RAR2018

# KRUGER PARK

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## Rubberized Asphalt • Asphalt Rubber

# Proceedings


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# Road Pavement Preservation Trial with Reacted and Activated Rubber at JORR W2 Toll Road- Indonesia

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***ABSTRACT:*** *This study documents results of a first of its kind crumb rubber modified asphalt trial using reacted and activated rubber in Jakarta, Indonesia. Reacted and activated rubber (RAR) is unique form of modified crumb rubber. Reacted and activated rubber consists of crumb rubber from scrap tire rubber of approximately 30 mesh size or smaller that is chemically altered to create a dry crumb rubber powder that when mixed with hot asphalt instantly creates a rubberized asphalt binder with excellent elastic properties.*

*The trial test section was designed by Consulpav at the request of CONBLOC INFRATECNO a prominent highway paving contractor in Indonesia. CONBLOC INFRATECNO recognized that in many areas of Indonesia pavement failures such as cracking and potholing occur within a few years of construction. Recognition of such pavement failures by CONBLOC INFRATECNO, along with their general knowledge of crumb rubber pavements having the ability to successfully rehabilitate such pavements in other parts of the world, lead them to request Consulpav to design a very thin overlay of a recently failed section of concrete pavement with the goal of providing several years of cracking and potholing free service.*

*Consulpav observed that the three year old concrete pavement was in a cracked and patched condition. It appeared that poor drainage, lack of uniform subgrade support and heavy traffic loading all contributed to the early concrete pavement failures. This condition presented a significant engineering challenge for any type of pavement rehabilitation short of a very thick asphalt overlay (15 cm plus) or complete reconstruction. Based upon Consulpav past experience of designing rehabilitation pavements for similarly distressed pavements in Brazil and China Consulpav recommended that a stress absorbing membrane interlayer (SAMI) using RAR be placed on top of the concrete followed immediately with a 4.5 cm of SMA type mix using RAR. This study documents the design and construction of the test section in March 2017, as well the material properties of reacted and activated rubber binder and SMA type mix.*

***KEYWORDS:*** *rubberized asphalt, SAMI, SMA, overlay of concrete, cracked pavement, reacted and activated rubber*

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## 1. Introduction

Asphalt rubber maintenance strategies have been successfully used worldwide.

Asphalt Rubber mix is composed of aggregate, filler and crumb rubber modified bitumen (binder), mixed at high temperature, (Way, 2012), Figure 1.

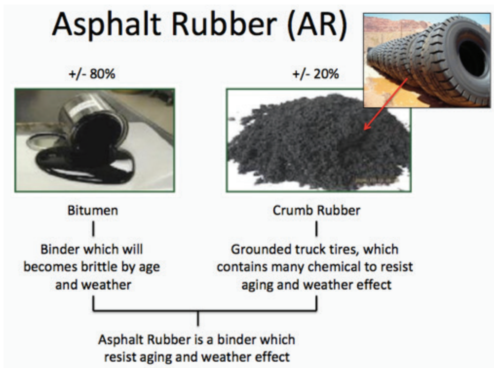



**Figure 1:** *Asphalt rubber composition*

Advancement in technology brought Reacted and Activated Rubber (RAR) technology, which is a pre-processed Crumb Rubber, already swelled with bitumen, (Sousa, 2015), Figure 2. Conventional AR has to be mixed inside a special blending plant and continued in a reaction tank to swell the Crumb Rubber within the binder. With RAR, those processes are no longer required and thus can be directly mixed with the available plant.


**Figure 2:** *RAR Composition*

This technology is expected to be the solution of current road preservation needs, as well as improving the quality and service life on toll roads in Indonesia.

To investigate the benefit of the possible maintenance strategies with RAR on 18 March to 24 March 2017, PT. Preservasi Jalan Indonesia (PJI) has completed an Asphalt Rubber trial on JORR W2 (Jakarta Outer Ring Road West 2) toll road, at Station 12+540B to Station 12+290B. The Owner of the road is PT. Marga Lingkar Jakarta (MLJ). The contractor appointed for its maintenance was PT. Jasa Layanan Pemeliharaan (JLP).

## 2. Referenced Specification

Asphalt Rubber technology has been accommodated in Spesifikasi Khusus Interim SKh-3.6.3.2 Campuran Beraspal Panas Dengan Aspal Yang Dimodifikasi Crumb Rubber Atau Asbuton Dengan Crumb Rubber.

Specifically:

a. Stress Alleviating Membrane Interlayer (SAMI) Mod-CR2
b. Stone Mastic Asphalt (SMA) Mod-CR2. In this project we used the lower part of the Indonesian SMA curve because it fits the GAP Graded gradation of Arizona. The medium and top part of the SMA provide too much fines and therefore reduce the VMA not allowing enough crumb rubber to be placed in the mix.

For the particular project the issue was how to rehabilitate a cracked concrete pavement section. The solution adopted was to use a RAR-SAMI with 20mm aggregate chips and a RAR-GAP GRADED with 4.5 cm thick, Figure 3.

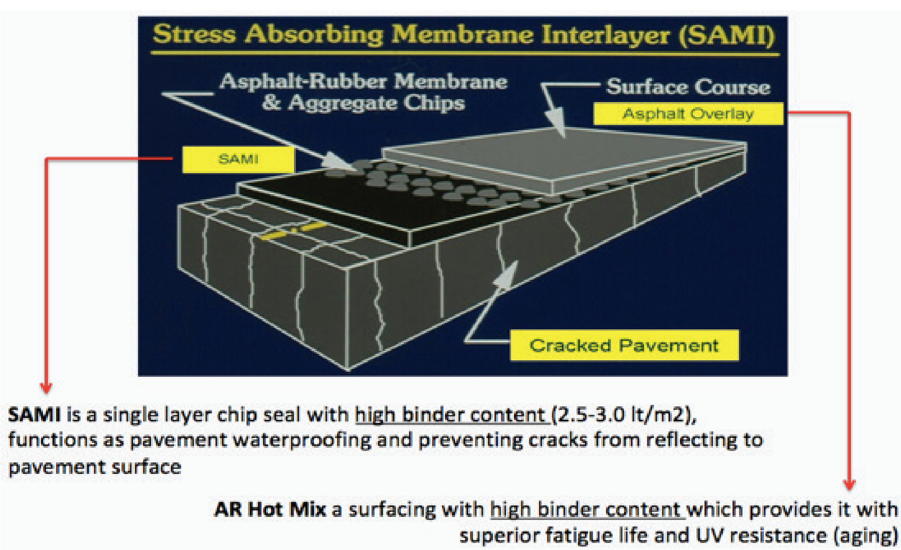



**Figure 3:** *Rehabilitation strategy using SAMI and RAR GAP Graded*

The particular reason to use a 20 mm chip is presented in Figure 4. The chip covers the crack/joint converting the shear stress over the crack tip into compression stresses over the chip thus reducing significantly the crack intensity effects. Figure 5 shows the thickness of SMA and SAMI sections on top of the cracked concrete pavement.

