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Optimizing Performance Asphalt Concrete Hot Rolled Sheet– Wearing Course (HRS-WC) Using Chitosan Powder

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A B S T R A C T

Road quality is also affected by temperature and weather, leading to surface pavement deformation. It is necessary to improve the quality of the road pavement so that the quality of the road becomes more durable and stable. Hot Rolled Sheet – Wearing Course (HRS-WC) is flexible and has high durability. The natural mineral has been used as the filler for pavement construction. However, further research is necessary to obtain alternative and more sustainable materials. This study will discuss portland cement filler as a reference to compare filler replacement with chitosan powder (shellfish) based on the general specifications of the 2018 highway revision 3 division 6. Chitosan powder contains calcium oxide of 3.04% and silica oxide of 17.98%, which are similar to cement fillers. The composition of chitosan powder are 100%: 0%, 50%: 50%, 25%: 75%, and 0%: 100%. performance analysis is done through the marshall test. The results showed that the comparison of the use of the best chitosan powder was at the asphalt content of 7.3 with 50% : 50% with a marshall test value of 993.4 kg, flow 3.20 %, VMA 18.36%, VFB 72.01%, VIM 5.14, MQ 301.440 kg/mm. From the result which meets the requirement, the filler has shown quality improvement as an additional mixture according to (SNI 03-6723-2002). Hence still not optimal to replace portland cement because, from the value of the marshall test, portland cement has a higher marshall value than chitosan.

1. Introduction

The road is one of the important means in an area to connect one area to another for various purposes in terms of economy, social, culture, government, and so on. To support its function as road construction, a highway pavement is made in layers to have adequate carrying capacity and durability. The pavement layer consists of a surface layer. The top layer consists of a wear layer (Wearing Course) and an intermediate layer (Binder Course). The upper foundation layer (Base Course) is located between the surface and lower foundations. The type

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of pavement layer commonly used in Indonesia is asphalt concrete or typically HRS (Hot Rolled Sheet) [1][2]. HRS is asphalt concrete used as a road surface layer for light traffic. The wear layer of asphalt concrete and Hot Rolled Sheet has different gradations, namely well-graded and gap graded, respectively [3]. Hot Rolled Sheet (HRS) is used on roads with moderate traffic loads. Hot Rolled Sheet is flexible and has high durability. This is due to the mixture of HRS with lame gradations having a large cavity in the mixture to absorb the amount of asphalt large amounts (7-8%) without bleeding [4]. The HRS mixture consists of coarse aggregate, fine aggregate, and asphalt.

In general, the addition of filler will affect the elasticity properties of the mixture and sensitivity in asphalt-concrete mixtures, which increases stability. Still, the addition of large amounts of filler will result in a brittle mixture, whereas a mixture with low filler content will produce a soft mixture in hot weather [5]. More and more research is starting to focus on applying various types of solid waste materials to replace natural mineral powders with sustainable materials in asphalt mixtures [6]. Solid waste has been applied to asphalt pavements for many years, but the potential environmental impact of mixing porous asphalt with solid waste needs further research [7]. The increasing need for research in road construction automatically leads to alternative filler materials in the asphalt layer to develop durability from temperature and weather. Therefore, it is necessary to have the latest innovations from waste materials: chitosan powder. Chitosan powder comes from the shells of marine animals containing chitin, usually found in shrimp, clams, and crabs. The shells of marine animals containing chitin are deacetylated, which eventually becomes chitosan. Chitosan is used to increase the viscosity and stability by forming a dense network [8][9]. Hou reinforces this, Wang who researched chitosan as an asphalt emulsifier, showing that chitosan can increase the viscosity of asphalt emulsions without adverse effects on stability [8].

As one of the filler materials commonly used for HRS pavements, they generally use stone ash, extinguished lime, and Portland cement. Understanding demand for mineral aggregates and fillers, the researchers obtain to utilize solid waste as alternative road pavement construction materials with similar characteristics [10][11].

This study will discuss the use of Portland cement filler as a reference for comparing replacement with chitosan powder (shellfish) which had been ground into a fine powder (pass 0.075 mm sieve) which would later be used as a filler in the asphalt mixture. Chitosan (shellfish) is the shell of a mollusk. This chitosan (shellfish) contains calcium carbonate ($CaCO3$), which, when heated, will turn into CaO (3.04 %) [12]. From the preliminary observation by ITS

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Chemical Laboratory in 2019, it was also found that chitosan contains Silicon Oxide - SiO2 (17.98), which affects stability and viscosity to increase the value of marshall characteristics.

