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Volumetric Properties and Abrasion Resistance of Stone Mastic Asphalt Incorporating Eggshell Powder

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Abstract. Stone Mastic Asphalt (SMA) is designed to improve durability and life span of road pavement through the use of a stable stone-on-stone skeleton held together by a rich mixture of asphalt. However, over time the structure is subjected to damage from cracking, rutting, stripping and rapid aging under the effects of repeated vehicle loading, hot climates and heavy rainfall. Previous studies proved that eggshell is capable to enhance the strength and durability of concrete. Thus, the aim of this study is to evaluate the performance of these stone mastic asphalt mixtures with the eggshell powder and overcome the issue that is related to SMA. A mixture contains varying percentages of eggshell powder were assessed to check which samples gives the best performance as per the requirement by using laboratory tests which are LA Abrasion and volumetric properties. Results indicated that eggshell powder can effectively recover and enhance abrasion resistance of asphalt and increases the marshal stability of SMA. SMA mixtures modified with eggshell powder produce the performance enhancement of SMA as a road surfacing material. It is concluded that the asphalt mixtures containing eggshell powder could be increases the stability and strength of the mix.

1. Introduction

Stone mastic asphalt (SMA) mixtures were developed in Germany with the main purpose of resisting high loads from heavy traffic and nailed tires providing a good macro texture [1]. Due to their excellent permanent deformation resistance, several countries are applying these solutions in their road pavements. It is used in many countries around the world as a hardwearing material for use on heavily trafficked roads. SMA is one of the suitable materials for pavement design to be implemented in heavily trafficked roads due to the outstanding performance on the pavement structure. Stone mastic asphalt is a gap graded hot mix asphalt with more than 65% of course aggregates. Stone mastic asphalt are the mixing of the aggregates with polymer modified binder. The stone skeleton, with its high internal friction, gives excellent shear resistance. The aggregates, in fact, have a high angularity that improves interlocking, packing and stone-on-stone contact between grains [2]. In general, the asphalt



binder is mixed with the aggregate at desired temperature to fully coated aggregate and binder and prepare for suitable for paving. This reduced viscosity allows the aggregate to be fully coated at a lower temperature than what is traditionally required in HMA production [3]. However, when the temperature is lower, the asphalt tends to lose its adhesive bond with the aggregate. These will contribute to the combined weakening of the mastic and weakening of the aggregate mastic bond. According to [4], the eco-friendly bitumen produced with waste materials (waste engine oil, waste polyethylene and crumb rubber) show low thermal susceptibility, upraised values of high temperature performance grade and also low non-recoverable creep compliance values. When used in the production of SMA mixtures, that bitumen modified with waste materials revealed to be excellent solutions for road paving works due to their good mechanical and surface performance without affecting the environment or the human health. Various studies have been conducted to identify the new materials that can be used as modifiers of bitumen in hot mix asphalt concrete. Modification in the mixture is one approach that can be taken to improve the performance of the pavement. The eggshell powder is an alternative to enhance the properties of conventional asphalt binders in the asphalt mixture. Thus, by using eggshells as a modifier, sustainable performance can be improved. Performance of the mixture specified by obtaining the optimum bitumen content (OBC) and optimal eggshell content (OESC) [5,7]. According to [6], the use of alternative materials such as fly ash and eggshell will definitely be environmentally beneficial and these materials not only can improve the asphalt binder properties and durability, but also have a potential to be cost-effective and save the environment. This research study is done to identify the characteristic and the performance of stone mastic asphalt incorporating eggshell powder. This research might provide ways of optimising the eggshell powder performance in asphalt pavement

2. Materials and method

2.1. Materials

For this study, penetration grade 60/70 bitumen was used to prepare SMA20 mixtures. Then, the eggshell used was 0% to 6% with the increment of 2% by weight of mixture. Table 1 and Table 2 show the properties of aggregate and bitumen used in this study. All materials fulfil the requirement stated by Malaysian Public Work Department for Roadworks [8]. Optimum binder content used are adopted by a study [9].