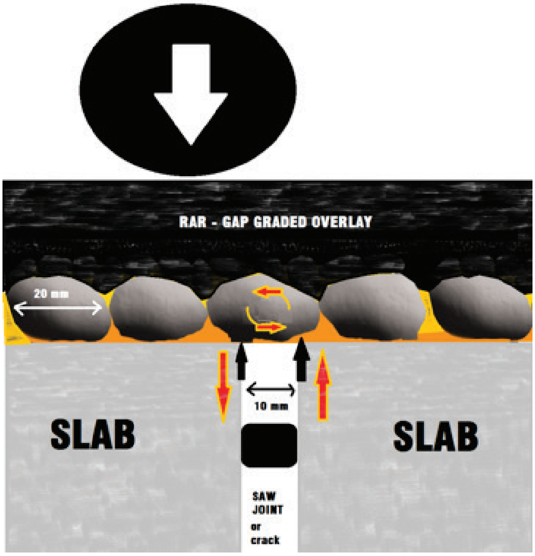



**Figure 4:** *Detail mechanism of crack propagation retardation*


**Figure 5:** *Pavement composition with rehabilitation strategy*

Affecting the pavement performance is the water content in the underlying layers. Once the granular courses and subgrade soil have a mechanical behavior dependent of the water content, this leads to an increased susceptibility of unbound materials to change in the water content according to the weather seasonal variations. For a better understanding of the values obtained, we proceeded to an analysis of mean month precipitation during 2000 and 2011.

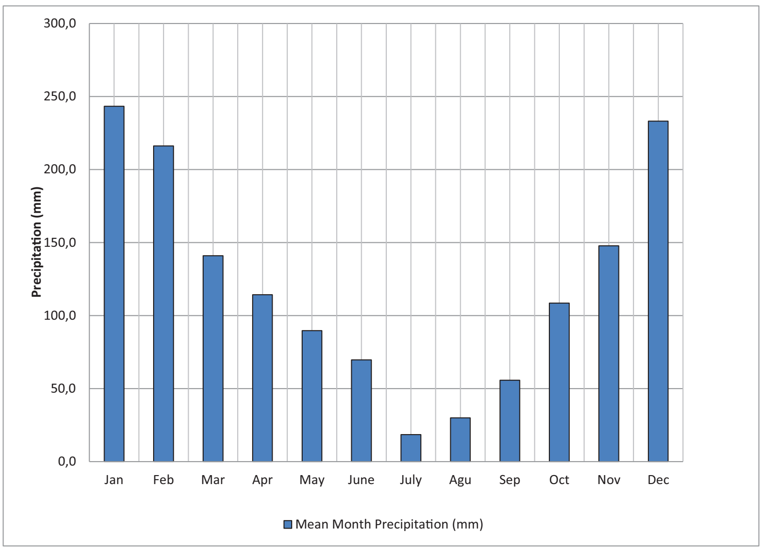



**Figure 6:** *Mean Month Precipitation for Jakarta (2000 and 2011)*

Figure 6 shows that Jakarta is an area with a considerable average monthly precipitation, mainly in the months between October and April, so the behavior of pavements is naturally influenced by water status in granular materials and soils of the foundation, when there isn't an adequate drainage system. To mitigate this effect a waterproof SAMI membrane was designed and built over all the pavement platform. Nevertheless, future improvement would lead to waterproofing the median and the shoulders and part of the embankments.

The amount of rain that falls in a month in Jakarta is quite high.

### *Ultraviolet Index (UVI)*

Another particular important aspect affecting pavement performance in Indonesia is the very high UV levels that have no parallel to those encountered in Europe or North America (from where most design methods come from). It is clear that the UV levels affecting Indonesia roads as a few times higher than those encountered in Europe.

The UVI is an international standard index that describes the level of solar UV radiation at the earth's surface. The index ranges from 0 to 11+ and the values are grouped into various exposure categories. A higher index value indicates a greater potential for harmful effects to the skin and eyes.

The UV Index (UVI) is a simple and informative index jointly developed by the World Health Organization (WHO), United Nations Environment Programme (UNEP), and the World Meteorological Organization (WMO) to measure the level of UV radiation exposure, Figure 7. The UVI describes the level of solar UV radiation at the Earth's surface and is dependent on both UVA and UVB radiation. UV radiation levels and therefore the values of the index vary throughout the day. The maximum UV radiation level typically occurs during the four-hour period between 11am and 3pm.

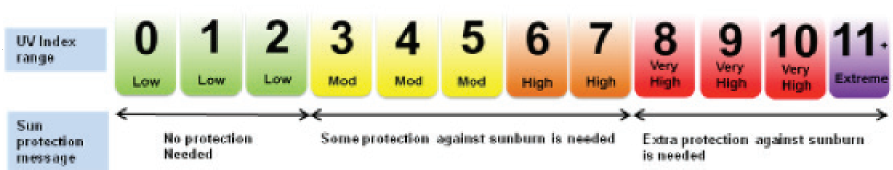



**Figure 7:** UV Index Levels

Ultraviolet (UV) radiation refers to the region of the electromagnetic spectrum that has a wavelength between 100-400 nm. The sun emits ultraviolet radiation in three bands, UVA (315-400 nm), UVB (280-315 nm) and UVC (100-280 nm). The ozone layer in the stratosphere prevents almost all UVC rays and up to 90% of UVB rays from reaching the earth's surface, Figure 8. Thus 94% of UV radiation reaching the earth's surface consists of UVA rays and only 6% consists of UVB rays.

