Prediction of long-term volumetric parameters of asphalt concrete binder course mixture using artificial ageing test

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Abstract. Ageing of asphalt mixture occurs during the production and construction, and it will continue until the end of the pavement lifetime. Modified Butonic bitumen consists of petroleum bitumen and extracted bitumen from natural asphalt was used as a binding material to produce asphalt concrete binder course (AC-BC). This study purposed to predict the effect of long-term ageing on volumetric parameters of asphalt concrete binder course mixture using an artificial laboratory test. Three different treatments were conducted, the first treatment without the ageing process as the control specimen, the second and third treatments used oven heating as the artificial ageing process for 2 and 4 days 85°C. After ageing process completion, the volumetric parameters were determined by the value of the void in the mixture (VIM), void of mineral aggregates (VMA) and the void filled with asphalt binder (VFB).

1. Introduction
Highways are important transportation infrastructures that influence the economy, society, culture, and defence and security. Highways serve nearly 80-90% population mobility and flow of goods so that the development of road transport infrastructure is a priority. It is reflected by the amount of national budget absorbed for the construction of new road or maintenance of roads [1, 2]. The contractor, as a service provider, influences the quality of road construction and has a potential risk of construction failure in every stage of the project. The contractor failure is always generated from the unskilled workers [3]. It is important to use a material that can withstand the negative impact of vehicle emission, climate, weather action, and can be easily used in road construction.

The impact of this activity is an increasing need for both asphalts. The asphalt is imported as many as 600,000 tonnes per annum. It results in reducing the availability of foreign exchange [4, 5, 6, 7, 8]. A lot of discussions was made on a large amount of the national bitumen import looking for another alternative of refined bitumen. The natural rock asphalt in Buton Islands Indonesia is named as Buton rock asphalt (BRA). Buton natural rock asphalt can be refined to separate bitumen from the minerals [9, 10, 11]. In this study, we refer to such bitumen as semi extracted bitumen from Buton rock asphalt is Retona Blend 55 as the binder.

Asphalt concrete is a construction layer consisting of a mixture of asphalt and continuously graded aggregate, mixed, spread, and compacted at a specific temperature. Layers of asphalt concrete consist of a mixture of three types namely Asphalt Concrete-Wearing Course (AC-WC), Asphalt Concrete-Binder Course (AC-BC), and Asphalt Concrete Base (AC-Base) with a maximum aggregate size of 19, 25.4, and 37.5 mm respectively [12].
The ageing process influences the characteristic of asphalt mixture compounds corresponding to the service life of the pavement [13, 14, 15, 16]. Figure 1 describes the ageing of bitumen during mixing, subsequently during storage, transportation and application and finally, service.

In this present paper, an ARC-BC mixture made with Retona Blend 55 as the binder. The present experimental investigation focuses on determining the influence of long term oven ageing on the volumetric alteration of AC-BC mixtures by conducting Marshall volumetric test. Void in the mix (VIM), void in mineral aggregate (VMA) and void filled bitumen (VFB) were evaluated in AC-BC mixture.

![Figure 1. Ageing of bitumen during mixing, subsequently during storage, transportation and application and finally service [16].](image)

2. Materials and Methods

2.1. Aggregates

Two fractions of coarse aggregates derived from crushed river stone were used: one with aggregate diameter 5-10 mm and the other with crushed stone diameter 10-20 mm. River sand and stone dust obtained from the stone crushing process were used as fine aggregate and filler, respectively. These aggregates were from Jeneberang River, Gowa Indonesia. The physical properties of coarse aggregate and fine aggregate are presented in table 1 and table 2.

| Parameter                  | Value |
|----------------------------|-------|
| Bulk density               | 2.55  |
| SSD density                | 2.61  |
| Apparent density           | 2.72  |
| Abrasion (%)               | 22.64 |
| Particle flat and oval (%) | 8.21  |
| Absorption (%)             | 2.37  |

Table 2. Some properties of fine aggregate and filler.
### 2.2. Retona Blend 55

Table 3 shows the characteristics of Asbuton modification; Retona Blend 55 used this research.

**Table 3. Characteristics of Retona Blend 55.**

| No. | Kinds of Testing                  | Testing Result |
|-----|-----------------------------------|----------------|
| 1   | Penetration before weight loss (mm) | 78.6           |
| 2   | Softening point (°C)              | 52             |
| 3   | Ductility in 25°C, 5cm/minute (cm)| 114            |
| 4   | Flashpoint (°C)                   | 280            |
| 5   | Specific gravity                  | 1.12           |
| 6   | Weight loss                       | 0.5            |
| 7   | Penetration after weight loss (mm) | 86             |

### 2.3. Combined Aggregate Gradation and Mixtures Design

The combined aggregate gradation is shown in figure 2. The combined aggregate gradation was kept. The mixtures were all prepared in the laboratory. The content of asphalt Retona Blend 55 optimum is 5.80% of the total weight of the mixture. Table 4 shows the mixture by weight of AC-BC mixture with 5.80% Retona Blend 55. Retona Blend 55, aggregates and filler were mixed and compacted into the cylindrical mould with a capacity of 1,200 gram and diameter of 101.6 mm. The specimens were compacted with 75 blows each face by using Marshall compactor. Mixing and compaction process was carried out in the laboratory at temperature room 27°C.

