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To cite this article: N Martina *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **739** 012005

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Analysis of the use of rubber waste to improve the performance of the asphalt concrete mixture against tidal floods

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Abstract. The increasing rainfall can increase sea level, which increases the frequency of tidal flooding. The effects of tidal floods can emerge directly or indirectly, and the direct effects are the damage to people's houses and infrastructure. Seawater puddles due to tidal floods have inundated road infrastructure. Meanwhile, humidity in asphalt is an essential factor affecting the durability of asphalt pavement. The asphalt concrete mixture requires a proper mixture to increase durability and life. The addition of used tire powder to the asphalt mixture can increase the asphalt pavement's resistance to the effects of tidal flooding. The steps of this research include the preparation of materials, testing materials (coarse aggregate, fine aggregate, and asphalt), manufacturing of test objects with and without added materials rubber waste, the immersion of test specimens for 0 and 4 days, Marshall Stage 1 and Stage 2 testing, density testing, wheel tracking test. The results show that the effect of tidal floodwater immersion in the asphalt mixture decreases the strength and quality of the asphalt mixture, the skid resistance, which can be seen from the decreased stability and increased flow. The addition of crumb rubber to the asphalt mixture can reduce the decline in stability value, increase flow value, and better skid resistance results. The Wheel Tracking Machine test results show the effect of adding crumb rubber to the asphalt mixture to reduce the deformation speed of the asphalt mixture.

1. Introduction

Increasing rainfall can increase sea level, which increases the frequency of tidal flooding. Periodic tidal flooding causes the groundwater level to rise and consequently limits oxygen penetration into the soil [1]. The frequency of roob flood events depends on the time the water level rises due to tidal variations [2]. It generally occurs in big cities in coastal areas, such as North Jakarta, Indonesia. The effects of tidal floods can emerge directly or indirectly, and the direct effects are the damage to people's houses and infrastructure [3]. As a result of the tidal flooding, seawater puddles emerged that submerged road infrastructure. Meanwhile, humidity in asphalt is an essential factor affecting the durability of asphalt pavement [4]. For a long time, stagnant seawater can reduce the asphalt mixture's durability index, resulting in cracks on the pavement. Damage to concrete occurs due to water penetration, destroying the concrete layer, and weakening the pavement body [5]. Besides, seawater inundation on flexible pavement causes decreased road performance and caused road life to be shorter.

Based on these conditions, the asphalt concrete mixture requires a proper mixture to increase durability and life. The design of a mixture of heat-resistant and fracture-resistant pavements caused by climate change and traffic conditions can be used as an alternative to mitigate road damage due to seawater infiltration on flexible pavements [6]. The rubber asphalt mixture shows good compatibility



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with two sustainability technologies widely used in the asphalt pavement industry, namely reclaimed asphalt pavement and warm mix asphalt [7]. Besides that, rubber waste has slightly higher flexibility [8]. So, the addition of used tire powder to the asphalt mixture can increase the asphalt pavement's resistance to the effects of tidal flooding.

Asphalt concrete is a type of pavement consisting of a mixture of aggregate and asphalt, with or without additives. This additive comes from materials that can be mixed with aggregate and asphalt, such as rubber waste. Rubber waste is one of the waste materials that can be easily obtained in Indonesia's regions in relatively large quantities [9]. Rubber waste is tough to decompose if left unchecked, and it will become an environmental problem. One solution is to recycle the rubber waste. Recycling Crumb Rubber provides considerable environmental benefits such as reduced rubber waste and reduced atmospheric pollution from the combustion process [10]. Recycled crumb rubber can also be used as a mixture of asphalt roads modified with rubber [11].

Based on Nguyen and Tran's research in 2017, rubber waste in asphalt concrete mixture provided a significant increase in marshal stability and asphalt concrete resistance. This research aims to compare the mixture of asphalt concrete with the added material of tire rubber waste and without using the added material of tire rubber waste in tidal flood soaking [12].