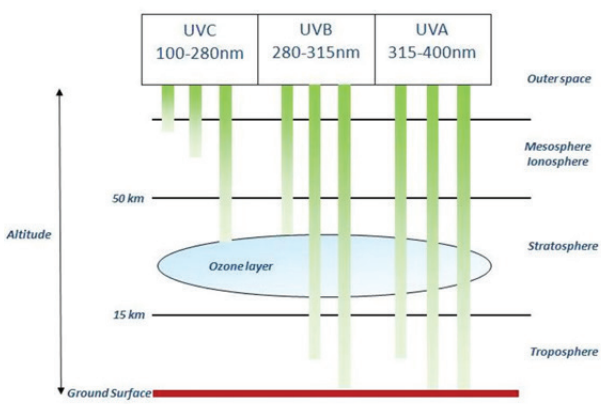



**Figure 8:** *Schematic diagram showing the interaction of ultra-violet radiation with the earth's atmosphere before it reaches the surface.*

It is common for the UVI to reach Very High and Extreme levels in the four hour period between 11 am and 3 pm on a day with little cloud cover, as in Jakarta, Figure 9.

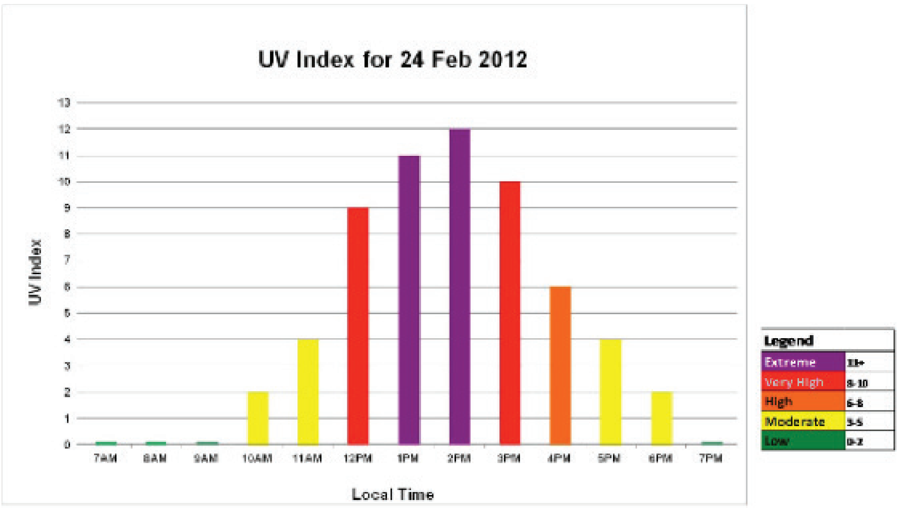



**Figure 9:** *Example of UV index daily variation in Jakarta*

UVI values are higher during months where there is less cloud cover and when the position of the sun is directly over the equator. Figure 10 below depicts the average variation of daily maximum UVI values across the year for Jakarta.

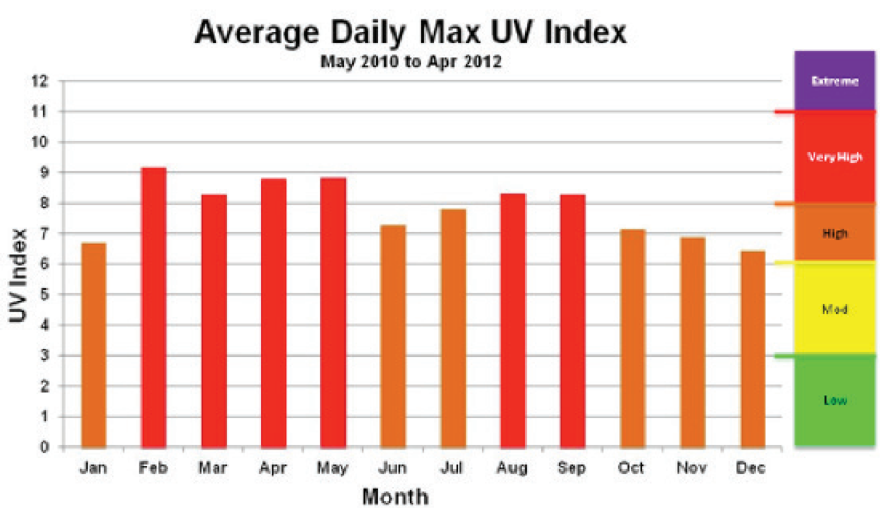



**Figure 10:** *Variation of UV levels in Jakarta*

UV radiation and UVI values are highest near the equator and decrease with increasing latitude, Jakarta's UV levels are very high.

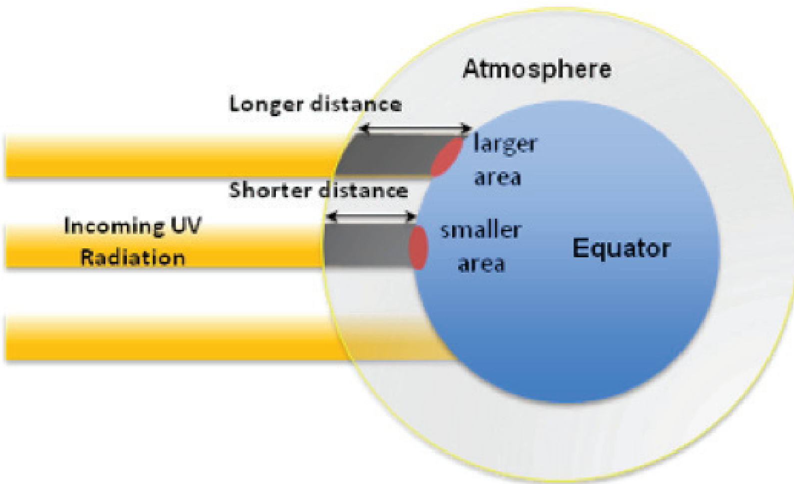



**Figure 11:** *Variation of UV Index with latitude*

The schematic diagram above, Figure 11, shows the effect of latitude on UV radiation levels. At lower latitudes, UV radiation passes through a shorter distance in the atmosphere and is focused on a smaller area as it reaches the earth's surface due to the curvature of the earth.

