation for the test section has been plotted in Figure 1 together with the Public Works Department’s (JKR) grading specifications envelope. This Figure illustrates that the grading on the test sections were similar conformed to the JKR grading specifications. The design binder content for both AC14 PMA and Control asphalt mixes was 5.3%.

5.4 Compaction of Sections
On the both test sections using AC14 PMA and AC14 conventional mix, the compaction effort was similar. The rolling pattern was four passes (2 static, 2 vibratory) with 8 tonne steeled wheel roller followed by 10 passes of 12 tonne pneumatic tyre roller and finally 2 further static passes with the steel wheeled roller.

6. PERFORMANCE

6.1 Rut depth Progression
The maximum rut depth was measured before construction of trial section and it shows 29mm for Control Section and 40mm at PMA section. After the construction, rut depth measurements were made at time intervals of 1 month, 2 month, 3 month, 6 month, 15 month and 18 month in both wheel path at 10 meter spaces test point using a 2 meter straight edge and calibrated wedge. As expected, there is no progression of ruts along both sections until 18 month time. The result of rut measurement was shows in the Figure 2 below.
6.2 Crack Progression

Crack progression measurements also were made along the test section at same time interval in both wheel paths. The results show that there is no cracks progression on PMA test section until 18 month after road constructed. As expected, the cracks were appearing at the Control test section after 15 month road constructed. The result of cracks progression was shows in the Figure 3 below. It is expected that the cracks was propagated from the bottom layer because the cracks was appeared at the same location as the cracks location before construction.
6.3 Surface Roughness
The pavement surface roughness was measured by the unit of International Roughness Index (IRI) using ARRB Walking Profiler. The IRI is expresses in terms of accumulated vertical displacement of the simulated suspension in meter per measured kilometer (m/km). The result shows the IRI was reduced after construction of PMA and control test section using mill and replace construction method. The value of IRI initially reduced after 3 month construction compared to IRI before construction. The value was keep increasing after six month and until 15 month after construction. As expected, the value of IRI for control section was higher than the ACW14 PMA section.

![Figure 4. IRI result on the test section](image)

<table>
<thead>
<tr>
<th>Time</th>
<th>Control</th>
<th>AC14 PMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>6.29</td>
<td>3.52</td>
</tr>
<tr>
<td>Month 3</td>
<td>2.31</td>
<td>1.83</td>
</tr>
<tr>
<td>Month 6</td>
<td>2.37</td>
<td>1.95</td>
</tr>
<tr>
<td>Month 15</td>
<td>2.41</td>
<td>2.02</td>
</tr>
</tbody>
</table>

7.0 CONCLUSIONS

The results shows there are no rut progression on both AC14 PMA test section and control section. The results shows that the rutting does not appear at both test section may due to the flat terrain on the site. Since the rut do not exist on the control section it can shows that the conventional asphalt mix is resistant to deformation under severe loading condition on the flat terrain as good as AC14 PMA test section.

The cracks that appear on the pavement surface on the control test section were same location as before construction of the road. Results from this study have indicated that, under severe loading, the cracks at the bottom layer are able to propagate to the upper layer and form the reflective cracking. The modified asphalt mix is able to avoid cracks at bottom layer to propagate to the upper layer.

An initial IRI after 3 month construction show that the pavement surface roughness can be corrective by using the mill and replace method. The increasing of IRI on the both test section may due to many factors that related to the construction method. The constructed section may be was not fully compacted during construction or there are some mistake while carry out the compaction. However, the value of IRI was not rapidly increase when using the modified asphalt.
REFERENCES: