Experimental Study on Use of Reclaimed Asphalt Pavement as Aggregate Substitution for Flexible Pavement

by Elsa Eka Putri

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Elsa Eka Putri[1,*], Purnawan[1], *M. Agung* Triandila[1], *Agung* Pratama[1], *Rindi*[1]

[1]Civil Engineering Department, University of Andalas, Padang, 25163 Indonesia

Abstract. The present study is to assess the suitability of Reclaimed Asphalt Pavement (RAP) as a coarse aggregate substitution for flexible pavement mixture. The RAP in this investigation was taken from roads in Padang, Indonesia. There were three types of flexible pavement chosen to be tested for RAP substitution, i.e. Asphalt Concrete-Wearing Course (AC-WC), Asphalt Concrete-Binder Course (AC-BC), and Hot Rolled Sheet-Wearing Course (HRS-WC). Laboratory studies have been carried out on flexible pavement mixes with RAP material and their performance has been compared with flexible pavement without RAP substitution. Marshall tests were carried out in laboratory as per 2010 specification 6th division from Indonesia Public Work Department standard. The effects of RAP on physical and rheological properties of the final bituminous blend were investigated. The research aims to find out the effect of RAP as coarse aggregate substitution to the flexible pavement characteristics, i.e. Stability, Flow, Marshall Quotient (MQ), Void in Mix (VIM) and Void in Mineral Aggregate (VMA). The percentage of RAP substitution are 35%, 55% and 60%. From the results of the tests in laboratory, it was concluded that the AC-WC pavement was more appropriate due to, it has achieved the highest Marshall stability, with VIM, VMA, and VFB were in the standard.

Keywords — Marshall Test; Reclaimed Asphalt Pavement; AC-WC; AC-BC; HRS-WC

1 Introduction

There are two types of material used for pavement construction, aggregate and asphalt. Material requirements for development, especially for the construction and pavement are very large. Nowadays, asphalt production is 600,000 tons per year in Indonesia, while it needs 1.2 million tons per year. In this situation, it should be imported from abroad to fulfil the insufficient asphalt production [1].

Meanwhile, the aggregate has taken from the rivers as well as mountains can cause environmental damage. As happened in sand and stone mining in Batang Sitanang, Ampek Nagari, West Sumatera [2]. In addition, Tulung Agung, East Java where there is activity of mechanical sand mining in Brantas river [3]. As well as in Tanjung Johor, Pelayangan, Jambi that sucks up to 5000 tons of sand [4].

Taking stones and sand in the river, can lead to disaster. Damage that often occurs if the flow rate of water is very large, without any obstructions and even more dangerous if the flow of the river hit the foundation of the bridge, causing their foundations to wash away and structural elements to break apart.

Therefore, research on alternative materials that can be used as road material becomes the important issue.

The use of alternative materials to replace course aggregate partially has been widely studied, such as oil palm shells to replace course aggregate and palm shell ash to substitute asphalt filler [5].

An attempt to conserve aggregate and asphalt usage on road construction becomes a major concern. The use of RAP (Reclaimed Asphalt Pavement) in asphalt pavement construction is expected to be a solution in road paving industry [6].

The objectives of this research are as follows:

- Investigate the effects of RAP into asphalt mixtures on Marshall characteristics.
- Determine the optimum RAP substitution on course aggregate for the AC-WC, AC-BC and HRS-WC pavement mixtures.
- Identify the pavement type with RAP substitution which giving the best result of the Marshall properties, then determine its optimum bitumen content.

Using RAP is potential material due to it can decrease the amount of construction debris placed into landfills as well as can substitute the virgin aggregate. Ultimately, recycling asphalt creates a cycle that optimizes the use of natural resources and sustains the asphalt pavement industry.

* Corresponding author: elsaeka@eng.unand.ac.id

2 Material and Methodology

2.1 Materials

Asphalt Concrete – Wearing Course (AC-WC), Asphalt Concrete-Binder Course (AC-BC) and Hot Rolled Sheet-Wearing Course (HRS-WC) were investigated their suitability in using RAP for course aggregate substitution. The aggregate gradations were based on the 2010 specification 6th division from Public Work Department standard in Indonesia. In addition, these types of pavement were chosen because these are widely used in road construction in Indonesia.