Table 1. Aggregate Gradation for SMA20

Sieve Size (mm)	Passing (%)	Retained (%)	Retained (G)
19	100	0	0
12.5	85 – 95	10	120
9.5	65 - 75	20	240
4.75	20 – 28	46	552
2.36	16 – 24	4	48
0.6	12-16	6	72
0.3	12-15	0.5	6
0.075	8-10	4.5	54
Pan	0	7	84
OPC	0	2	24
Total			1200

Table 2. Physical Properties of Aggregate and Bitumen

Description	Results	Specification	Status
LAHV	21.28%	<25%	Pass
AIV	14.64%	<30%	Strong
ACV	11.96%	<25%	Pass
Penetration	63.33mm	60mm to 70mm	Pass
Softening Point	49°C	48°C to 52°C	Pass

Eggshell Powder used is obtained from Concrete Pharmacy company at Selangor, Malaysia. The size of eggshell powder used was in micro size. Figure 1 shows the eggshell powder while Table 3 shows the chemical properties of eggshell powder.

**Figure 1.** Eggshell Powder**Table 3.** Chemical Properties of Eggshell Powder.

Description	Composition (%)
Calcium Oxide	62.35%
Sulphur Trioxide	1.32%
Iron Oxide	0.63%
Silicon Dioxide	0.61%
Magnesium Oxide	0.36%
Potassium Oxide	0.22%
Aluminum Oxide	0.07%

2.2. Sample preparation

The bituminous mixture was prepared by using SMA graded aggregates with 60/70 penetration grade bitumen with the eggshell powder. The crush aggregate granites have been dried and sieved into a selected size range with nominal size of aggregates. The dry blending method has been used in this research which the eggshell was added to the mixture before the binder and the optimum binder content for this research was 6.2% by weight of the mix, where this comes from the past research. All specimen was prepared using Marshall Compactor machine to have the identity samples. The number of compactions for each of the samples are 50 blows at the top and the bottom side of the specimen. The temperature used for all specimens were controlled in the range of 160°C to 180°C.

2.3. Abrasion test

Abrasion resistance use to indicate aggregates toughness and to obtain the Los Angeles number in the form of percentage wear of aggregates which reflects their resistance to degradation using Los Angeles testing machine. Figure 2 show the abrasion machine.



Figure 2. Los Angeles Abrasion Machine

2.4. Volumetric properties

Marshall Stability test used to measure the resistance to plastic flow of cylindrical specimens of an asphalt paving mixture loaded on the lateral surface by means of the Marshall Apparatus. Two main parameters obtained from this test which are stability & flow values. Then, 6 graphs were plotted to indicate the volumetric properties of asphalt mixture [10]. Those parameters are stability, flow, void in total mix, void filled with bitumen, density and stiffness

3. Results and discussion

3.1. Abrasion test

As shown in Figure 3, the abrasion loss value for control sample (0% eggshell powder content) is slightly higher than modified sample (2% of eggshell powder content) of stone mastic asphalt after 300 revolutions. We can see small different between the modified and unmodified samples. From the graph below, we can conclude that eggshell powder content of 2% is much lower from others samples, therefore 2% eggshell powder content is the most effective eggshell powder content for Los Angeles Abrasion Test. The eggshell powder helps to increase the strength of SMA, thus improving the performance of the SMA Besides, the average of loss of mass is less than 15% which is good according to the JKR specification.



Figure 3. Abrasion values

3.2. Volumetric properties

3.2.1. Stability

Figure 4 shows the stability and density values for SMA20 asphalt mixture with 0% to 6% eggshell powder. From the graph, maximum value of stability and density are obtained at 6% eggshell powder. It was a clear trend for both parameters, where the stability and density increase with the increment of

eggshell powder. It is indicated that higher stability and density contribute to more resistant towards deformation [11, 12, 17]. At 6% eggshell modified SMA, maximum stability is reaching 1000 N with maximum density of 2.23 g/mm³, compared to stability of 500 N and density of 2.22 for 0% eggshell modified SMA. The increment is about 50% for stability and 2% for density. However, the addition of more than 6% eggshell powder is not evaluated in this study, where the possibility to obtain higher values for both parameters are possible according to the graph trend. There is a clear indication that the use eggshell powder in SMA mixture was more effective in enhancing stability and density.