As such to address the high UV level in Jakarta a high percentage of crumb rubber from recycled tires were used, due to the UV protection chemicals already present in those tires.

## 3. Job Mix Formula

The material used in this trial was:

a. Aggregate from Sidomanik Quarry (West Java, Indonesia)
b. Bitumen Pen 60/70 from Shell Singapore
c. RARX from CIRTEC/SPAIN

Due to limitation of binder viscosity that can be sprayed evenly with the Asphalt Distributor pump, the optimum RAR proportion for SAMI work was adjusted a few times (the target was to spay binder at 2000 to 3000 cP), Figure 12:

a. Day 1: 71.5% Pen 60/70, 28.5% RARX
b. Day 2: 68% Pen 60/70, 32% RARX
c. Day 3 & 4: 70% Pen 60/70, 30% RARX

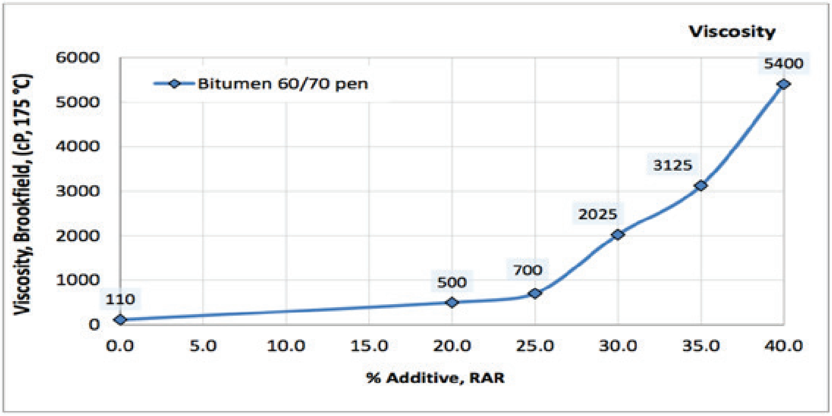



**Figure 12:** *Binder Viscosity to RAR Proportion in Binder*

Chip Aggregate size was 16-19 mm, which was screened in AMP and precoated at 0.5% to its weight.

Through trials, the application parameter was decided to be:

a. Binder spray rate: 2.5 +/- 0.2 liter/m2
b. Chip spread rate: 22 +/- 0.5 kg/m2
c. Rolling with Pneumatic Tire Roller: 3 passes back and forth

Binder proportion in SMA (GAP GRADED gradation) was 65% Pen 60/70 and 35% RARX. This was determined through lab testing to determine softening point, Figure 13 and PG Performance Grade, Figure 14.

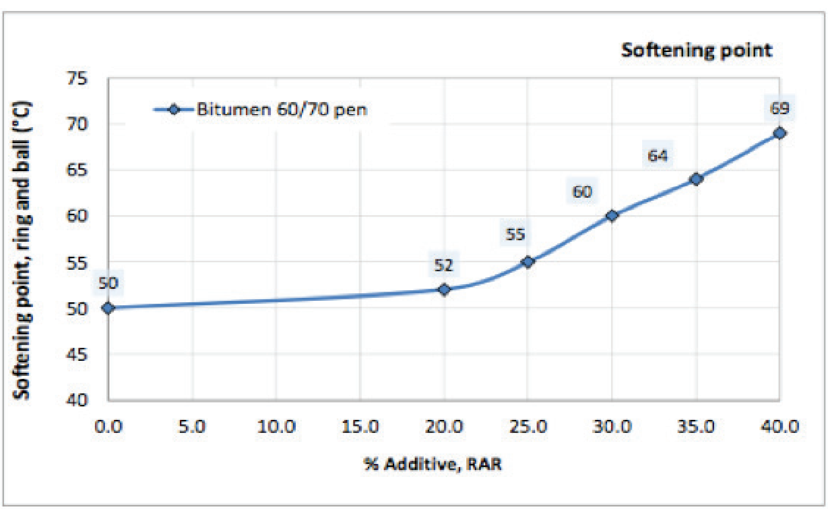



**Figure 13:** *Binder Softening Point to RAR Proportion in Binder*

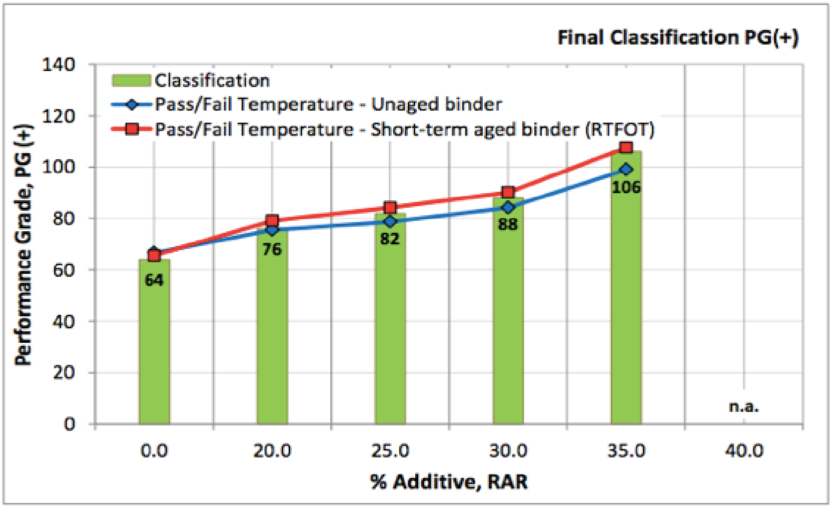



**Figure 14:** *Performance Grade to RAR Proportion in Binder*

Partial values after PAV aging are presented in Table 1. Figure 15 and Figure 16 show graphically the influence of RAR percentage on long-term aged binder performance and final classification [Performance Grade, PG (-)].