AC-WC is the topmost pavement layer and serves as a non-structural layer. Although it is a non-structural pavement, AC-WC can increase pavement resistance to quality degradation so as to increase the service life of pavement construction. AC-WC has the most delicate texture compared to other Asphalt Concrete types.

Asphalt Concrete-Binder Course (AC-BC) layer is a pavement layer that lies beneath the wearing course and above the base course. The traffic load that will be distributed to the underlying layer of base and sub grade. Although, AC-BC layer is not directly related to the weather, but it must have thickness and enough clarity to reduce the stress/strain. The most important characteristic of this mixture is stability.

Hot Rolled Sheet-Wearing Course (HRS-WC) is a gap graded aggregate pavement which means having a missing fraction that needs a substantial amount of fine aggregate [7].

The properties of those AC-WC, AC-BC and HRS-WC pavement containing RAP substitution must meet the requirement listed in Table 1.

Table 1. The Properties of Flexible Pavement

The Properties		AC-WC	AC-BC	HRS-WC
Asphalt Absorption (%)	max	1.2		1.7
Number of blows (per face)		75		
Void in Mixture (%)	min	3		3
	max	5		6
Void in Mineral Aggregate (VMA)(%)	min	15	14	18
Void Filled with Bitumen (%)	min	65	63	68
Marshall Stability (kg)	min	800		
Flow (mm)	min	3		
Marshall Quotient (kg/mm)	min	250		
Residual Marshall Stability (%) after soaking (24 hours, 60ºC)	min	75		
Void in Mixture (%) at refusal density	min	2,5		2

Source: Road and Bridge Specification of Public Works Indonesia (2005)

2.2 Reclaimed Asphalt Pavement (RAP)

When removing the existing pavement material during resurfacing, rehabilitation, or reconstruction operations pavement material, it becomes RAP, which contains valuable asphalt binder and aggregate. As an aggregate and virgin asphalt binder substitute it can also be used as a granular base or subbase, stabilized base aggregate, and embankment or fill material or any other construction applications.

RAP is a stripping or pavement repacking material containing asphalt and aggregate. This material arises when asphalt pavement is peeled for reconstruction, resurfacing, or to access the embedded utility network underneath. When shelled, and filtered properly, RAP contains high-grade and well-aggregated aggregates [8].

2.3 Laboratory Investigations

Marshall mix design method which is commonly used to assess the pavement mixtures in laboratory was used throughout this investigation. The parameter determined by this method were Stability, Flow, Void in Mineral Aggregate, Void in Mixtures, Void filled with Bitumen and Marshall Quotient.

RAP used to substitute the course aggregate partially of these pavement mixtures were varying by 35%, 55% and 60% at each of pavement type. hot recycling is one of the most widely techniques used nowadays, where virgin materials and RAP are combined in different proportions and sizes [9].

The RAP material was heated together with the new aggregate at high temperature (about 150ºC) as well as bitumen, then mixed all together with temperature between 135-150ºC manually. Then, the mixtures were compacted by 75 blows at each face.

3 Results and Discussions

Studies performed to determine the response of different pavement mixtures with RAP replacements between 0 and 60% presented in the appendix from Figure 1 until Figure 6.

3.1 Stability (kg)

The results of the Stability are shown in Figure 1 for the three types of pavement tested. As seen on Figure 1(a), the stability for AC-WC shows that the value increases with increasing bitumen content up to the optimum bitumen content and thereafter decreases. The highest stability achieved at 0% RAP followed by 35%, 55% and 60% of RAP in mixture. However, for all the RAP usage for AC-WC pavement, the 35%RAP was achieved the highest stability value at 1022 kg and the optimum bitumen content was found to be 6.8%.

Moreover, the stability of AC-BC was presented on Fig. 1(b). The results were indicated that the asphalt mixture with RAP has better stability than that without RAP. The use of RAP in AC-BC seems to be potentially used to replace the coarse aggregate partially. It can be seen from the higher stability value for 35%, 55% and some samples of 60%RAP. The highest stability value achieved at 35%RAP followed by 55%RAP, 60%RAP. The 35%RAP was achieved the highest stability value at 1140 kg and the optimum bitumen content was found to be 5.8%.

