Spent Molasses Concentration (SMC) As Bio Asphalt in Flexible Pavement

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ABSTRACT

This study investigates the effect of increasing the spent molasses concentrtion (SMC) in hot mix asphalt on its performance and strength. The Marshall Test, aggregate properties, and bitumen properties were assessed in this study. For the investigation, bitumen of grade 60/70 PEN and ACW14 was utilized. In order to assess the effectiveness of hot mix asphalt incorporating 10% SMC as a partial bituminous replacement. A control sample was included in the total of 30 specimens prepared for this study. The results of the aggregate and bitumen properties indicate that, in addition to penetration and flow, both of these materials met the requirements of JKR Standard 2008. The penetration point value exceeds the level of penetration specified in standard JKR 2008. The result is an increase in a softening point that corresponds to the passage of SMC. The Marshall Test results illustrate the variation in parameters that occur with the addition of SMC and bitumen. In conclusion, additional testing and a variety of SMC percentages are still required.

Keywords: Bitumen, binder, spent molasses concentration, marshall.

1. INTRODUCTION

One of the key ways to reduce bitumen usage and improve the environment, economy, and health is to employ bio-asphalt in asphalt mixes (Sun *et al*., 2017; Dong *et al*., 2019; Gao, 2018). Swine manure Sun *et al*., 2017), waste cooking oil (Dong *et al*., 2019), sugarcane and beet molasses (Bahadori *et al*., 2019), and wood waste (Zhang *et al*., 2018) are potential bio-binders. Studies showed that bio-asphalts are moisture-sensitive because moisture may damage hot-mix asphalt HMA pavements. Sugarcane molasses replaces bitumen in pavement construction with less environmental effect and expense. It decreases greenhouse gas emissions by 30% and enhances asphalt pavement thermal durability (Abdulahi, 2017). Sugarcane molasses (SM) is one a viscous dark brown syrup by-product of sugarcane refining, has been tested as a partial asphalt binder substitute in many studies (Mose & Ponnurangam., 2019).

This research explored the possibility of Spent Molasses Concentration (SMC) as a partial asphalt binder replacement via comprehensive experimental testing. In this study, the molasses used as a material was sourced from Fermwaste Sdn Bhd, a company located in Perlis, Malaysia. Fermwaste Sdn Bhd specializes in the production and supply of molasses, which is a by-product of the sugar industry. Molasses is obtained from the extraction process of sugar from sugarcane or sugar beets.

2.MATERIAL AND METHODS

To achieve the objectives of this research, the raw materials used in this research are sugarcane molasses (SM) as Spent Molasses Concentration (SMC). This research focused on the mechanism of bio asphalt using SMC as a partial replacement of bitumen for hot mix asphalt mixture is to investigate and understand the effects and benefits of incorporating SMC into traditional bitumen-based asphalt.

The first phase of this research was to obtain the optimum bitumen content (OBC) mixture with partial replacement bitumen which is SMC. The percentage of SMC used in this research was 10% of SMC to find OBC using different ratio of bitumen, 4%, 4.5%, 5%, 5.5% and 6%. The type of aggregate of used was limestone with grading size AC14 for wearing course mixture (Le, 2021a). Bitumen and SMC was mixed together. According to ASTM D1559-12, the Marshall Test starts with asphalt mixture preparation. Based on mix design, aggregate, asphalt binder, and other additives or fillers are mixed in certain amounts (Ogundipe, 2019). To ensure binder and aggregate dispersion, the mixture is carefully mixed. Marshall Compactors compress cylindrical specimens from the produced mixture. Compaction includes pouring a certain quantity of mixture in a mold and using a hammer or mechanical compactor to compress it (Hareru & Gherab, 2020). Test procedure criteria determine blows and compaction pressure. After compaction, specimens are taken from the mold and cooled to room temperature. After 24 hours, the sample was soaked in water bath for 45 minutes. The last steps, the testing of Marshall Sample was test and record the data showed up. The data and calculation was carried out to obtain a graph for stability (kN), Void Filled Bitumen, VFB (%), Void Total Mix, VTM (%), flow (mm) and stiffness (%) according to the American Society for Testing and Materials (ASTM, 2015) and JKR Road Work Specification 2008 (JKR, 2008).

3. RESULT AND DISCUSSION

3.1 Penetration Test

The bitumen grade 60/70 was used for 0% (control sample) and 10% addition of spent molasses concentration (SMC) as partial replacement in bitumen. Figure 1 shows the effect of addition of SMC on penetration.

