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Laboratory Evaluation of Cold Mix Asphalt Materials for Road Rehabilitation Work

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Abstract: An increase in road accidents rate as a result of insufficient maintenance operations of road pavement and environmental issues has becoming a major concern in Malaysia's asphalt industry. Pavement failure such as potholes, shear failure cracking and alligator cracking require immediate attention to overcome for safety and comfort of road users. Cold mix asphalt is commonly used for temporary patching in road rehabilitation works as it is efficient, time saving, and economical for pavement maintenance. Thus, this study focused on the assessment of the performance of three commercially available cold mix asphalt products in Malaysia. The patching materials chosen were A Cold Premix, Viking Easlylay Cold Tarmix and Advanced Patchmix. The laboratory tests included to evaluate the properties using Sieve Analysis, Specific Gravity and Water Absorption along with the performance evaluation using Marshall Stability and Flow Test accordance to ASTM D1559. Viking Easlylay Cold Tarmix ranked first as the highest score of conformity with the specification requirements based on the ranking performance criteria of three different cold mix patching materials. The result obtained for average stability from specimens of Viking Easylay Cold Tarmix is 13.871 kN, A Cold Premix is 11.334 kN, and Advanced Patchmix is 10.843kN. Therefore, it is recommended that Viking Easlylay Cold Tarmix are the most ideal cold mix materials to be used in patching maintenance work.

Keywords: Road Rehabilitation, Pavement Failure, Cold Mix Asphalt, Temporary Patching

1. Introduction

Pavement distress is a major issue that occur for the global concern to be regulate for maintenance before it bring harms to road users by inconvenient environment and fatal accidents. Pothole is a common type of damage in asphalt pavement [1]. The causes of potholes and damage to roads in the

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country are due to the failure to comply road specification during construction [2]. Pothole distress considerably degrades pavement performance and affects safety and driving quality. Therefore, distress on road pavement must be overcome to minimize further pavement damage and reduce the opportunity for potential accidents. However, pavement resurfacing is expensive, longer time consuming and requires considerable human resources [3]. It is also contributing to the problem by emitting greenhouse gases. CMA technology has proven the measure concern for temporary road patching in road rehabilitation works. CMA concretes consist of bituminous binder, either cutback or emulsion, and aggregates that have not been heated [4]. Manufacturing temperature for CMA is between 0℃ to 40℃ [5]. CMA materials can be easily and swiftly prepared for repairing potholes on a pavement surface. Moreover, the construction and compaction of CMA patching material can be conducted at ambient temperatures and directly open for traffic which considerably reduces energy requirements which considerably reduces energy requirements [4]. Therefore, CMA materials are efficient, time saving, and economical for pavement maintenance [6]. In pavement industry, CMA materials are sold by various types of brand and price. The performances of the materials are different by each brand. However, CMA has its drawbacks such as high moisture susceptibility [5] and has low initial strength and cohesion [7].

Several studies have investigated the performance of the CMA materials using Marshall Stability with different indicators. Shou and Zhou [8] mentioned Marshall specimens of cold mix epoxy asphalt mixture were examined for stability at various temperatures and curing durations. The test findings demonstrate that the mixture cures quickly at normal temperature, and that the curing rate increases as the temperature rise. The cold mix epoxy asphalt mixture was also evaluated, the best asphalt aggregate ratio was calculated, and the material strength change law was investigated. Five samples are chosen for Marshall testing to identify the best asphalt aggregate ratio, according to the design of the asphalt aggregate ratio. The Marshall stability test value after curing is 90.1kN, and the flow value is 39.3, both of which fulfill the criteria of technical indices, based on the concept of the best oil stone ratio. Dash and Panda [9] indicated Marshall and gyratory methods were used to generate dense and gap graded CMA with varied levels of compaction. Variations in filler materials such as cement, lime, and fly-ash were also used to assess CMA properties. The results shows 2% of additives helps to increase the Marshall stability of CMA up to 40% to 150%. Higher levels of compaction should be avoided in both Marshall and gyratory compaction since they can cause cold mix degradation and workability loss, making field applications more challenging. Al-Ihekwaba E. [10] reported Marshall Stability and Resilient Modulus were used to evaluate CMA with bitumen content of 4% to 8% by 1% incremental along with limestone replacement of 10% incremental. As a result, maximum bitumen content was at a stability of 9.5kN and all the limestone replacement have a lower tensile strength and stability than the control mix. Finally, the maximum resilient modulus was at 40% of limestone replacement.

Accordingly, in this study, Marshall Stability and Flow was conducted to evaluate CMA performance on three different selected ready-to-use CMA materials. The properties were characterize by sieve analysis, specific gravity and water absorption. Figure 1 shows the flow chart of the study.