![Combined aggregates gradation](image)

**Figure 2.** Combined aggregates gradation.

**Table 4.** Asphalt mixture with 5.80% Retona Blend 55.
4
Retona Blend 55 (gram) 69.600
Coarse aggregate (gram)
• Crushed stone 1-2 cm 218.750
• Crushed stone 0.5-1 cm 405.000
Fine aggregate (gram) 506.250
The total weight (gram) 1200

2.4. Long Term Oven Aging (LTOA)
Long term oven ageing (LTOA) process was performed by subjecting the prepared asphalt concrete binder course mixture, using Retona Blend 55 as the binder. The prepared porous asphalt samples were subjected in an oven at 85˚C for 2 and 4 days to perform long term oven ageing [14].

2.5. Volumetric Test of AC-BC Mixture
The Marshall volumetric test was conducted on AC-BC mixture specimens according to SNI 06-2489-1991 [17]. Figure 2 shows the volumetric properties of the asphalt mixture.

![Volumetric properties](image)

Figure 3. Volumetric properties.

3. Results and Discussion
Volumetric in asphalt mixtures, especially VIM, has a great effect on strength and durability, so it is very important to measure each asphalt mixture. Table 5 shows the results of the asphalt mixture volumetric test consisting of VIM, VMA and VFB values on all variations of good specimens without undergoing ageing processes and specimens undergoing laboratory ageing for two days and four days at 85°C.

It can be seen in table 5 that the VIM value is increasing while the VMA and VFB values are decreasing along with the increase in the ageing process in the laboratory. There was an increase in the average value of VIM test specimens from the ageing process to the specimens that underwent a laboratory ageing process for 2 and 4 days, which were 6.62% and 55.61%, respectively. Based on the Bina Marga requirements, 2010 in Indonesia, the VIM value requirements are 3% - 5% so that the ageing process for four days does not meet the required specifications.

While the decrease in VMA values that occurred was 16.49% and 26.18%, respectively, and VFB values were 9.88% and 30.23% respectively. Therefore, the VMA and VFB values for all variations of test objects meet the specifications required by the general Bina Marga requirement, 2010 in Indonesia.
Table 5. Volumetric value of asphalt mixture affects the ageing process.

| No. | Laboratory aging process (oven 85°C) | Test specimen treatment | VIM (%) | VMA (%) | VFB (%) |
|-----|-------------------------------------|-------------------------|---------|---------|---------|
| 1   | 0 day                               | √ Volumetrik            | 3.02    | 22.13   | 90.91   |
| 2   |                                     |                         | 3.94    | 21.54   | 86.37   |
| 3   |                                     |                         | 3.46    | 17.77   | 80.40   |
| ⋅   | Two days                            | √ Volumetrik            | 3.47    | 20.48   | 85.89   |
| 1   |                                     |                         | 5.02    | 16.54   | 69.66   |
| 2   |                                     |                         | 4.71    | 16.78   | 71.95   |
| 3   |                                     |                         | 1.38    | 19.43   | 92.88   |
| ⋅   | Four days                           |                         | 3.70    | 17.58   | 78.16   |
| 1   |                                     |                         | 5.54    | 16.13   | 65.67   |
| 2   |                                     |                         | 7.08    | 14.90   | 52.49   |
| 3   |                                     |                         | 3.59    | 17.67   | 79.69   |
| ⋅   |                                     |                         | 5.40    | 16.23   | 65.95   |
|     | Spesification                       |                         | 3 - 5   | > 15     | > 65     |

The increase in VIM value that occurs in the test object is caused by the influence of ageing in the laboratory. This effect causes evaporation of the liquid part of the asphalt due to hardening so that the asphalt becomes brittle and loses its adhesion. This adhesive loss causes cavities in a large mixture. Therefore it affects flexibility and adhesion of asphalt and can cause the road to be easily damaged when receiving traffic [13,15,16].

4. Conclusions

- Good adhesion between bitumen and aggregate particle arose from a good cohesion between bitumen of BRA and petroleum bitumen as droplet phase in the Asbuton modification, Retona Blend 55.
- Before and after the LTOA process completion, the VIM, VMA and VFB obtained from Marshall volumetric test showed that the AC-BC mixture using Retona Blend 55 as the binder could affect the VIM value. In contrast, there was no significant change in the values of VMA and VFB as the results of the ageing process.

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