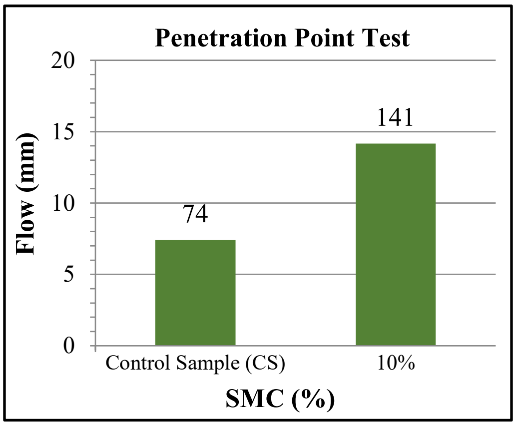

Figure 1. Penetration for 0% (control sample), and 10% of SMC.

According to the illustration, the expansion of 10% had an impact on the increase from 74mm (control sample) to 141mm (10%). Based on this perspective, it can be predicted that the material will exhibit a further increase in entrance value as the SMC rate continues to increase. As a result, the increase in the molasses content leads to an expansion in the infiltration capacity of the asphalt cover, indicating a decrease in the hardness qualities of the folio and rendering it more susceptible to damage.

3.2 Softening Point

Figure 2 shows the softening point values for the control sample and addition of SMC as partial replacement in bitumen. The values show in 10% of SMC for temperature if softening point test.

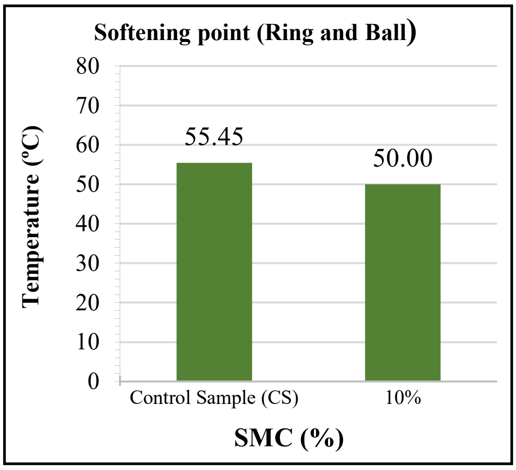

Figure 2. Softening point for 0% (control sample), and 10% of SMC.

Based on the data shown in Figure 2, it is evident that the inclusion of SMC results in a reduced level of variability in the softening point of the asphalt binder. The figure illustrates a noticeable decrease in the softening temperature as the proportion of SMC increases at 10% compared to control sample. The decline in the softening point has an adverse impact on the characteristics of asphalt binder. The observed enhancements in the softening point are indicative of improved resistance to rutting at higher temperatures [12].

3.3 Marshall Test

The Marshall Test measures asphalt mixture stability and flow at various temperatures. This test helps design and quality control asphalt pavements by revealing asphalt mixture behavior under different situations. Three samples were prepared for control sample and 10% of addition of SMC as a partial replacement in bitumen. Table 1 shows the correlation parameter of testing result binder asphalt and the use of spent molasses concentration (SMC) compared to standard Jabatan Kerja Raya (JKR) 2008.

Table 1 The correlation parameter of testing result binder asphalt and the use of spent molasses concentration (SMC) compared to standard Jabatan Kerja Raya (JKR) 2008

Parameter	JKR Standard	Control Sample (CS)	Requirement	10%	Requirement
Stability (kN)	**> 8000N**	11850	Accepted	12850	Accepted
VFB (%)	**70 - 80%**	74.10	Accepted	70.93	Accepted
VTM (%)	**3.0 - 5.0%**	3.10	Accepted	3.66	Accepted
Flow (mm)	**2.0 - 4.0 mm**	3.92	Accepted	4.85	Not Accepted
Stiffness (%)	**> 2000N/mm**	2680	Accepted	2300	Accepted

According to Table 1, stability is the highest load that would cause the specimen to fail when applied at a steady pace of 50 mm/min with a rise in bitumen content. From the control sample, stability increases by 8.44% to 10% of SMC. Because the binder fills in the gaps in the mineral aggregate, this pattern is seen. Then, void filled bitumen (VFB) is the percentage of the volume in the mineral aggregate that is bitumen-filled. As the binder content drops from the control sample by 4.28% using 10% of SMC, it is still within the permitted range of 70–80% according to standard JKR 2008. In general, when 10% of SMC was partially replaced with bitumen, void Total Mix (VTM) increased. The compaction affects the VTM. Increased compaction minimizes voids in the whole mixture. Due to an improper binding, 4.85 mm is the maximum flow value at 10% SMC. The permissible flow standard in the binder ranges from 2-4 mm, as shown in Table 1. According to the observation, when 10% of the bitumen is replaced with SMC, the flow value increases because the 10% SMC decreases the ductility of the binder. Lastly, the resistance against rutting failure and persistent deformation was shown by the stiffness. The stiffness is reduced when 10% of SMC is added to the mixture. Increased stiffness prevents rutting and indicates that the combination can support a greater weight without deforming.