**Table 1:** *PAV results for bitumen 60/70 (0, 20, 25, 30, 35, 40)*

| Property | | Bitumen (60/70 penetration) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Additive, RAR (%) | | | | | |
| | | 0 | 20 | 25 | 30 | 35 | 40 |
| Dynamic Shear Rheometer | **Temp. Pass (°C)** | **25** | **22** | **19** | **16** | **16** | **16** |
| | Phase Angle (°) | 52.09 | 46.69 | 44.26 | 40.59 | 39.12 | 38.16 |
| | G*/sin delta (10 rad/sec., kPa) | 3872 | 3998 | 4860 | 4473 | 4717 | 4676 |
| | **Temp. Fail (°C)** | **22** | **19** | **16** | **13** | **13** | **13** |
| | Phase Angle (°) | 48.93 | 43.72 | 40.91 | 38.82 | 38.30 | 36.93 |
| | G*/sin delta (10 rad/sec., kPa) | 5891 | 5706 | 6823 | 6382 | 6111 | 6496 |
| Bending Beam Rheometer | **Temp. Pass (°C)** | **-12** | **-12** | **-12** | **-12** | **-12** | **-12** |
| | s (60 s, MPa) | 250 | 75 | 89 | 77 | 62 | 58 |
| | M-value (60 s) | 0.307 | 0.333 | 0.325 | 0.314 | 0.329 | 0.324 |
| | **Temp. Fail (°C)** | **-18** | **-18** | **-18** | **-18** | **-18** | **-18** |
| | s (60 s, MPa) | 490 | 199 | 203 | 149 | 132 | 110 |
| | M-value (60 s) | 0.234 | 0.266 | 0.266 | 0.254 | 0.226 | 0.288 |

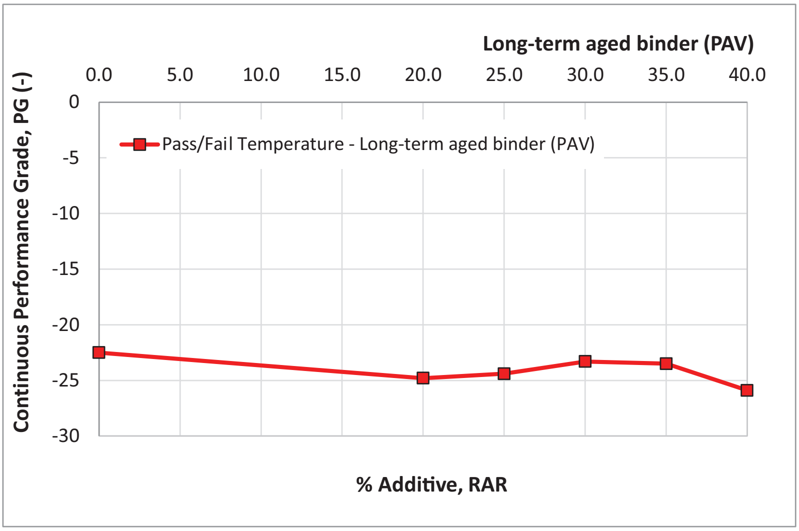



**Figure 15:** *Continuous Performance Grade, PG (-) (long-term aged binder, PAV)*

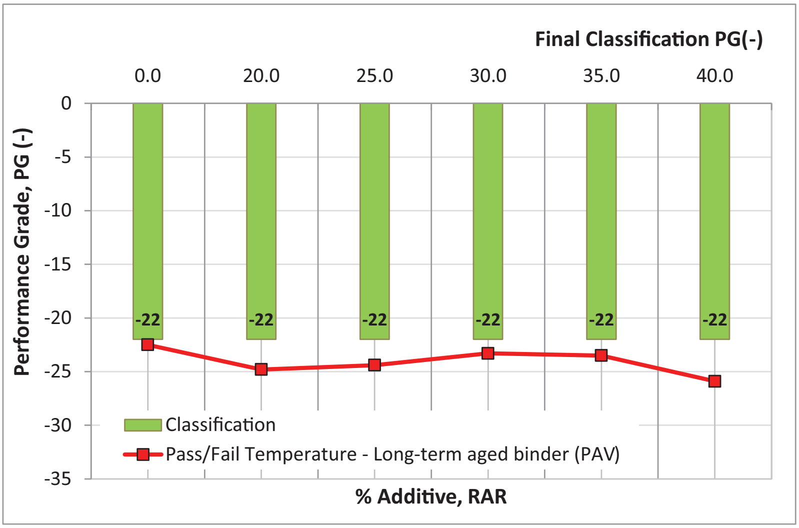



**Figure 16:** *Final Classification, PG (–)*

***Rutting criteria MSCR - Jnr***

The Multi Stress Creep Recovery (MSCR) accordingly to AASHTO TP 70 gives an indication of the quality of the binder in order to permanent deformation resistance and general ability to recover from deformation. Loading is applied as presented in Figure 17.

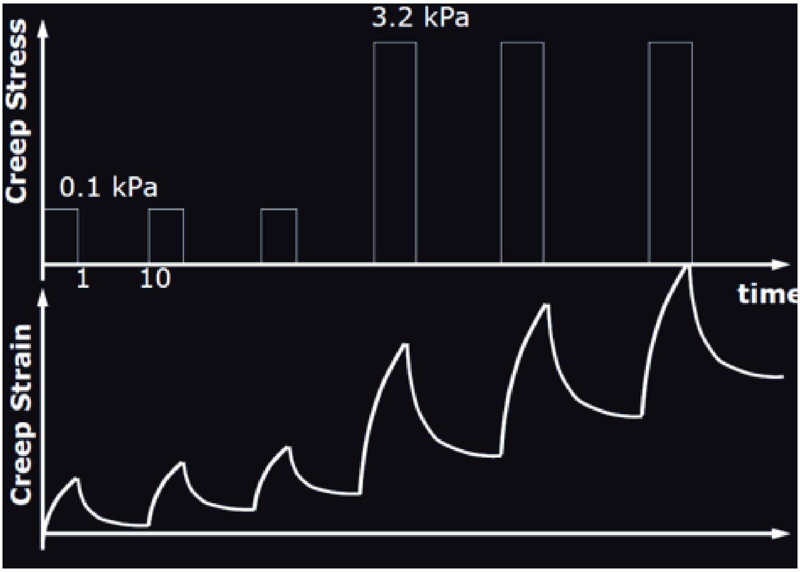



**Figure 17:** *MSCR loading and deformation typical patterns*

Table 2 presents a summary of Jnr testing and Figure 18 to Figure 19 presents the graphically results.