This research objective is to determine the effect of the addition used tire powder on asphalt concrete mixture submerged in tidal floodwater. Hopefully, it can be the solution for road infrastructure problems that are often submerged by tidal flooding in coastal areas and the solutions for reducing waste that cannot be biodegraded naturally.

2. Methods

This research is experimental and was carried out at the Laboratory of the Civil Engineering Department of the Jakarta State Polytechnic in 2020. The stages of this research include the preparation of materials, testing materials (coarse aggregate, fine aggregate, and asphalt), manufacturing of test objects with and without added materials rubber waste, the immersion of test specimens for 0 and 4 days, Marshall Stage 1 and Stage 2 testing, density testing, wheel tracking test. The coarse aggregate used is crushed stone that meets the requirements in SNI (Standar Nasional Indonesia) 1969:2008 regarding specific gravity, water absorption, and sludge content of coarse aggregate materials [13]. The fine aggregate material used is natural sand and meets the requirements in SNI 03-4428 related to specific gravity, water absorption, and sludge content of fine aggregate materials [14].

The asphalt used in this research is shell asphalt with penetration of 60/70 and meets the requirements related to specific gravity, penetration test, ductility test, and asphalt softening point test. Density testing of asphalt based on SNI 2441:2011 [15]. Asphalt penetration testing refers to SNI 2456:2011 [16]. Ductility testing for asphalt, according to SNI 2432:2011 [17]. And softness testing of asphalt based on SNI 2434:2011 [18].

In this study, rubber waste comes from used tires is used. The testing objects with a mixture of rubber waste mixtures of 6%, 8%, 10%, 12% by weight of the optimum asphalt were used in this research. A total of 15 specimens of asphalt concrete mixture in Table 1 with variations in asphalt content of 4%, 4.5%, 5%, 5.5%, 6% (each of 3 specimens) were used to determine the optimum asphalt content After obtaining the optimum bitumen content, 12 asphalt concrete test specimens (Table 2) will be made with optimum rubber waste with variations of 6%, 8%, 10%, 12% of the weight of the optimum asphalt (3 specimens each). At this stage, there will also be further testing of the Marshall Stage 1 to obtain the optimum percentage of rubber waste. The test object, with known asphalt content and optimum rubber content, is immersed in seawater. This process is carried out for engineering the test object submerged by tidal floodwater. The test object was immersed using a time variation of 0 days and four days. The variation in immersion time is supposed to produce the optimal asphalt concrete mixture for coastal areas that are often flooded.

When the optimum asphalt content and the optimum additional rubber waste content were obtained, 6 test specimens (Table 3) will be made for the Marshall Test- Stage 2 with immersion variations in tidal floodwater for 0 days and four days (3 specimens each). Marshall test is based on SNI 06-2489:1991 [19]. The Marshall testing process is fundamental to determine hot mix asphalt stability

[20]. SNI 4427:2008 is the standard for testing the rigidity [21]. Tensity testing of the asphalt concrete mixture is essential to test the strength of asphalt concrete because it will determine the strength of the asphalt concrete so that it is safe to use in areas that have large deformations [20]. Meanwhile, the wheel tracking test uses a Wheel Tracking Machine (WTM) tool. This WTM test has a significant result to determine the resistance of an asphalt mixture to periodic loads and the asphalt concrete mixture's ability to retain moisture [22].

Table 1. Specimens Used in The Marshall Test - Phase 1 to Obtain Optimum Asphalt Content

No	Testing type	Variations of asphalt content	Number of specimens	Total of specimens
1A	Marshall Testing Phase 1	(4%)	3	15
		(4.5%)	3	
		(5.0%)	3	
		(5.5%)	3	
		(6.0%)	3	

Table 2. Specimens Used in The Marshall Test - Stage 1 to Obtain Optimum Waste Tire Content

No	Testing type	Variations of waste tire content	Number of specimens	Total of specimens
2	Marshall Test- Stage 1 with waste tire (additional filler)	6%	3	12
		8%	3	
		10%	3	
		12%	3	