Meanwhile, the stability of the HRS-WC mixture with RAP was found to be the highest than the other two types of pavement mixture i.e. AC-WC and AC-BC, where, the 35% RAP for HRS-WC was achieved the highest stability value, followed by 55% and 60% of the RAP (Figure 1.c)

The higher value of stability indicated the stronger the pavement to carry load from wheel passing. In addition, higher stability indicated the aggregate and bitumen were strongly adhere to withstand the traffic load passing.

3.2 Flow (mm)

The flow values of the pavement mixtures against bitumen content are shown in Fig. 2. As a whole for the three types of the pavement, the flow increases with increasing bitumen content. The flow values were met the 2010 specification 6th division from Public Work Department standard in Indonesia that was between 3-5 mm. The slight increase in flow value might be due to the increase in quantity of the RAP used in the mixture which resulted in greater deformation.

For AC-WC mixture the flow value of 35% RAP and 55% RAP were laid in between 3- 5 mm, meanwhile the flow value of 60% RAP for binder content above 7% were above the specification required. It was the same trend result with AC-BC, that the 35%-55% RAP met the specification required as seen on Table 1, while the 60%RAP was not for bitumen content above the 6%.

Furthermore, for HRS-WC, the 35% RAP met the requirement for all the bitumen content, however for 55% RAP, only the bitumen content above the 3%, then the 60% RAP only the bitumen content above 7.3% can met the requirement.

3.3 Void in Mineral Aggregate (VMA, %)

As seen on Fig 3(a) to Fig 3(c) the VMA value for all the pavement types were within the limits of specification. It has been observed that the VMA decreases with the increase in the RAP percentage in the mixture.

The values of VMA for AC-WC pavement were 19-23%, where the 35%RAP and 55% RAP achieved the higher level then followed by 60% RAP. It means that the 35%RAP and 55%RAP having more void for asphalt to bind the aggregate as well as thicker asphalt film then consequently more durable mixture.

Similarly, AC-BC pavements, where the 35% RAP and 55% RAP VMA values were very high for compared to 60% RAPs with VMA values ranging from 19% - 22%. This VMA value is needed to ensure the availability of adequate voids for asphalt aggregate.

However, the trend was different for HRS-WC where the highest VMA value is at the highest percentage of RAP, i.e. 60% RAP, then it followed by 55% and 35% RAP.

Even though the VMA value was very fluctuated, it was still in the range of the standard in Table 1 for all the RAP percentages.

The greater the addition of RAP, the larger the VMA, thus the more space for asphalt binder. As a result, the film asphalt simultaneously gets thicker and increases the durability of the pavement but requires more asphalt to form the mixture.

3.4 Void in Mixture (VIM, %)

In Fig. 4, for all pavement types show a large VIM value for a mixture without RAP substitution. Meanwhile, for the pavement mixed with RAP, the higher VIM were at the 35% RAP then followed by 55% and 60%. It can be an indication that the void in the mixture decreases as the increasing the RAP with the given bitumen content.

The VIM value may be influenced by the procedure of preparation, mixing temperature, the compaction temperature as well as compaction energy. A mixture of 35% RAP, 55% RAP and 60% RAP resulted in lower VIM values. It indicates that the RAP can fill the void in the mix well.

However, the use of RAP for AC-BC and HRS-WC resulted in higher VIM. The higher the RAP content with lower bitumen content resulted in the increasing void in mix as shown in Fig. 4(b) and Fig. 4(c). So, the possibility of pavement oxidation tends to be occurred, and then the age of pavement plan will last quickly.

3.5 Void Filled with Bitumen (VFB, %)

As shown in Fig. 5(a), on an AC-WC pavement, a large VFB value corresponding to the required standard was obtained. Meanwhile, the AC-BC and HRS-WC pavement, asphalt capability to wrap aggregate (VFB) was small but having larger VIM value. It indicated the decreasing the VFB which results lower durability of pavement mixture due to a decreasing the effective asphalt film thickness, hence the aggregate is not covered properly. Thus, the pavement deterioration tends to be occurred.

3.6 Marshall Quotient (MQ, kg/mm)

Figure 6(a) shows the MQ value of the AC-WC vs. binder content. As the increasing of RAP substitution in the mixture, the Marshall Quotients of the samples were decreased. The 35% and 55% RAP were met the Public

Work Department Indonesia standard (Table 1). Similarly, AC-BC type of pavement, as seen on Fig. 6(b), the MQ for all RAP content were at 200-260 kg/mm.