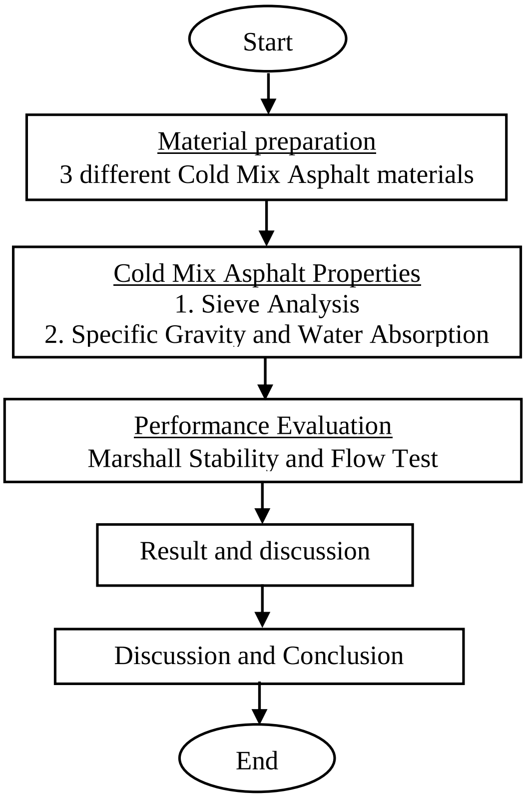

Figure 1: The outline of the methodology

2. Materials and Methods

2.1 Materials

Three selected ready-to-use materials of CMA that available in Malaysia's asphalt industry were studied. The selected materials were Cold-Premix, Advanced Patch Mix, and Viking Easylay Cold Tarmix. The main components of CMA are aggregates and binding material such as cutback and emulsion. Table 1 shows the properties of each CMA patching material. A Cold Premix with 4.9% penetration grade bitumen consisted of unheated 10mm granite, special formulated emulsified asphalt and additive. Meanwhile, Advanced Patchmix were using 9.5mm granite aggregate and 5.18% penetration grade bitumen. The grade of the bitumen utilized in this study was 60/70 for A Cold Premix and Advanced Patchmix. Both of the materials using 60/70 of penetration grade bitumen. Viking Easylay Cold Tarmix provided 7mm graded chipping bituminous pre-mix with penetration grade bitumen of 80/100 and optimum binder content of 6.0% from the weight of mix. The materials were prepared separately to be test in terms of strength in few core specimens.

Table 1: Properties for selected CMA materials

CMA	A Cold Premix	Viking Easylay Cold Tarmix	Advanced Patchmix
Asphalt content (%)	4.92	6.00	5.18
Penetration Grade Bitumen	60/70	80/100	60/70

2.2 Preparation of samples

In this study, there are 9 specimens which 3 specimens from A Cold Premix, 3 specimens from Viking Easylay Cold Tarmix and another 3 specimens from Advanced Patchmix. Preparation of laboratory specimens for Marshall Stability Test were accordance to ASTM D 1559 [11] using the 75 blows/face compaction standard. CMA mixture were poured into the mould within 1200g then were compacted by automatic Marshall Compactor Machine as shown in Figure 2.

Figure 2: Marshall Compactor Machine

The weight of mixed aggregates were taken for the preparation of specimens with thickness of 63.5 ± 3 mm. The specimens were extracted from the mould by pushing it out with the extractor after being compacted both sides of face. The sample left to be hardened before weighed it. In Figure 3, the specimens have been compacted and the dimension were recorded. Then, the specimens were left in water bath at 60℃ for 30 to 40 minutes before tested.

Figure 3: Cold Mix Asphalt specimens

2.3 Specific Gravity and Water Absorption

Specific gravity and water absorption which conducted in compliance standard of ASTM D2726 [12]. SSD method is designed for compacted mixture specimens with a water absorption of less than or equal to 2.0 % of the total weight. Weight of dry specimens, W1 were taken before submerged in water as shown in Figure 3.5. Then, the weight of the specimens in water, W3 were recorded. Lastly, the wet specimens wiped with damped towel and the weight, W2 were taken again. The theoretical maximum specific gravity, Gmm is depend on the aggregate specific gravity and asphalt binder content. Typically, theoretical maximum specific gravity results ranged from 2.400 to 2.700. A value outside of this typical range could be caused by unusually light or heavy aggregates. G_{mm} can be calculated using Eq 1.

$$Gmm = \frac{100}{a/Sg(a) - \mathrm{b}/\mathrm{Sg(b)}} \quad Eq. 1$$

where, a and b is the percentage bitumen by weight of aggregate and percentage bitumen by weight of mix respectively. While, Sg (a) known as specific gravity of aggregate and Sg (b) known as specific gravity of bitumen.