Table 3. Specimens Used in The Marshall Test - Stage 1, Toughness Test, and Wheel Tracking Test

No	Testing type	Variation of Immersion Time	Number of specimens	Total of specimens
3	Marshall Test-Stage 2	0 day	3	6
		4 days	3	
4	Toughness Test	0 day	2	4
		4 days	2	
5	Wheel Tracking Test	0 day	2	4
		4 days	2	

3. Results and Discussions

3.1. Optimum Asphalt Content

Optimum Asphalt Content is obtained from the results of Marshall test with variations of asphalt content of 4.5%, 5%, 5.5%, 6%, and 6.5%. The test results are presented in Table 4.

Table 4. Marshall Test Properties to Obtain Optimum Asphalt Content

Asphalt Content (%)	VMA (%)	VFB (%)	VIM (%)	Stability (Kg)	Flow (mm)	Marshall Quotient (kg/mm)
4.5	16.09	73.61	4.25	1762.92	4.7	380.05
5	16.74	73.40	4.48	1772.88	3.97	449.92
5.5	16.03	80.84	3.16	1611.03	2.91	557.29
6	15.89	84.57	3.08	1586.13	3.77	425.75
6.5	16.47	84.50	2.64	1600.24	4.37	371.19

The data in Table 4 when compared with the requirements contained in SNI 8198: 2015 [23], it is found that the VMA value for all specimens meets the minimum requirements 15%. The VFB value for all specimens also meets the minimum requirements 65%. Stability values for all specimens also meet the minimum requirements 800 kg. The VIM value for mixtures with asphalt content of 6.5% does not meet the minimum requirements of 3%. While the flow value that exceeds the maximum requirement of 4% is a mixture with asphalt content of 4.5% and 6.5%. Based on these results, the optimum asphalt content can be calculated as shown in Fig. 1, the optimum asphalt content is 5.25%.

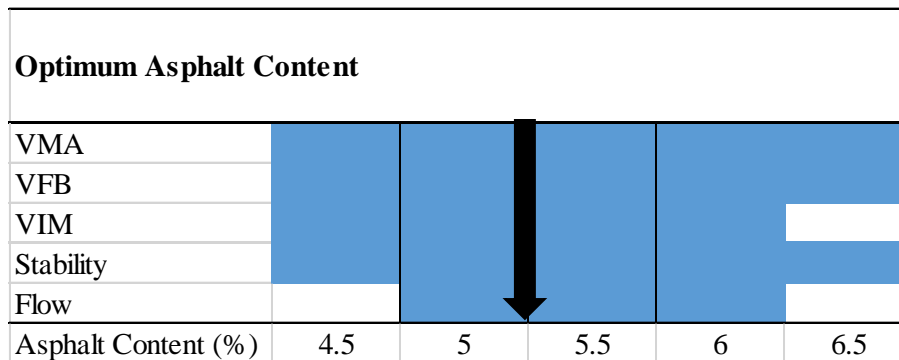


Figure 1. Optimum Asphalt Content

3.2. Optimum Crumb Rubber Content

After obtaining the optimum asphalt content, Marshall test was performed for mixed specimens with variations of 0%, 6%, 8%, 10%, and 12% crumb rubber content to obtain the optimum value of crumb rubber content. Based on the results in Table 5., it is found that all test results parameters for all variations of crumb rubber content meet the requirements set by SNI 8198: 2015 [23]. Based on these results, the optimum crumb rubber content at optimum asphalt can be calculated as shown in Fig. 2. with the optimum crumb rubber content is 9%.