**Table 2:** *Recovery and Jnr results for bitumen 60/70 (0, 20, 25, 30, 35, 40)*

| Property | Bitumen (60/70 penetration) | | | | | |
|---|---|---|---|---|---|---|
| | **Additive, RAR (%)** | | | | | |
| | 0 | 20 | 25 | 30 | 35 | 40 |
| **Average recovery (0.1 kPa, %)** | **1.90** | **50.37** | **69.64** | **81.54** | **93.60** | **95.77** |
| **Average recovery (3.2 kPa, %)** | **0.56** | **19.59** | **29.91** | **43.63** | **60.91** | **75.22** |
| Difference between average recovery at 0.1 kPa and 3.2 kPa (%) | 70.42 | 61.05 | 57.05 | 46.48 | 34.92 | 21.44 |
| **Jnr (0.1 kPa)** | 3.40 | 0.35 | 0.14 | 0.06 | 0.01 | 0.00 |
| **Jnr (3.2 kPa)** | **3.65** | **0.64** | **0.38** | **0.19** | **0.08** | **0.03** |
| Difference in **Jnr** between 0.1 kPa and 3.2 kPa (%) | 7.30 | 84.10 | 163.00 | 241.95 | 612.95 | 592.05 |

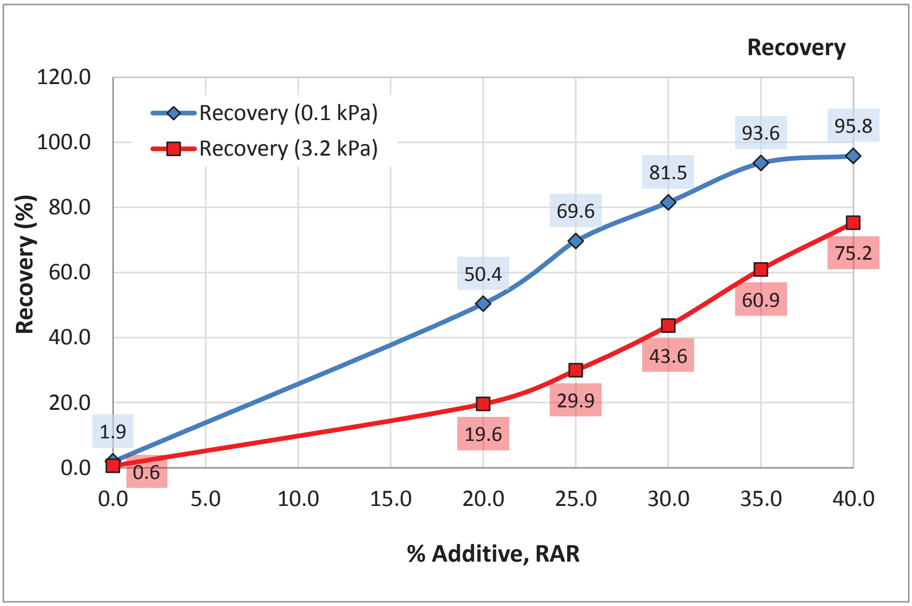



**Figure 18:** *Recovery results at 0.1 kPa and 3.2 kPa*

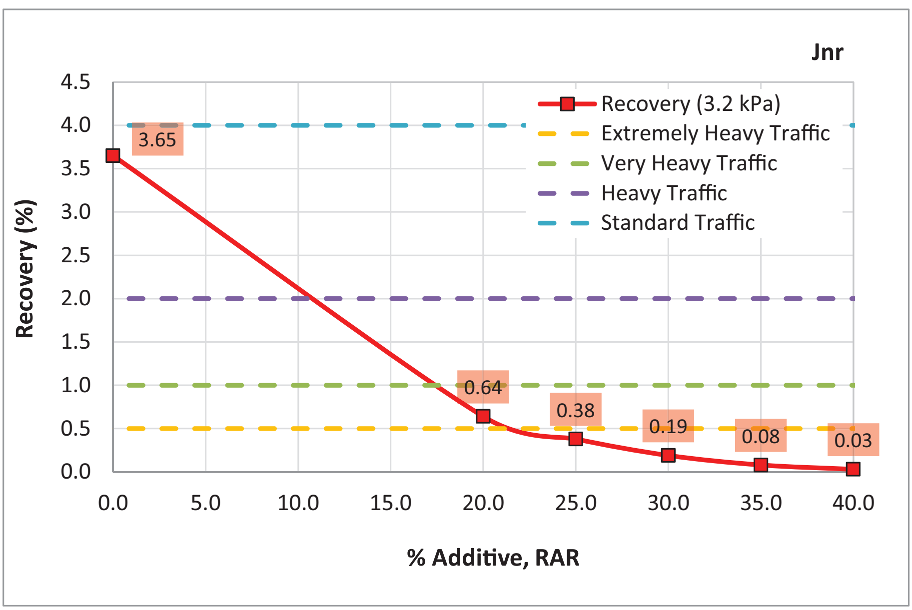



**Figure 19:** *Jnr at 3.2 kPa values function of the RAR percentage versus traffic type*

The aggregate gradation curved used was designed to fit an ADOT Gap Graded with maximum aggregate size of 19 mm, Figure 20.