Bulk specific gravity, Gmb is the ratio of the weight of aggregate in air to the weight of equal volume of water displaced by saturated surface dry aggregate. Each specimen's bulk specific gravity was calculated in accordance with ASTM D 2726. Therefore bulk specific gravity for all samples under test were be calculated using the Eq 2.

$$\mathrm{G_{mb}} = \frac{W1}{W2 - \mathrm{w3}} \quad (Eq. 2)$$

where, W1 is the weight of dry sample, W2 is the weight of saturated surface dry sample and W3 is the weight of sample in water. The determination percentage of water absorption the specimen were expressed using the Eq 3.

$$\text{Absorption (\%)} = \frac{Saturated\ Surface\ Dry\ (SSD) - In\ Air}{In\ Air}\ X\ 100 \quad (Eq. 3)$$

2.4 Marshall Stability and Flow

Marshall stability test was performed in accordance with ASTM D6927. Marshall Stability and Flow Test was conducted to get to the maximum load that can be sustained by the designed samples and also records the potential of flow of a cylindrical sample during loading applied on a lateral surface with loading rate of 50.8 mm/min. The samples were cured in water bath for 30 to 40minutes at 60℃. Then, the samples were load in the Universal Compression Frame Marshall Test Machine as shown in Figure 4 to obtain value of stability and flow that automatically appeared on the screen as the maximum load obtained at the point of failure.

Figure 4: Universal Compression Frame Marshall Test Machine (UTM)

3. Results and Discussion

3.1 Specific Gravity and Water Absorption

The result of specific gravity and water absorption for specimens is shown in Table 2. However, only specimens from Viking Easylay Cold Tarmix that fulfil the specification of water absorption within less than 2%. Advanced Patchmix contained highest percentage of water absorption. As most of specimens were absorptive, the internal voids were wetted and affected to the strength of specimens.

Table 2: Results of specific gravity and water absorption

CMA	Absorption (%)	Bulk Specific Gravity	Maximum Specific Gravity
A Cold Premix	2.78	2.190	2.431
Viking Easylay Cold Tarmix	0.17	2.139	2.387
Advanced Patchmix	3.19	2.257	2.472

3.2 Marshall Stability Test

Figure 5 displays the Marshall Stability results and Figure 6 represents the results of flow against to CMA materials. The result above shows that Viking Easylay Cold Tarmix yielded the highest Marshall stability with value of 13.871 kN compared whereas Advanced Patchmix exhibited the lowest Marshall stability by 10.843 kN. Meanwhile, for A Cold Premix the stability is 11.334kN. The results are consistent with the Marshall stability to the value of flow. The value of flow is within the specification of 2 mm to 4 mm. The flow values for the asphalt concrete A Cold Premix, Viking Easylay Cold Tarmix and Advanced Patchmix are 3.26mm, 3.97mm and 3.23mm respectively. High asphalt flow may distorted the shape of sample. Somehow, low flow implies to the asphalt proves that the sample have high voids causing it to crack early due to its fragility over the pavement's lifetime.

To relate the performance evaluation results with properties of CMA materials, the proportion size of coarse aggregate played important roles to bond the specimen together. Viking Easylay Cold Tarmix have smallest size of coarse aggregate which correlated to contact surface for the bonding of sample. The presence of water in the sample as shown in water absorption can minimize strength and durability. Advance Patchmix absorbs highest water volume compared to other CMA materials.