Table 5. Marshall Test Properties to Obtain Optimum Crumb Rubber Content at Optimum Asphalt Content

Crumb Rubber Content (%)	VMA (%)	VFB (%)	VIM (%)	Stability (Kg)	Flow (mm)	Marshall Quotient (kg/mm)
0	16.3	75.3	4.1	1772.9	4.0	443.2
6	17.02	73.21	4.84	1420	3.8	320.21
8	16.3	77.15	3.8	2240	3.63	513.66
10	15.81	79.99	3.17	1576	3.23	404.09
12	16.09	78.35	3.49	1938	3.73	456.92

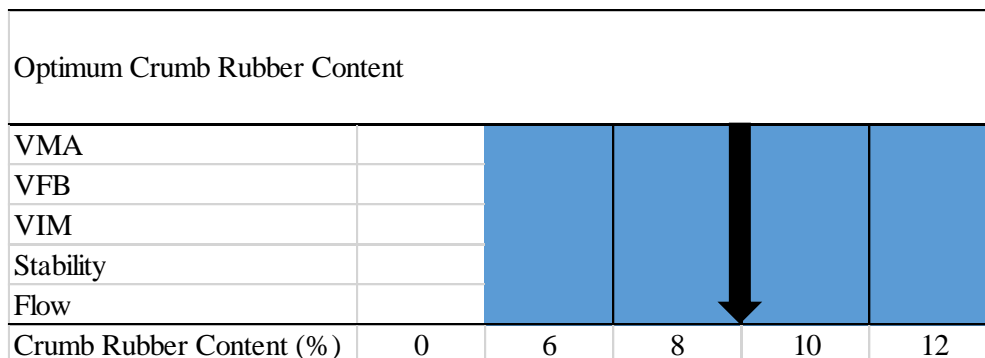


Figure 2. Optimum Crumb Rubber Content at Optimum Asphalt Content.

3.3. Tidal Flood Immersion Effect

Test specimens with optimum asphalt content of 5,25% and optimum crumb rubber content of 9% which were treated with immersion in tidal floodwater for 0 days and 4 days were tested by Marshall and the results were compared with test objects with optimum asphalt content of 5,25% without the addition of crumb rubber. The test results are presented in Fig. 3 – Fig. 7.

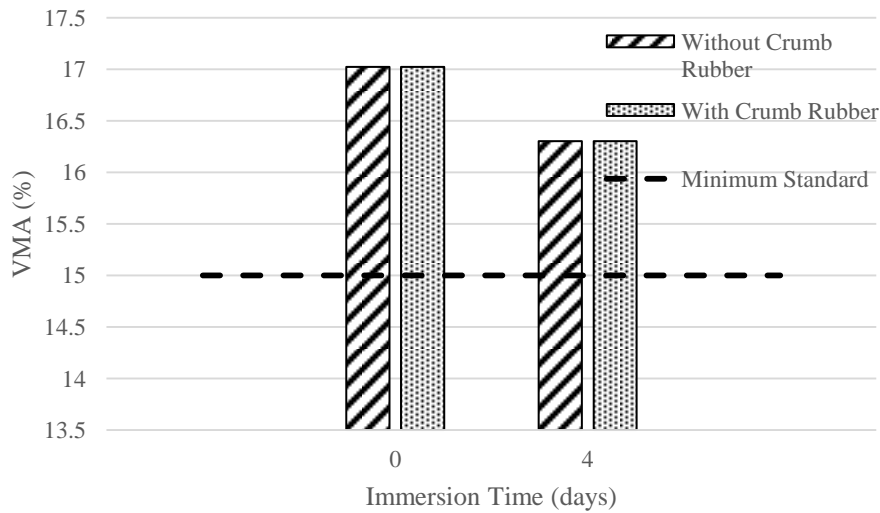


Figure 3. Result of Marshall Test with Immersion Variation of Voids in Mix Aggregate (VMA)