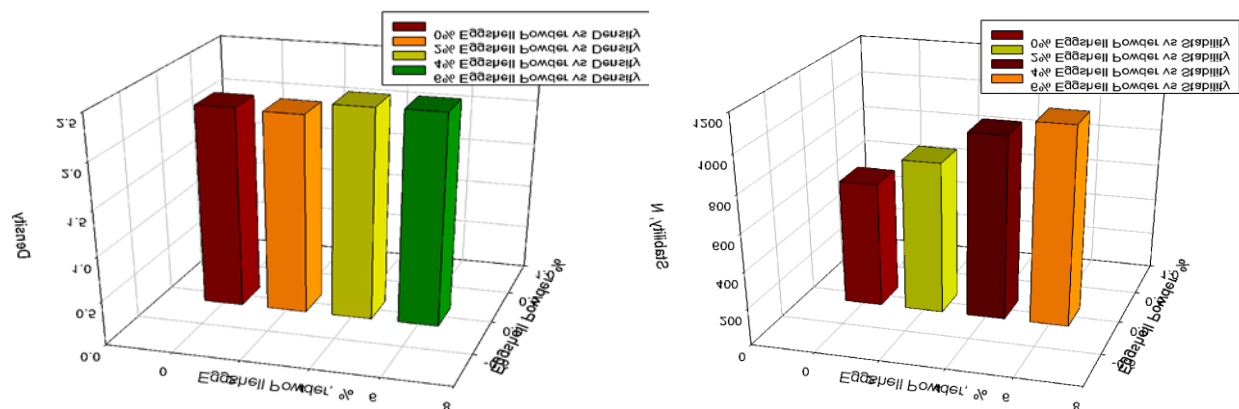


Figure 4. Stability (left) and density (right)

3.2.2. Flow

The flow performance of asphalt mix at different percentage of eggshell is illustrated in Figure 5. The modified SMA20 mixture produced inconsistent flow value when adding eggshell, where the flow values are in the range of approximately 2.5 mm to 6 mm. According to Malaysian Public Work Department Roadworks specification [8], the flow values for the purpose of surfacing and pavement under heavy traffic category should be in the range from 3 mm to 5 mm. Thus, only the flow at 6% Eggshell modified SMA that did not fulfil the requirement. It could be seen from the graph; flow is consistent from 0% to 4% eggshell. However, it increases rapidly at 6% eggshell. It shows that the usage of more than 6% eggshell powder does not provides better resistance towards deformation for SMA mixture.

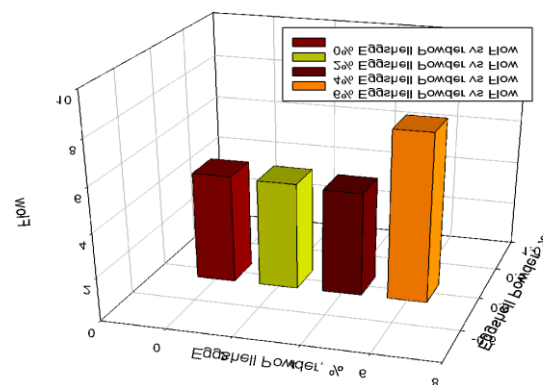


Figure 5. Flow

3.2.3. Stiffness

Figure 6 illustrate the stiffness value of the SMA mixture with different amount of eggshell powder content. Theoretically, higher stiffness of asphalt mixture will give better resistance and durability [11,

12]. Flexible pavement surface distresses such as ravelling and bleeding will decrease significantly for stiffer asphalt mixture. From the graphs, it shows that the addition of 4% eggshell powder provides the highest stiffness of SMA mixture. The value of stiffness at 4% eggshell powder is about 1500 N/mm, compared to only 950 N/mm for control specimen. It indicates that the addition of eggshell powder improved the stiffness characteristic of asphalt mixture by almost 40%. However, the usage of 6% eggshell reduce the stiffness value of SMA. The result is consistent with a study by [13, 14, 17].