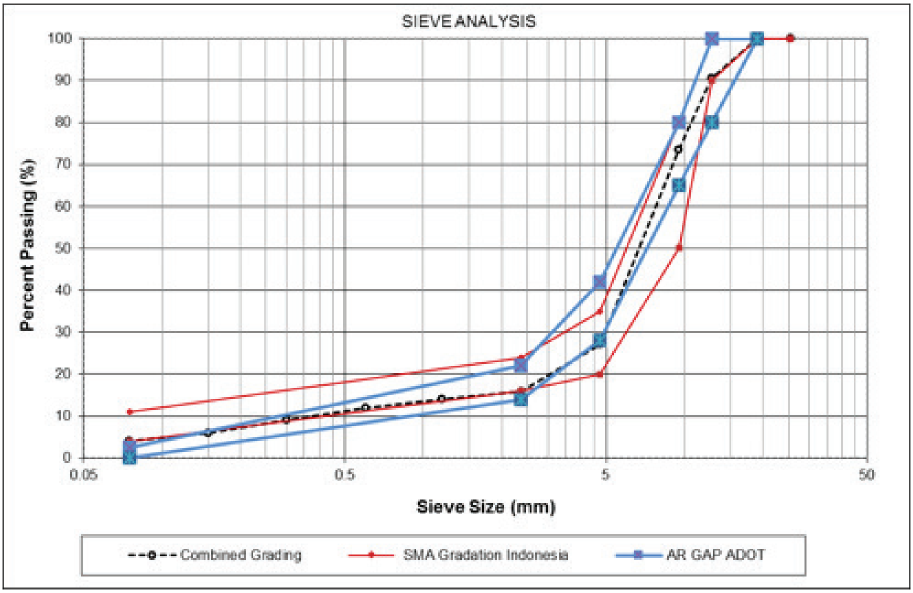



**Figure 20:** *Gradation of RAR - GAP GRADED*

The gradation was designed to be as coarse as possible within the SMA Indonesia grading curve to increase its VMA structure and to fit within the Asphalt Rubber Arizona Department of Transportation Gap grading curve such that more Asphalt Rubber binder can be accommodated in the mix. A new GAP graded gradation curve should be added to the mixes allowed with the Indonesia road network. Mix design information is shown in Table 3.

**Table 3:** *Mix Design Information*

| DESCRIPTION | TEST RESULT |
|---|---|
| Asphalt Content (%) | 9.25 |
| Density (gr/cm3) | 2.178 |
| Voids In Mix ( VIM ) (%) | 3.8 |
| Voids In Mix ( VIM Refusal ) (%) | 2.63 |
| Voids Filled Bitument (%) | 83.5 |
| Voids Mineral Aggregate ( VMA ) (%) | 22.9 |
| Stability (kg) | 960 |
| Stability After 24 Hour at 60° C (%) | 92.20 |
| Flow (mm) | 4.4 |
| Marshall Quotient (kg/mm) | 215 |
| Bitument Film Thickness (micron) | 26.2 |

Compaction effort was determined from trial compaction, 12 passes back and forth using Steel Wheel Tandem Roller. Uncompacted thickness factor was 1.3x target layer thickness (4.5 cm), thus laying was set at 5.9 cm. Compaction fleet comprised of 3 Steel Wheel Tandem Roller working in echelon to cover the laying width.

## 4. Trial Execution

PJI was working jointly with JLP in the execution of this maintenance strategy. Their scope included joint sealing, crack sealing and traffic management.

The trial was scheduled to be done in 3 days, however the realization required 4 days due to weather and traffic condition. Figure 21 shows cracked condition of concrete pavement before overlay.

a. 1st day: Saturday 18 March 2017 - Sta. 12+540 – Sta 12+390, 3.95 m wide on Inner Shoulder and Lane 3.
b. 2nd day: Monday 20 March 2017 - Sta. 12+390 – Sta 12+290, 3.95 m wide on Inner Shoulder and Lane 3.
c. 3rd day: Thursday, 23 March 2017 - Sta. 12+540 – Sta 12+290, 3.85 m wide on Lane 2.
d. 4th day: Friday 24 March 2017 - Sta. 12+540 – Sta 12+290, 5.3 m wide on Lane 1 and Outer Shoulder.

**Figure 21:** *Joint and Crack Sealing on Existing Pavement*

### *5.1 Preparation Work*

The site was cleaned using Air Compressor and Power Broom prior to laying the work. Loose material and/or damp surface might negatively impact SAMI adhesion to the concrete which directly affect the overlay service life.

Prior to next day work, longitudinal and transverse joint had to be cut, Figure 22.

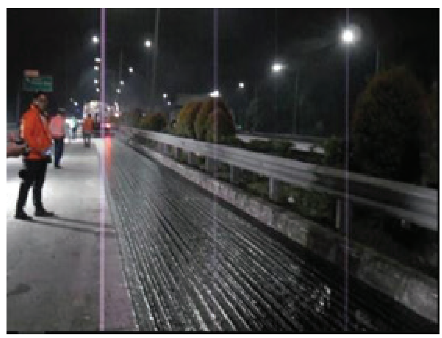
**Figure 22:** *Joint Cutting Process*

### *5.2 RAR - SAMI Mod-CR2*

Bitumen Pen 60/70 and RAR mixing was done directly inside the Asphalt Distributor tank which was equipped with mixer system. Bitumen Pen 60/70 was put into the tank at 190ºC, added with RAR at ambient temperature. The temperature was maintained at 175ºC during mixing. Figures 23-27 show mixing of RAR and hot asphalt followed by placement of the SAMI over the concrete.

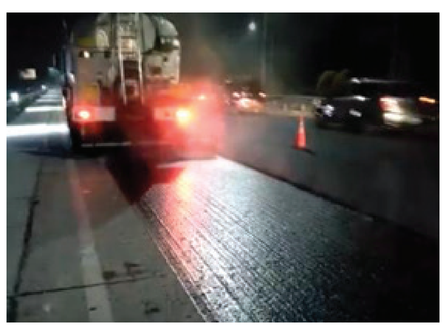
**Figure 23:** *Binder preparation (adding RAR to the bitumen) at 175-185ºC*

Spray Binder – 1st day



Spray Binder – 2nd day

Spray Binder – 3rd day



Spray Binder – 4th day

**Figure 24:** *Binder spraying*

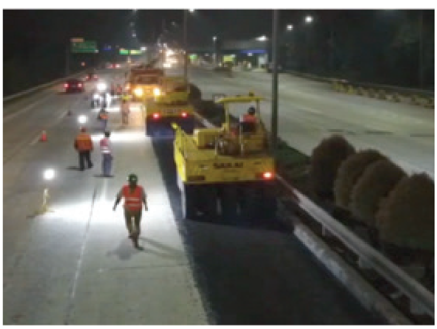
Spread Chips – 1st day

Spread Chips – 2nd day

Spread Chips – 3rd day

Spread Chips – 4th day

**Figure 25:** *Precoated chip spreading directly after binder spraying at 120°C*



SAMI Rolling


SAMI Rolling

**Figure 26:** *Continued with rolling which had to be finished within 20 minutes after spraying*

After rolling, the SAMI was let to cool down for about 30 minutes to 1 hour. Then continued by cleaning the loose material using Power Broom.