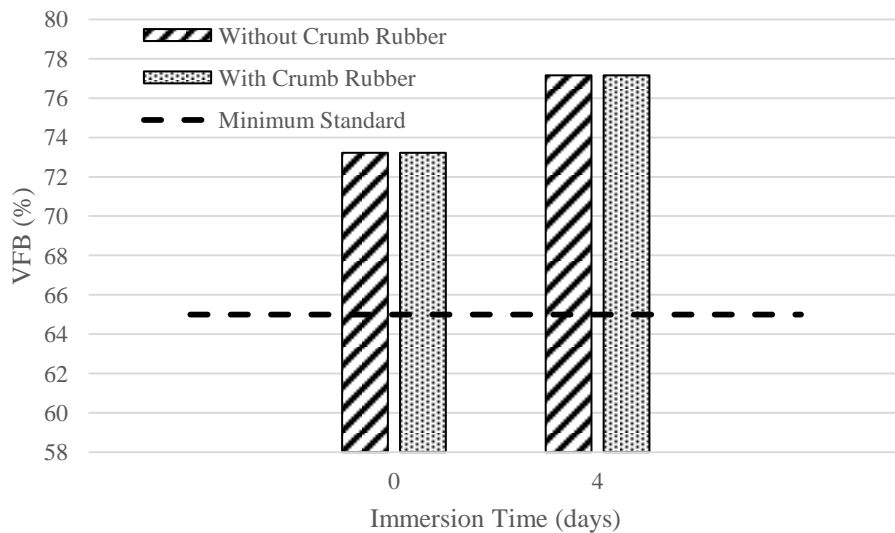


Figure 4. Result of Marshall Test with Immersion Variation of Voids Filled with Bitumen (VFB)

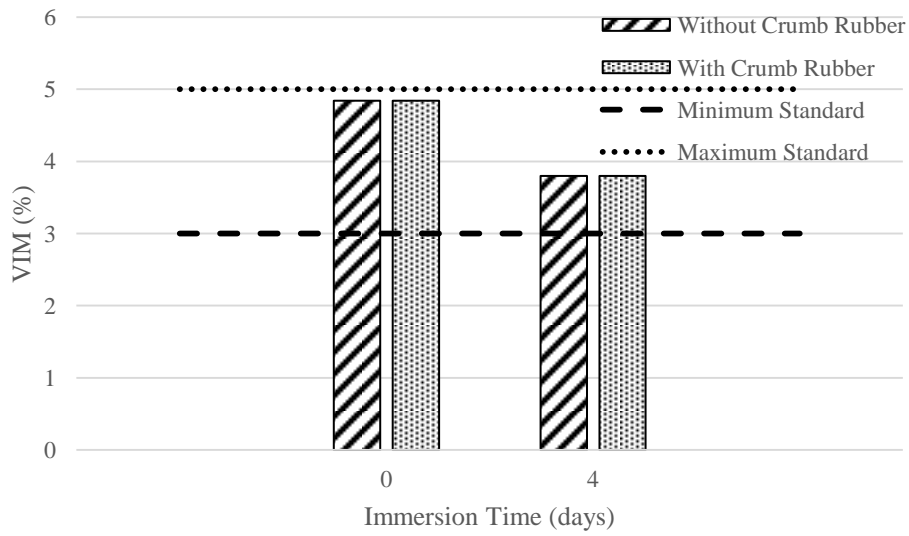


Figure 5. Result of Marshall Test with Immersion Variation of Voids in Mix (VIM)