The use of RAP in HRS-WC, resulted in more rigid mixture rather than AC-WC and AC-BC due to the very high result of the MQ. It was shown by the high MQ value, especially for the low bitumen content. Thus, the use of RAP on HRS-WC pavement type can be implemented with asphalt content above 7%.

4 Conclusions

The objective of using RAP to partially replace the aggregate to evaluate the effect on Marshall properties, i.e. stability, flow, VMA, VIM, MQ used in the design of three pavement mixtures. They were Asphalt Concrete-Wearing Course (AC-WC), Asphalt Concrete-Binder Course (AC-BC), and Hot Rolled Sheet-Wearing Course (HRS-BC).

Marshall test was conducted comparing RAP usage to virgin course aggregate pavement mixture. From the investigation result shown in Fig.2 to Fig. 7 demonstrate that RAP usage is having a better result to flexible pavement mixture. The optimum bitumen content was determined. Hence, it can be concluded as follows,

1. Based on stability value, the HRS-WC achieved the highest stability. Nevertheless, the stability value for AC-WC and AC-BC were met the requirement from 2010 specification 6th division from Public Work Department standard in Indonesia.
2. The Flow of the 60% RAP-AC-WC was not met the requirement, while the flow of AC-BC, all the percentages met the requirement, but only 60% RAP met the requirement for HRS-WC
3. Meanwhile, the VMA for all the pavement mixture met the requirement
4. The AC-WC showed a better result based on VIM none for the AC-BC and HRS-WC.
5. For VFB, the AC-WC have enough film thickness for all the RAP percentages. Meanwhile, only 60%RAP for AC-BC, and none for the HRS-WC
6. Marshall Quotient only 35% RAP of the AC-WC met the requirement, none for the AC-BC, and fortunately all of the RAP percentages met the requirement for HRS-WC.

The use of RAP in flexible pavement expected to have environmental benefits as well as economics saving, because it can reduce the use of virgin aggregate and the amount of virgin asphalt binder required in the production of flexible pavement. Lowers transportation costs required to obtain quality virgin aggregate, and preserves resources.

It was found that, the best type of pavement mixture using RAP for course aggregate substitution was 35% RAP for AC-WC, due to from six Marshall parameters only one parameter i.e. void in mixture was not met the requirement.

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References

1. Feby Dwi Sutianto - *RI Punya Cadangan Aspal 660 Juta Ton, Tapi Tiap Tahun Masih Impor,* detikFinance, 9 September 2015 https://finance.detik.com/industri/3014500/ri-punya-cadangan-aspal-660-juta-ton-tapi-tiap-tahun-masih-impor

2. Sumbarsatu.com, *Merusak Lingkungan, Penambangan Pasir Batu di Batang Sitanang dihentikan*, 11 Januari (2017) http://www.sumbarsatu.com/berita/14458-merusak-lingkungan-penambangan-pasir-batu-di-batang-sitanang-dihentikan

3. Media Indonesia, BBWS *Keluhkan Penambangan Pasir Ilegal di Sungai Brantas*, 29 October 2017 http://www.mediaindonesia.com/news/read/129580/bbws-keluhkan-penambangan-pasir-ilegal-di-sungai-brantas/2017-10-29

4. Elviza Diana, Kala Warga Resah Penambangan Pasir di Sungai Batanghari, http://www.mongabay.co.id/2017/07/01/kala-warga-resah-penambangan-pasir-di-sungai-batanghari/Jambi di 1 July 2017

5. Putri. E. E, Adrian A, Hariadi M, Jodin Makinda. *Using Oil Palm Shell Agregate (OPSagg) for Flexible Pavements,* Electronic Journal of Geotechnical Engineering (EJGE), Vol. **20.7** (2015)