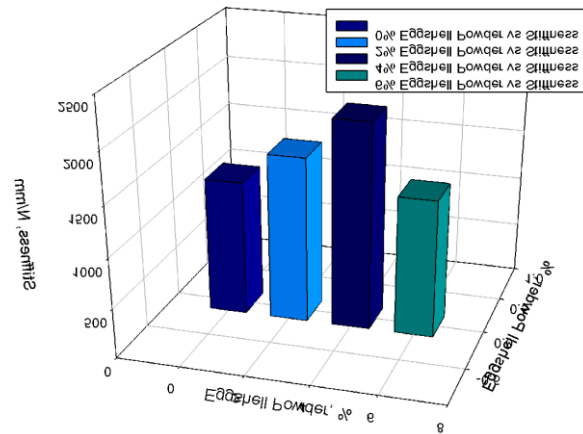


Figure 6. Stiffness

3.2.4. Voids

Figure 7 presents the void in total mix (VTM) and void filled with bitumen (VFB) for different eggshell powder contents. It shows that void in mix is reduced with the addition of eggshell and increases in terms of void filled with bitumen. It shows that the eggshell is disperse well in bitumen and bond well with the aggregate in the asphalt mixture [15]. From the graph, the VTM reduced drastically with the increment of eggshell and increased significantly for VFB. These trends indicate that the existence of eggshell powder is significantly reduce the negative impact that is related to air void in asphalt mixture.

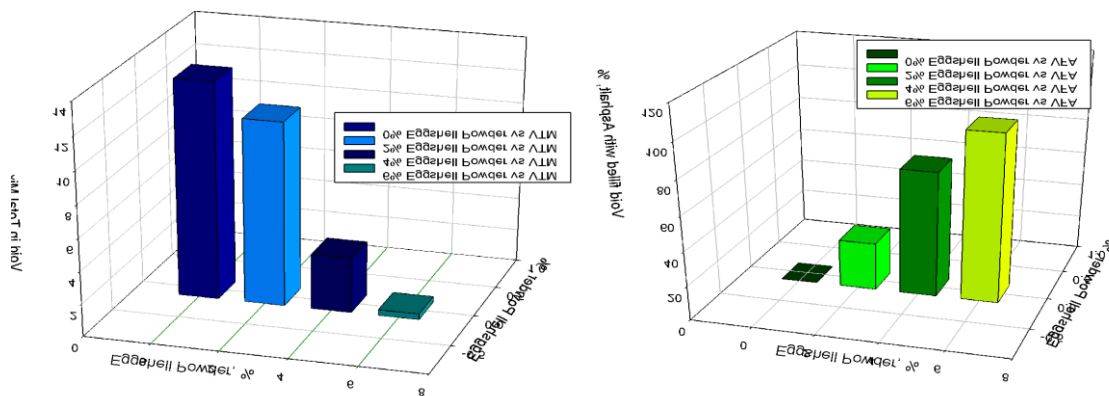


Figure 7. VTM (left) and VFB (right)

4. Conclusions

This study experimentally investigated the performance of stone mastic asphalt incorporating eggshell powder with different percentage of eggshell content on abrasion resistance and volumetric properties of stone mastic asphalt mixture. Based on the results, the following conclusions can be drawn:

Eggshell powder can effectively recover and enhance abrasion resistance of asphalt. With the addition of eggshell powder in stone mastic asphalt mix, the volumetric properties of stone mastic asphalt are significantly increased

5. References

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