2. Methodology

This research was conducted at the PT. MIX PRO INDONESIA with the type of road pavement mixture to be used is Hot Rolled Sheet – Wearing Course (HRS-WC) gap grading with guidance from the General Specifications of Highways 2018 Revision 3 Division 6[13][14]. Research on making asphalt specimens into four different compositions using Portland cement and Chitosan fillers by ratio 100:0, 50:50, 25:75, and 0:100 with 3 samples for each composition. Which later will be tested for stability, flow, void in mineral aggregate (VMA), a void filled with bitumen (VFB), void in the mixture (VIM), and Marshall Quotient (MQ).

2.1. Materials Characterization

2.1.1. Aggregate

Aggregate consists of crushed rock, gravel, and sand of natural origin. Aggregate is divided into 2, namely coarse aggregate in the form of rocks gravel while fine aggregate in the form of sand[15]. In this study, the coarse aggregate used was 2 inches to 4.75 mm (sieve no. 4), while the fine aggregate used was 2.36 mm (sieve no. 8) to 0.075 mm (sieve no. 200)[16][17].

2.1.2. Asphalt

Asphalt is a black found at room temperature in the form of solid to slightly dense and is thermoplastic. Thus it is clear that the fine aggregate, especially the filler, greatly determines the performance of the HRS mixture [18]. At high temperatures, the asphalt will melt, and when the temperature decreases to room temperature, the asphalt will return to being hard (solid), so that asphalt is a thermoplastic material.

2.1.3. Filler

Inspections carried out on aggregates include sieve analysis, weight testing type and absorption of coarse aggregate, wear of aggregate with Los Angeles machine, testing of specific gravity and absorption of fine aggregate, and testing of specific gravity of shell filler[19]. Binder gives a strong bond between the asphalt, aggregate, and asphalt.

Filler fills the voids between the aggregate grains and the pores within the aggregates themselves. Filler requirements, according to the Ministry of Public Works, Directorate General

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of Highways in 2010 must be dry, free from lumps, and generally considered to be that portion of the mineral material that can pass through a 0.075 mm sieve[20]. Based on these provisions, filler often uses cement in field applications because it contains 60-65% quicklime, silica 20-24%, and alumina of about 4-8%. The content of these materials affects the stability and viscosity of the asphalt mixture. Aggregate is a collection of grains of a certain size obtained from natural or artificial products in the form of crushed stone, gravel, sand, and ash.

Portland cement is made from limestone (limestone) and other minerals, mixed and burned in a kiln, and after that, the material is in the form of powder. The powder will harden, and a strong bond occurs due to a chemical reaction when mixed with water. The chemical elements contained in portland cement are CaO, SiO2, Al2O3, Fe2O3, SO3, MgO, Loi, Na2O, K2O, C3S, C2S, C3A, and C4Af [21] [22].

Chitosan powder (shellfish) will be ground into a fine powder (0.075 mm sieve pass) which will later be used as a filler in the asphalt mixture. Chitosan (shellfish) is the shell of a mollusk. This chitosan (shellfish) contains calcium carbonate (CaCO3), which when heated, will turn into CaO (3.04 %) and release CO2 into the air, leaving only CaO (quicklime) and Si (Silica), whose content is a cement-forming component other than Fe2O3 (ferric oxide) and AL2O3. Chitosan iresults fromthe chitin deacetylation process by removing the acetyl group to obtain polymer compounds and glucosamine [12]. The preliminary observation by ITS Chemical Laboratory in 2019, also found that chitosan has Silicon Oxide - SiO2 (17,98 %), which affects stability and viscosity.

2.2. Marshall Tests

Inspections on asphalt include Marshall Tests carried out to describe the performance of the HRS WC to obtain the values as listed below:

2.2.1. Stability

The Marshall test determines the stability and flow of asphalt concrete mixtures [23]. This test can estimate the optimum asphalt content by determining stability and flow value in combination with the volumetric analysis. The maximum load that the specimen resists is presented by stability, whereas the deformation is measured as the flow of the mixture. The stability test calculation is as follows [24].

Stability = Dial watch reading x load correlation number

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2.2.2. Flow

Flow is regarded as an opposite property to stability. It determines the reversible behavior of the wearing course under traffic loads and affects asphalt concrete's plastic and elastic properties. The flow value is obtained from reading the flow measurement watch [25].