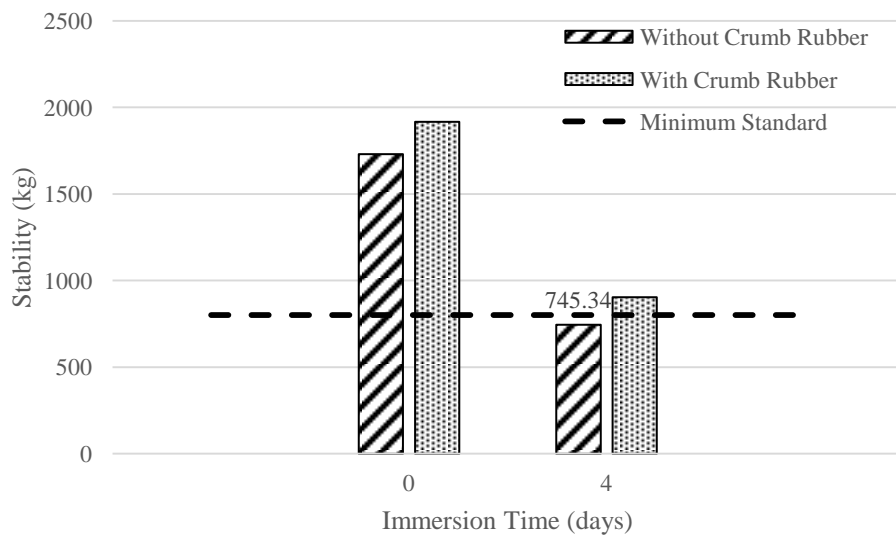


Figure 6. Result of Marshall Test with Immersion Variation of Stability

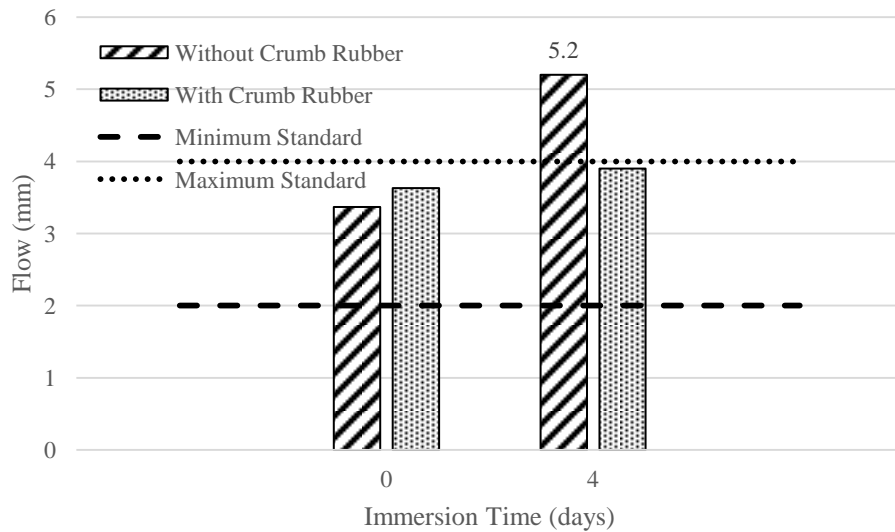


Figure 7. Result of Marshall Test with Immersion Variation of Flow.

Figures 3 and 4 illustrate that the immersion of tidal floodwater decreases the VMA value and increases the VFB value, this means that the void between the aggregates that occur will be filled with asphalt. However, all results of VMA and VFB values still meet the minimum requirements of SNI 8198: 2015 [23]. On the other hand, Fig. 5 shows the effect of tidal floodwater immersion in reducing the VIM value, which illustrates that the specimen becomes increasingly porous. The results of the VIM value also show that the VIM value still meets the requirements of SNI 8198: 2015 [23].

The stability value of the specimen without the addition of crumb rubber with tidal floodwater immersion for 4 days is shown in Fig. 6 does not meet the minimum requirements of SNI 8198: 2015 [23], while the stability value of the specimen with the addition of crumb rubber and the same immersion variation gives a higher value and meets the minimum requirements of SNI 8198: 2015 [23]. This shows that the addition of crumb rubber increases the stability of the asphalt mixture to the effect of tidal floodwater immersion.

The flow value of the specimens with the addition of crumb rubber and variations of tidal floodwater immersion for 4 days gave better results than specimens without the addition of crumb rubber with the same immersion variation. This is shown in Fig. 7 where specimens without the addition of crumb rubber with variations in tidal floodwater immersion for 4 days do not meet the maximum requirements of SNI 8198: 2015 [23].