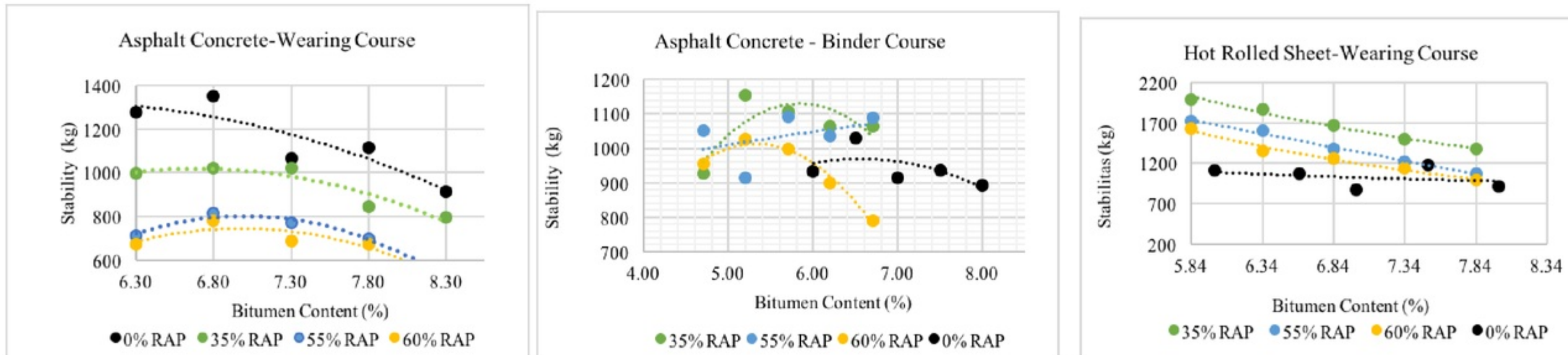
6. Valdés, G., Pérez-Jiménez, F., Miró, R., Martínez, A., & Botella, R. Experimental study of recycled asphalt mixtures with high percentages of reclaimed asphalt pavement (RAP). Construction and Building Materials, **25**(3), (2011).

7. Putri, E. E, and Andilla, M,. *Pemanfaatan Material Reclaimed Asphalt Pavement (RAP) Sebagai Bahan Campuran Untuk Lapisan Asphalt Pavement Concrete Wearing Course (AC-WC)*. Proc. 4th ACE Conf., Andalas University, Padang, (2017)

8. National Asphalt Pavement Association, *Hot Mix Asphalt Materials, Mixture Design, and Construction,* NAPA Education Foundation, Maryland, (1996)

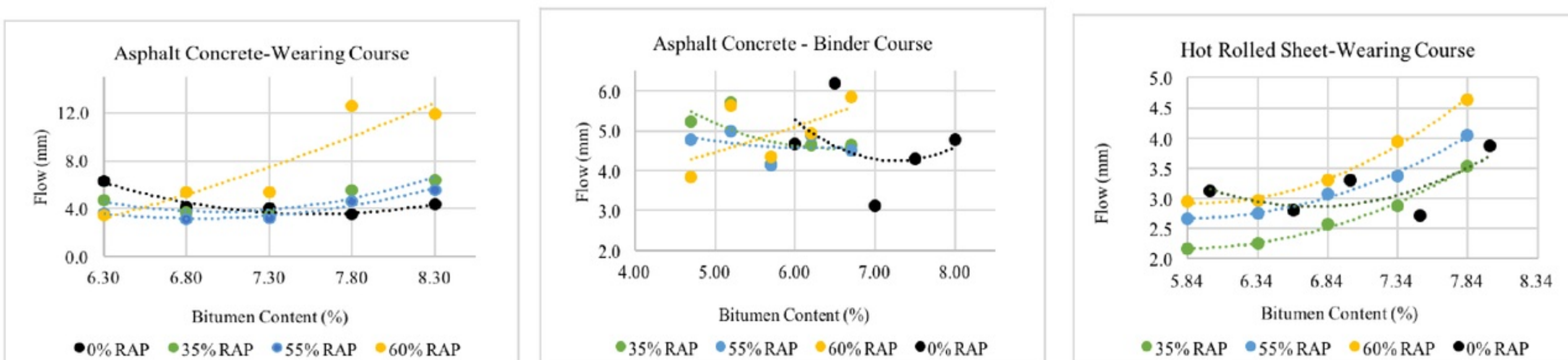
9. British Standard Institution, BS 594:Part 1:1992, “Hot-Rolled Asphalt for Roads and other Paved Areas”, BSI, London, (1992).