2.2.3. Void in Mineral Aggregate (VMA)

VMA is the cavity space between the aggregate particles on pavement, including the air cavity and the effective asphalt volume (excluding aggregate absorbed asphalt volume). VMA calculation is as follows.

$$VMA = 100 - \frac{G\ mb\ x\ Ps}{G\ sb}$$

With :

VMA = voids between mineral aggregates, percent of the total volume of the mixture

Gmb = Density of solid bulk mixture (AASHTO T-166)

Gsb = Aggregate bulk density

Ps = Percentage of aggregate to the total weight of the mixture

Pb = Total asphalt content, percent of the total weight of the mixture

2.2.4. Void in Mixture (VIM)

The air cavity in the mixture (Va) or VIM in a paved asphalt mixture comprises the upper air space between the asphalt aggregate particles.VIM calculation is as follows.

$$VIM = 100\ \frac{G\ mm - G\ mb}{G\ mm}$$

With :

VIM = voids in the mixture, percent of the total volume of the mixture

G mm = maximum density of the mixture

G mb = Density of solid bulk mixture (AASHTO T-166)

2.2.5. Void Filled with Bitumen (VFB)

Void Filled with Bitumen (VFB) is the percent of the cavity present between the aggregate particles (VMA) filled with asphalt, not including the asphalt absorbed by the aggregate. VFB calculation is as follows.

$$VFB = \frac{100(VMA - VIM)}{VMA}$$

With :

VFB = void filled with asphalt, percent to VMA

VMA = voids between mineral aggregates, percent of the total volume of the mixture

VIM = voids in the mixture, percent of the total volume of the mixture.

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2.2.6. Marshall Quotient (MQ)

Marshall Quotient is the result of a comparison between stability and melt (flow). The higher the MQ, the higher the stiffness of a mixture and the more susceptible the mixture will be cracked,

3. Results and Discussions

3.1. Materials Characterization Result

1) Aggregate Test

Testing This material test is carried out to determine the nature and characteristics of the aggregate to be used in the HRS-WC asphalt mixture. Result of Inspection of Specific Gravity and Absorption of Coarse Aggregate Inspection of weight type of coarse aggregate by calculating the weight how to calculate specific gravity bulk, absorption, and specific gravity of SSD This test uses a sample with an aggregate weight This uses a sample with an aggregate weight concerning AASHTOO-85-74 and PB -0202-76

Table 1. Materials Characterization Result

No	Type of Inspection	Unit	Requirements	Results				
				Coarse Aggregate	Medium Aggregate	Fine Aggregate	Portland Cement	Chitosan
1	Weight Type Bulk	gr/cc	Min 2.5	2.583	2.535	2,553		
2	SSD Specific Gravity	gr/cc	Min 2.5	2.625	2.589	2,589		
3	Specific Gravity	gr/cc	Min 2.5	2.695	2.674	2.649	3.229	3.137
4	Water Absorption	%	Max 3%	1.607	2,004	1,420		

Sources: Preliminary test at PT. MIX PRO INDONESIA, 2019

Based on the results of the table above, it can be concluded that coarse aggregate measuring 10-15 mm, medium aggregate (fine aggregate) measuring 5-10 mm, fine aggregate (fine aggregate) measuring 0-5 mm on bulk density inspection, specific gravity SSD, apparent density and water absorption obtained all results have met the requirements of the 2018 Highways specification. Meanwhile, the results for the filler density obtained for cement are 3.229 gr/cc and chitosan 3.137 gr/cc. Thus the density of filler cement and chitosan has been determined also meet the minimum specification requirements of 2.5 g/cc.

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2) Asphalt Test

The aggregate used consists of coarse aggregate, fine aggregate, and filler granules, whereas the bitumen used is typically hard asphalt type AC 60-70.

Table 2. Asphalt Test Results

No	Type of Testing	Unit	Conditions Min	Conditions Max	Results	Information
1	Asphalt Penetration 25°C, 5 seconds	Mm	60	70	63.7	Meets
2	Points Soft	°C	48	58	51	Meets
3	Flash Points	°C	232	-	318	Meets
4	Specific Gravity Asphalt	gr/cc	1.0	-	1.032	Meets
5	Ductility 25°C, 5 cm/minute	Cm	100	-	140	Meets

Source: Research Results at PT. MIX PRO INDONESIA, 2019

Testing This material test is carried out to determine the nature and characteristics of the aggregate to be used in the HRS-WC asphalt mixture that meets the 2018 Highways specifications.