The effect of tidal floodwater immersion decreases the strength and quality of the asphalt mixture, this can be seen by decreasing stability and increasing flow. However, the addition of crumb rubber to the asphalt mixture provides stability and flow values that still meet the requirements of SNI 8198: 2015 [23]. This means that the addition of crumb rubber to the asphalt mixture can increase the strength and quality of the asphalt concrete mixture [24].

3.4. Skid Resistance

The effect of variations in tidal floodwater immersion in the specimens was also investigated on the results of the pavement surface roughness test using a British Pendulum Tester (BPT) tool. The test results are presented in Table 6.

Table 6. Skid Resistance Test Results

Specimen Variable	Immersion Time (Days)	British Pendulum Number (BPN)	Mu - Meter
Without Crumb Rubber	0	67	0.47
	4	60	0.4
With Crumb Rubber	0	67	0.47
	4	64	0.44

The test results show that the tidal floodwater immersion can reduce the skid resistance of the asphalt mixture. Meanwhile, the test results show that the addition of crumb rubber to the asphalt mixture increases the skid resistance of the asphalt mixture. The higher the roughness value will affect the friction against the wheels so that it can reduce the possibility of wheel slip occurring. The test results also show the skid resistance value for all specimens in A category (BPN above 65) according to ASTM E303-96: 2018 [25], fulfilling the skid resistance requirements fast traffic.

3.5. Wheel Tracking Machine

Wheel Tracking Machine is intended to simulate the deformation that occurs on the pavement due to vehicle trajectories. The test results in Table 7 show that the dynamic stability values of all specimens meet the dynamic stability values required in SNI 8198: 2015 [23], above 2500 cycle/mm. However, the results also show that the specimens without the addition of crumb rubber have a higher deformation speed, this indicates that without the addition of crumb rubber the deformation will occur faster.

Tabel 7. Wheel Tracking Machine Test Result

Specimen Variable	Immersion Time (Days)	Dynamic Stability (Cycle/mm)	Rutting Depth (mm/min)
Without Crumb Rubber	0	2625	0.016
	4	9000	0.0046
With Crumb Rubber	0	3937	0.0107
	4	10500	0.0004

4. Conclusion

Based on laboratory testing results, the conclusion of this research is the effect of tidal floodwater immersion in the asphalt mixture decreases the strength and quality of the asphalt mixture, which can be seen from the decreased stability and increased flow. However, crumb rubber to the asphalt mixture can reduce the decline in stability value and increase flow value. The skid resistance of the asphalt mixture decreased due to the effect of tidal floodwater immersion. However, the addition of crumb rubber to the asphalt mixture gave better skid resistance results. The Wheel Tracking Machine test results show the effect of adding crumb rubber to the asphalt mixture to reduce the deformation speed of the asphalt mixture.

References

- [1] Yang Z, Nolte S, Wu J 2017 Tidal flooding diminishes the effects of livestock grazing on soil micro-food webs in a coastal saltmarsh *Agric. Ecosyst. Environ.* **236** 177-86.
- [2] Clemmensen L B, Glad A C, Kroon A 2016 Storm flood impacts along the shores of micro tidal inland seas: A morphological and sedimentological study of the Vesterlyng beach, the Belt Sea, Denmark *Geomorphology* **253** 251-61.
- [3] Nugraha A L, Santosa P B, Aditya T 2015 Dissemination of tidal flood risk map using online map in Semarang *Procedia Environ. Sci.* **23** 64-71.