Appendix : Marshall Test Results for Asphalt Concrete-Wearing Course, Asphalt Concrete-Binder Course and Hot Rolled Sheet-Wearing Course



(a) (b) (c)

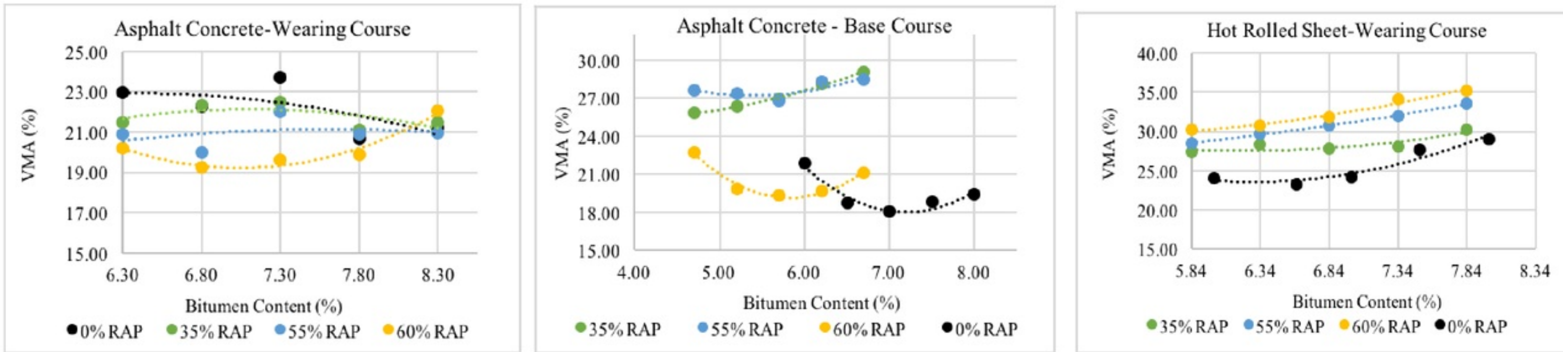
Fig. 1. Stability (kg) vs. Bitumen Content (%)



(a) (b) (c)

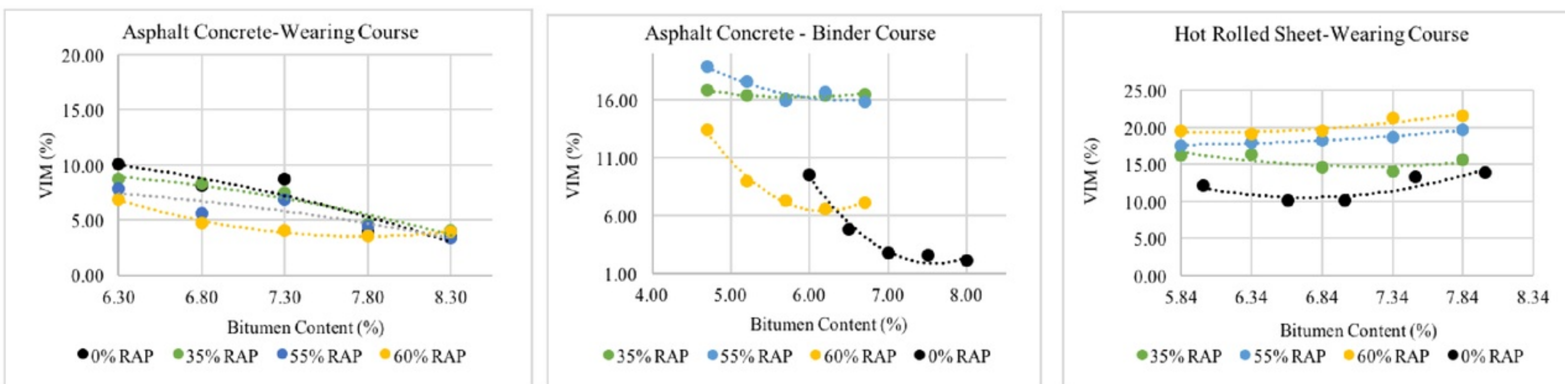
Fig. 2. Flow (mm) vs. Bitumen Content (%)