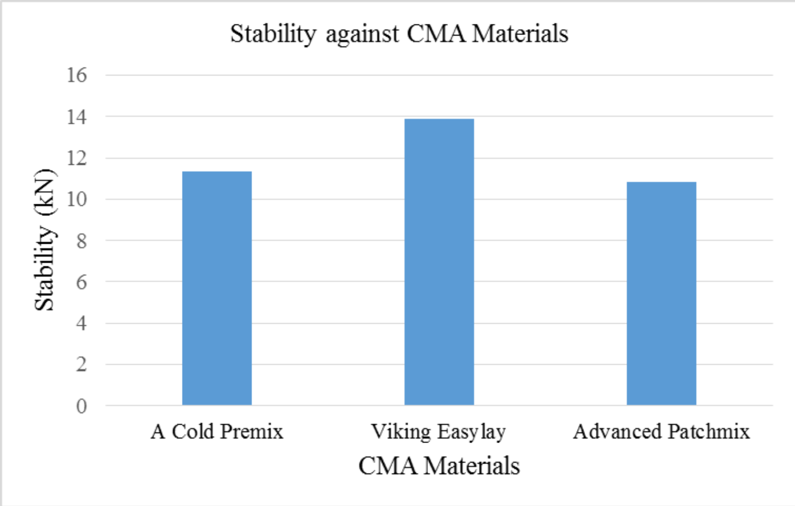

Figure 5: Results of stability against CMA materials

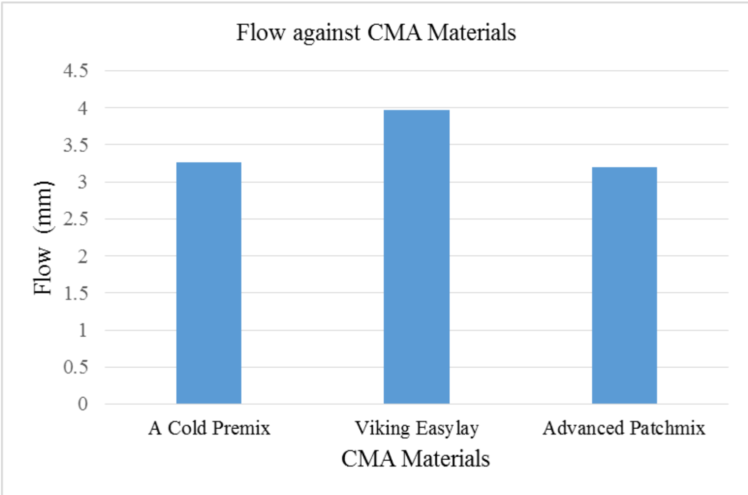

Figure 6: Results of flow against CMA materials

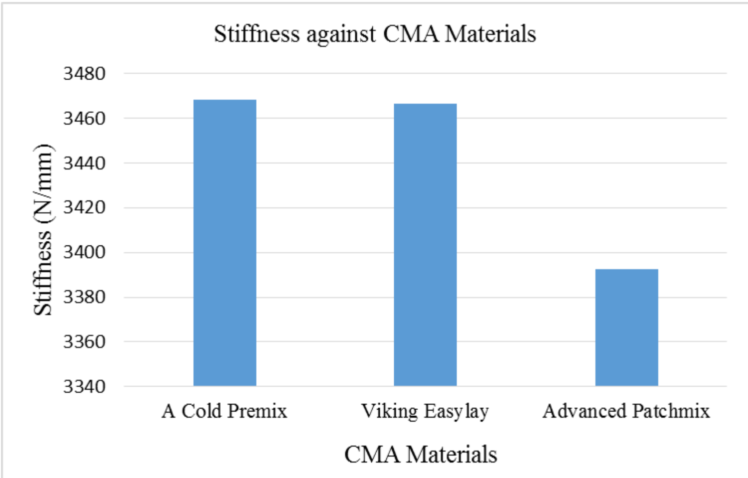

Figure 7: Results of stiffness against CMA materials

The results of stiffness in Figure 7 shows the highest stiffness contained by Viking Easylay Cold Tarmix. At odds, Advanced Patchmix had the lowest stiffness which can leads to a persistent deformation to the materials. In spite of that, all CMA materials complied to the specification by exceeding 2000 N/mm. Table 3 show Marshall Stability and Flow test result that compare with specification. Result that obtained from testing was comply with the specification required.

Table 3: Results of Marshall Stability and Flow

CMA	Stability (N)	Flow (mm)	Stiffness (N/mm)
A Cold Premix	13871	3.26	3468.2
Viking Easylay Cold Tarmix	11334	3.97	3466.3
Advanced Patchmix	10843	3.20	3392.4

4. Conclusion

From the overall study, the performance and physical properties of three commercially purchased CMA materials were assessed by laboratory test. The result of the laboratory tests indicates that the gradation for all the specimen were within the aggregate gradation requirements for the AC10 mix as per JKR Malaysia's specification. In addition, the performance of CMA in terms of Marshall Stability and Flow, Viking Easylay Cold Tarmix specimen obtained the highest score of compliance with the requirements of the specification. Therefore, it is suggested that Viking Easylay Cold Tarmix specimen are the most suitable cold mix materials to be used in patching maintenance work. To sum up, objectives for this study have been achieved. From this study, the comparison of results between three different CMA materials properties and performance assist the pavement industry to find the ideal CMA at it maximum strength. The following recommendations that can be derived from the conclusion:

(i) Considering CMA as the indicator is at its weakest state right after placement, moisture is the weakness to its strength. Therefore, more research on CMA is required to emphasize the correlation of indicator proposed to moisture damage using Indirect Tensile Strength Test.

(ii) With the aim to improve CMA performance, additives such as cement, lime, fly ash, fibers, and chemical additives are all commonly utilized. There are two phase to add additive suggested which is during production of CMA (dry method) and combine with emulsion at manufacture process (wet method).

(iii) Chemical additives such as polyvinyl acetate also can be applied to improve the properties of CMA which were indicated by increases Marshall Stability and Indirect Tensile Strength values.

(iv) CMA should be improves for long term performance in order to utilise large scale of rehabilitation work.

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