3.2. Sample Planning Preparation

3.2.1. Aggregate Combination

Aggregate combination planning is a combination of coarse aggregate, medium aggregate, fine aggregate, cement filler, and chitosan powder filler used in the HRS-WC laston mixture and is by the 2018 Public Works Department Specifications. The material used is Hot Bin, which is material that has been processed and heated.

Table 3. Planning Results of Aggregate Combination Sieve

Size Aggregate	Type: 10–15 mm *Coarse 18 %*	Type: 5–10 mm *Medium 14 %*	Type: 0-5 mm *Fine 66%*	Type: *Filler* S 1%	Type: *Filler* K 1%	Total Passed	Specifications	Description
2 "	18.00	14.00	66.00	1.00	1.00	**100.00**	100.00	Meets
1.5 "	18.00	14.00	66.00	1.00	1.00	**100.00**	100.00	Meets
1 "	18.00	14.00	66.00	1.00	1.00	**100.00**	100.00	Meets
3/4 "	18.00	14.00	66.00	1.00	1.00	**100.00**	100.00	Meets
1/2 "	13.10	14.00	66.00	1.00	1.00	**95.10**	80 - 100	Meets
3/8 "	4.83	12.16	66.00	1.00	1.00	**84.99**	60 - 85	Meets

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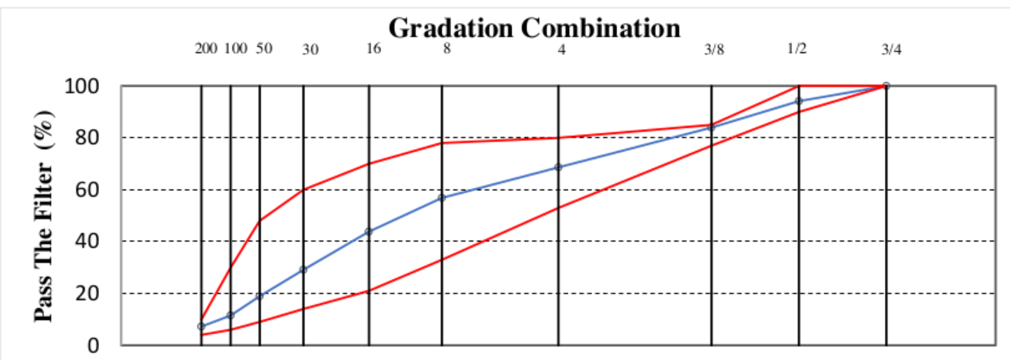
Size Aggregate	Type 10–15 mm *Coarse 18 %*	5–10 mm *Medium 14 %*	0-5 mm *Fine 66%*	*Filler* S 1%	K 1%	Total Passed	Specifications	Description
#4	0.68	4.89	64.36	1.00	1.00	**71.93**	56 - 80	Meets
#8	0.47	0.79	56.39	1.00	1.00	**59.64**	53 - 78	Meets
#16	0.40	0.40	43.02	1.00	1.00	**45.81**	40 - 70	Meets
# 30	0.28	0.27	28.74	1.00	1.00	**31.29**	25 - 60	Meets
# 50	0.25	0.22	20.15	1.00	1.00	**22.61**	13 - 48	Meets
# 100	0.20	0.18	10.54	1.00	1.00	**12.92**	8 - 30	Meets
# 200	0.15	0.10	5.12	0.94	0.91	**7.25**	5 - 10	Meets

Source: Research Results, 2019

Table 3. states that combination planning's composition of the mixture still meets the specifications.



Source: Research Results

Figure 2. Graph of the Result of Aggregate Combination

Information: Test Results = (blue line)

Specification Limit = (red line)

From **Figure 2,** it can be concluded that the result of the mixture gradation (the blue line) was placed inside the specification area.

3.3 Asphalt Content Planning

In this study, the asphalt content planning was obtained as follows.

Pb = 0,035(%AK) + 0,045(%AH) + 0,18(%BP) + constant.

Pb = 0,035(12,29) + 0,045(59,64) + 0,18(7,25) + 1

Pb = 5,41

So the asphalt content used is 5,41.