* Corresponding author: elsaeka@eng.unand.ac.id



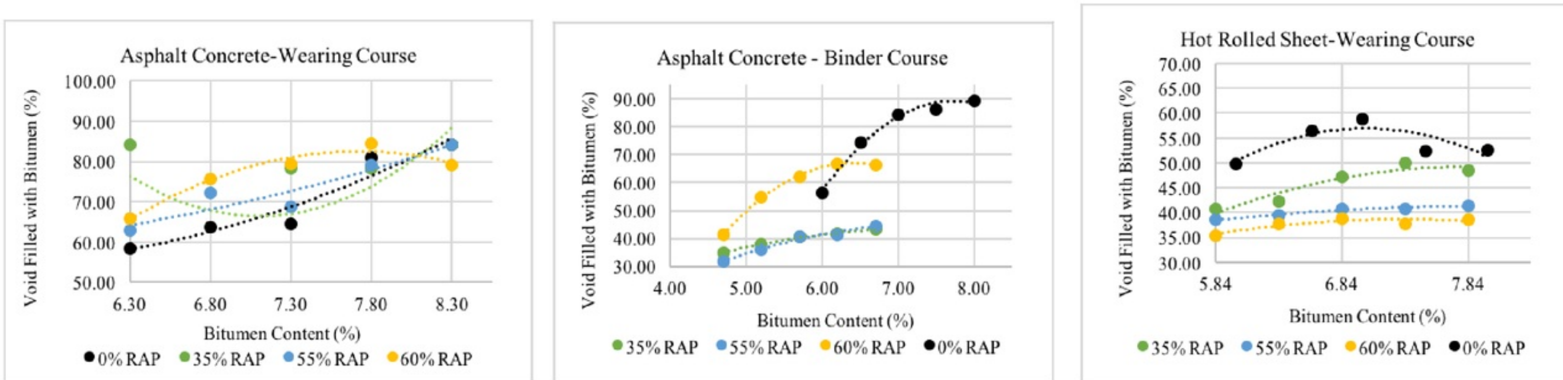
(a) (b) (c)

Fig. 3. Void in Mineral Aggregate (%) vs. Bitumen Content (%)



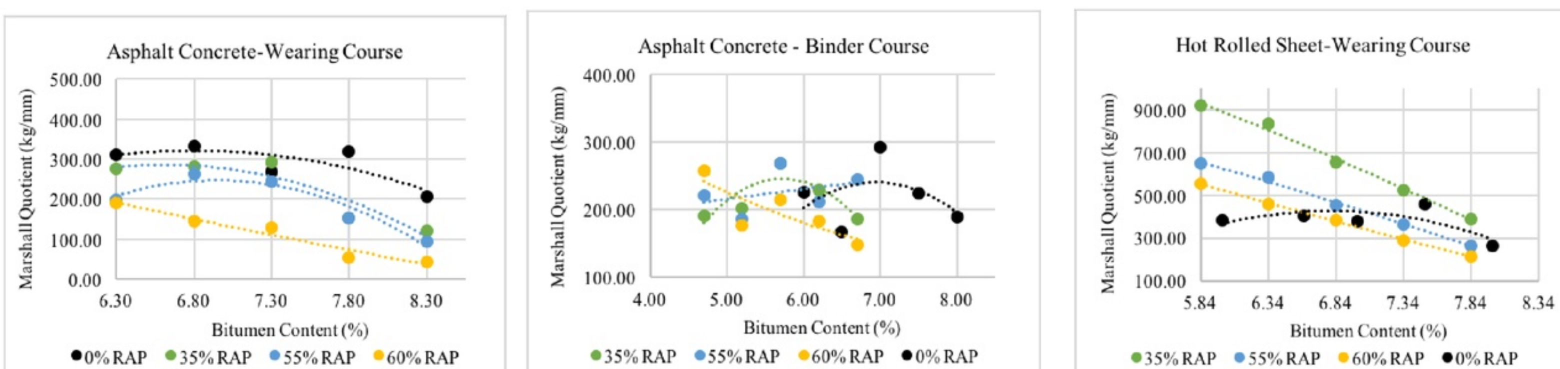
(a) (b) (c)

Fig. 4. Void in Mixture (%) vs. Bitumen Content (%)



(a) (b) (c)

Fig. 5. Void Filled with Bitumen (%) vs. Bitumen Content (%)



(a) (b) (c)

Fig. 6. Marshall Quotient (kg/mm) vs. Bitumen Content (%)

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