- [4] Ržek L, Turk M R, Tušar M 2020 Increasing the rate of reclaimed asphalt in asphalt mixture by using alternative rejuvenator produced by tire pyrolysis *Constr. Build. Mater.* **232** 117177.
- [5] Fakhri M, Amosoltani E, Aliha M R M 2017 Crack behavior analysis of roller compacted concrete mixtures containing reclaimed asphalt pavement and crumb rubber *Eng. Fract. Mech.* **180** 43-59.
- [6] Transportation Association of Canada 2013 *Pavement and Salt Management Syntheses of Best Practices Road Salt Management* (Canada).
- [7] Shu X and Huang B 2014 Recycling of waste tire rubber in asphalt and portland cement concrete: an overview *Constr. Build. Mater.* **67 (Part B)** 217-24.
- [8] Fakhri M and Amosoltani E 2017 The effect of reclaimed asphalt pavement and crumb rubber on mechanical properties of roller compacted concrete pavement *Constr. Build. Mater.* **137** 470-84.
- [9] Martina N, Hasan M F R, Setiawan Y 2019 Pengaruh serbuk ban bekas sebagai campuran agregat halus pada campuran aspal porous *Wahana Tek. SIPIL* **24 (2)** 144-52.
- [10] Silva L D, Benta A, Santos L P 2018 Asphalt rubber concrete fabricated by the dry process: laboratory assessment of resistance against reflection cracking *Constr. Build. Mater.* **160** 539-50.
- [11] Chaikaew C, Sukontasukkul P, Chaisakulkiat U, Sata V, Chindaprasirt P 2019 Properties of concrete pedestrian blocks containing crumb rubber from recycle waste tyres reinforced with steel fibres *Case Stud. Constr. Mater.* **11** e00304.
- [12] Nguyen H T T and Tran T N 2017 Effects of crumb rubber content and curing time on the properties of asphalt concrete and stone mastic asphalt using dry process *Int. J. Pavement Res. Technol.* **11 (3)** 236-44.
- [13] Standar Nasional Indonesia (SNI) 2008 *SNI 1969:2008 tentang Cara uji berat jenis dan penyerapan air agregat kasar* (Jakarta).
- [14] Standar Nasional Indonesia (SNI) 1997 *SNI 03-4428:1997 tentang Metode pengujian agregat halus atau pasir yang mengandung bahan plastik dengan cara setara pasir* (Jakarta).
- [15] Standar Nasional Indonesia (SNI) 2011 *SNI 2441:2011 tentang Cara uji berat jenis aspal keras* (Jakarta).
- [16] Standar Nasional Indonesia (SNI) 2011 *SNI 2456:2011 tentang Cara uji penetrasi* (Jakarta).
- [17] Standar Nasional Indonesia (SNI) 2011 *SNI 2432:2011 tentang Cara uji daktilitas aspal* (Jakarta).
- [18] Standar Nasional Indonesia (SNI) 2011 *SNI 2434:2011 tentang Cara uji titik lembek aspal dengan alat cincin dan bola (ring and ball)* (Jakarta).
- [19] Standar Nasional Indonesia (SNI) 1991 *SNI 06-2489:1991 tentang metode pengujian campuran aspal dengan alat marshall* (Jakarta).
- [20] Rombot P, Haseke O H, Manoppo M R E 2015 Kajian kinerja campuran beraspal panas jenis lapis aspal beton sebagai lapis aus bergradasi kasar dan halus *J. Sipil Statik* **3 (3)** 190-7.
- [21] Standar Nasional Indonesia (SNI) 2008 *SNI 4427:2008 tentang Cara Uji Kekesatan Permukaan Perkerasan Menggunakan Alat British Pendulum Tester (BPT)* (Jakarta).
- [22] Yin F, Chen C, West R, Martin A E, Mercado E A 2020 Determining the relationship among hamburger wheel-tracking test parameters and correlation to field performance of asphalt pavements *Transp. Res. Rec.* **2674 (4)** 281-91.
- [23] Standar Nasional Indonesia (SNI) 2015 *SNI 8198:2015 tentang Spesifikasi campuran beraspal panas bergradasi menerus (Laston)* (Jakarta).
- [24] Wulandari P S and Tjandra D 2016 Use of crumb rubber as additive in asphalt concrete mixture, *Procedia Eng.* **171** 1384-89.
- [25] American Standard Testing and Material (ASTM) 2018 *ASTM E303-96. To Measure Surface Frictional Properties Using British Pendulum Skid Resistance Tester* (Experiment No. 6).