**Figure 27:** *Visual of SAMI Mod-CR2*

### *5.3 SMA Mod-CR2 (GAP GRADED GRADATION)*

Mixing of the Bitumen Pen 60/70, aggregate and RAR was directly done in AMP's pugmill, Figure 28. Temperature of Bitumen Pen 60/70 at 185ºC, aggregate at 195ºC, and RAR at ambient temperature.

Mixing in AMP's pugmill was done in 2 stages:

a. Mixing of aggregate and RAR in 20 seconds
b. Mixing of bitumen, aggregate and RAR in 40 seconds
c. Total 1 batch cycle at about 70 seconds

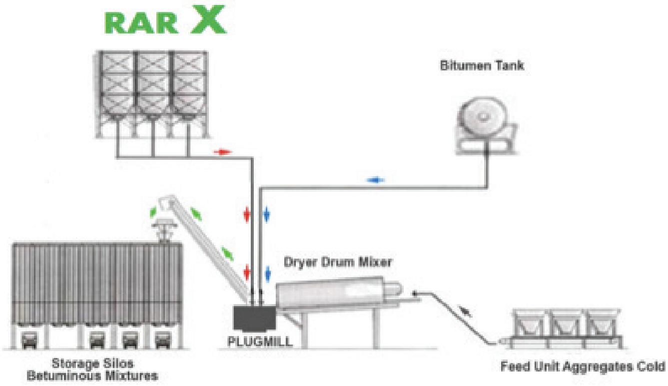
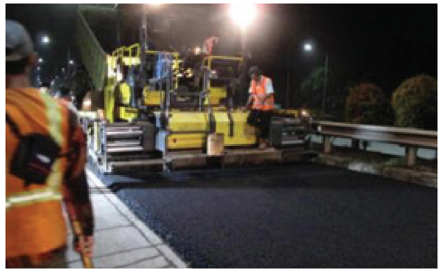



**Figure 28:** *Schematic diagram f placement of RAR into the mix*

The mix in Dump Truck was at 190ºC. During delivery to site, there was about 5-10ºC temperature drop per hour. Figures 29-33 show the placement and final Asphalt Rubber SMA surface.

AR Hot Mix – 1st day

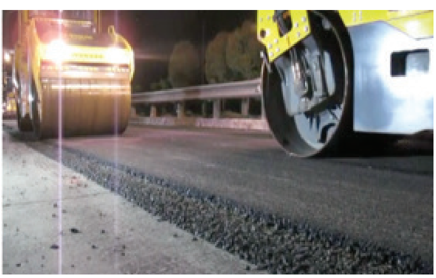


AR Hot Mix – 2nd day

AR Hot Mix – 3rd day

AR Hot Mix – 4th day

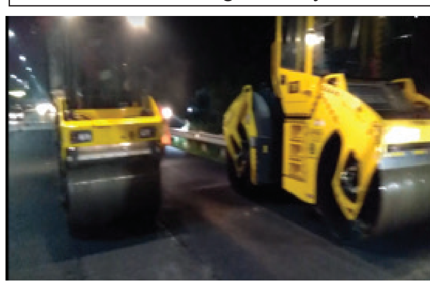
**Figure 29:** *Laying on site at 170ºC*



AR Rolling – 1st day

AR Rolling – 2nd day

AR Rolling – 3rd day



AR Rolling – 4th day

**Figure 30:** *Compaction passes referring to Trial Compaction result*

Rolling temperature range from 170ºC to 120ºC. Below 120ºC, the viscosity would be very high that rolling was not effective.

**Figure 31:** *Visual of SMA Mod-CR2*

**Figure 32:** *Visual on the 1st day of Open Traffic*

**Figure 33:** *Visual on the 1st day of Open Traffic*

***Current Condition***

After 18 months subjected to traffic, rain and UV the overlay is still in perfect condition, Figure 34. Only one spot developed a pot hole, Figure 35. This pot hole was found on a location where core sample was taken, indicating improper filling material/procedure. For comparison purposes Figure 36 shows an adjacent regular hot mix section built 2 months later which already has multiple potholes and extensive reflective cracking. This conclusively demonstrates the effectiveness of adding reacted and activated rubber to rehabilitation strategies.

**Figure 34:** *Trial section after 18 months of traffic*

**Figure 35:** *Patched Pothole*

**Figure 36:** *For comparison see Adjacent with the same pavement structure, same condition, and same traffic but with a Conventional Hotmix Section which is 2 months newer than the trial section and already has reflective cracks and many potholes*

## Conclusions

This new maintenance strategy using a combination of RAR-SAMI with RAR-GAP GRADED mixture has been proven very successful in Jakarta, Indonesia.

The success of this maintenance strategy relies on several key aspects:

a) The SAMI provides a water proof membrane reducing the water ingress into the pavement structure reducing slab relative movements. More should be done in this regard improving drainage systems and protecting embankments and medians against water penetration.
b) The SAMI is placed with hot asphalt rubber which penetrates and adheres very well against the concrete surface. This prevents any moisture to created de-bonding between the overlay and the concrete slabs
c) The aggregate size in the SAMI is such that in generate is larger than the crack /joint width. This make the aggregate rotate when the slabs mv thus reducing significantly the shear stresses near the crack edge.
d) The RAR asphalt rubber binder is very elastic and as such provides a crack tip stress reduction. Also, near the crack is a large amount of residual binder for healing of any eventual crack that develops
e) The RAR GAP gradation with large amounts of crumb rubber and of binder provides a UV resistant surface with reduces aging. This keeps the binder flexible and not brittle.
f) The RAR GAP Graded mixture has a flexible fatigue life much higher than any conventional mix. As such provide by itself a crack retardation mechanism.

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