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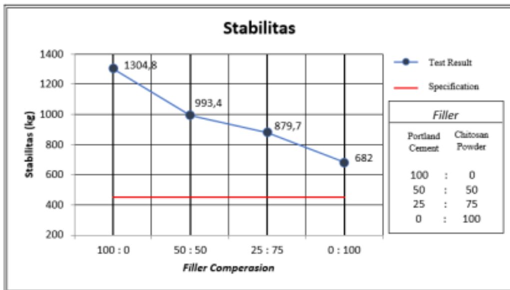
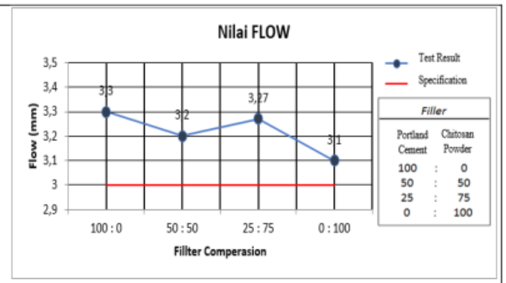
3.4 Marshall Test Results

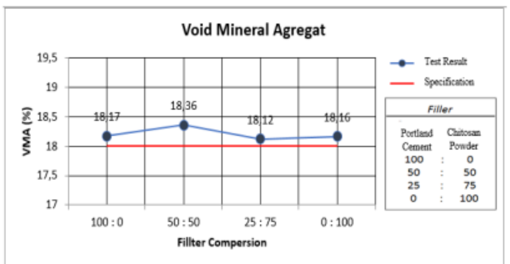
Marshall test was carried out on all sample with tests carried out including stability test, flow test, VMA test, VFB test, VIM test, Marshall Quotient test.



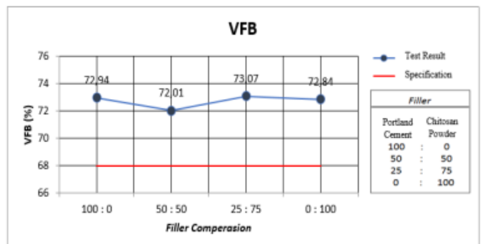
Graph of Stability Value Results against Filler Replacement



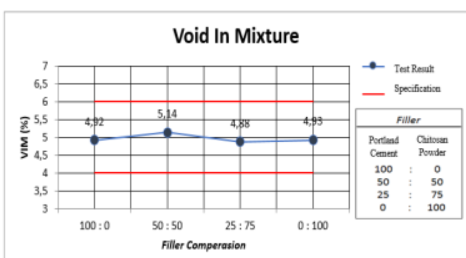
Graph of Flow Value Results against Filler Replacement



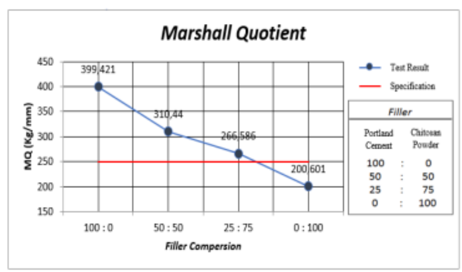
Graph of VMA Value Result for



Graph of VFB Value Result for Filler Replacement



Graph of VIM Value for



Graph of MQ Value Results for Filler Replacement

Figure 3. Marshall Test Result

Source: Research Results

Figure 3. Shows the use of a mixture of portland cement and chitosan powder as a filler which has the best test value at a ratio of 50:50. This can be seen from several tests such as stability test, flow test, VMA test, VFB test, VIM test, Marshall Quotient , and meet the requirements of the added mixture specification according to SNI 03-6723-2002.

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4. Conclusion

Based on the purpose of this study, the conclusion obtained is the Marshall test value using chitosan powder filler (shellfish) on HRS-WC pavement, the best is to use a combination of 50% filler mixture cement; 50% chitosan powder filler (shellfish) with asphalt content of 7.3 and obtained the following values: stability 993.4 Kg, flow 3.20%, VMA 18.36%, VFB 72.01%, VIM 5.14, MQ 301.440 Kg/mm. From the result which meets the requirement, the filler has shown quality improvement as an additional mixture according to (SNI 03-6723-2002). So chitosan can be used as a filler mixture, but it is not optimal to choose portland cement because, from the value of the marshall test, portland cement has a higher marshall value than chitosan. Therefore chitosan powder can be used as an alternative material when natural resources are reduced.

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