4. CONCLUSION

This study examined bitumen with 10% wasted molasses concentration (SMC) using softening points and penetration tests. Another purpose is to test Hot Mix Asphalt using an SMC in the Marshall Method to measure stability, flow, stiffness, voids total mix and void in an aggregate filled with a binder. Based on this research, after completing the penetration test and softness test, SMC in bitumen makes penetration softer and more elastic, while softening point tests meet JKR Standard requirements. Thus, further tests with different SMC percentage must determine whether it meets JKR requirements. Based on the Marshall Test, stability, flow, stiffness, VTM, and VFB were acquired and met the JKR Standard. The performance of Hot Mix Asphalt with a spent molasses concentration (SMC) of 10% needs more testing and a various percentage of SMC.

REFERENCES

[1] Sun, D.; Sun, G.; Du, Y.; Zhu, X.; Lu, T.; Pang, Q.; Shi, S.; Dai, Z. Evaluation of Optimized Bio-Asphalt Containing High Content Waste Cooking Oil Residues. *Fuel* 2017, 202, 529–540.

[2] Dong, Z.; Yang, C.; Luan, H.; Zhou, T.; Wang, P. Chemical Characteristics of Bio-Asphalt and Its Rheological Properties after CR/SBS Composite Modification. *Constr. Build. Mater*. 2019, 200, 46–54.

[3] Gao, J.; Wang, H.; You, Z.; Hasan, M. R. M.; Lei, Y.; Irfan, M. Rheological Behavior and Sensitivity of Wood-Derived Bio-Oil Modified Asphalt Binders. *Appl. Sci*. 2018, 8, 919.

[4] Bahadori, A.; Li, R.; Zhang, K.; Xin, J.; Muhunthan, B.; Zhang, J. Performance Evaluation of Hot Mix Biobinder. In Airfield and Highway Pavements; American Society of Civil Engineers: Reston, VA, USA, 2019; pp. 255–265.

[5] Zhang, R.; You, Z.; Wang, H.; Chen, X.; Si, C.; Peng, C. Using Bio-Based Rejuvenator Derived fromWaste Wood to Recycle Old Asphalt. *Constr. Build. Mater*. 2018, 189, 568–575.

[6] Abdulahi, T. Partial Replacement of Asphalt Bitumen with Sugarcane Molasses. Master's Thesis, Addis Ababa Institute of Technology, Addis Ababa, Ethiopia, 2017.

[7] Mose, G. Y.; Ponnurangam, P. Investigating the Effect of Cane Molasses on the Performance of Base Bitumen. *Int. J. Res. Innov. Appl. Sci*. 2019, III, 54–58.

[8] Le, T. H. (2021a). Effects of Sugarcane with Molasses (SWM) on the Rheological Properties of Asphalt Binder. *Journal of Materials in Civil Engineering*, 33(1), 04020213. doi: 10.1061/(ASCE)MT.1943-5533.0003682.

[9] Ogundipe, O. M. (2019). The Use of Polyethylene Terephthalate Waste for Modifying Asphalt Concrete Using the Marshall Test. *Slovak Journal of Civil Engineering*, 27(2), 9–15. https://doi.org/10.2478/sjce-2019-0010.

[10] Hareru, S. A., & Ghebrab, A. A. (2020). Utilization of molasses as a partial replacement of bitumen in asphalt mixtures. *International Journal of Innovative Technology and Exploring Engineering*, 9(2), 2974-2978.

[11] ASTM D6927-15, Standard Test Method for Marshall Stability and Flow of Asphalt Mixtures, ASTM International, West Conshohocken, PA, 2015, www.astm.org, DOI: 10.1520/D6927-15.

[12] JKR. (2008). JKR/SPJ/2008-S4 Standard Specification for Road Works Part4 Flexible Pavement. 1–187.