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A Laboratory Study on Open and Dense Graded Cold Asphalt Emulsion Mixtures for Surface Courses

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A Laboratory Study on Open and Dense Graded Cold Asphalt Emulsion Mixtures for Surface Courses

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Abstract. Cold Asphalt Emulsion Mixture (CAEM) is considered as an eco-friendly asphalt mixture because it eliminates the emission. It is produced at ambient temperatures and reducing the requirement to heat aggregates and bitumen prior to mixing process, so it is good for energy saving in pavement construction. In application, there are two type gradations of aggregate for cold asphalt mixture, dense gradation and open gradation. A series of laboratory works were conducted to analyse the performance of dense and open graded cold mixture for surface courses, which is the main objective of this study. Marshall Samples were kept indoor at room temperature for 7 days prior to Marshall Test to obtain the effect of curing process for cold mixtures. All samples were tested using Marshall Tests for stability and flow. The results show that dense graded mixtures need less bitumen content than open graded mixtures. For cured samples, dense graded mixtures produces higher Marshall Stability than open grades mixtures, while uncured samples have almost the same Marshall stability value for both gradations. For open graded mixtures, curing process reduce the porosity of mixtures.

1. Introduction

Cold asphalt emulsion mixture (CAEM) has the potential to be applied as a surface course. Considering the importance of infrastructure development in Indonesia, especially on road infrastructure project, CAEM is a good alternative of asphalt mixture application in some remote areas. CAEM is a mixture of aggregates, water, and bitumen emulsion. Unlike hot asphalt mixture, CAEM is produced at ambient temperatures and reducing the requirement to heat aggregates and bitumen prior to mixing process, so it is good for energy saving in pavement construction and also eliminates the emission.

CAEM is considered as an eco-friendly, energy efficient, low risk level, and saving time asphalt mixture. CAEM also have some limitations. This mixture are suitable for light to medium traffics due to the lower stability or strength than hot asphalt mixture [1]. It has also weak early life strength, thus curing is one of the most important requirement for cold asphalt mixture.

In Indonesia, some cities have already implemented CAEM such as Jember, Tulungagung [2], Wonosobo, Purwodadi [3], Sukabumi, and Tasikmalaya [4]. CAEM are designed for optimum performance considering the purpose of mixes, in this study is for surface courses, and climate of the construction area. The main objective of this study is to analyse the performance of dense and open graded cold mixture for surface courses. This comparative study are to estimate when dense or open gradation are suitable for the road construction in certain areas.

2. Literature Review

CAEM is a mixture of aggregates, water, and bitumen emulsion. Compaction is one of the key procedure for CAEM to obtain the higher strength of the mixes. The more compaction effort, the lower the porosity values for CAEM [5][6][7]. In previous studies, CAEM also need a period of curing time due to it has slower setting time than hot asphalt mixture. After a period of curing time CAEM were comparable to hot asphalt mixtures [8][9].

There are two types of aggregate gradation for CAEM application, dense and open. A dense graded CAEM uses a continuously graded of coarse and fine aggregates. An open graded CAEM uses coarse aggregates and a small percentage of fine aggregate. Open graded mixtures have larger porosity to allow surface water to drain away. Otherwise, dense graded mixtures are high in strength [10].

Standard bitumen emulsions contain bitumen, emulsifier, and water. Emulsifier are classified into anionic, cationic, and nonionic types. Based on setting time, bitumen emulsion is classified into four types, slow, medium, rapid, and quick setting [10].

3. Research Methodology

A series of laboratory works were conducted to analyse the performance of dense and open graded cold mixture for surface courses. The aggregate gradations were designed at middle limit according to the Specification of the Department of Public Works, East Java Province, Indonesia [10]. As shown in Figure 1 and Figure 2, Dense Graded Emulsion Mixture (DGEM) was designed for Type 4, while Open Graded Emulsion Mixture (OGEM) was designed for Surface Layer.

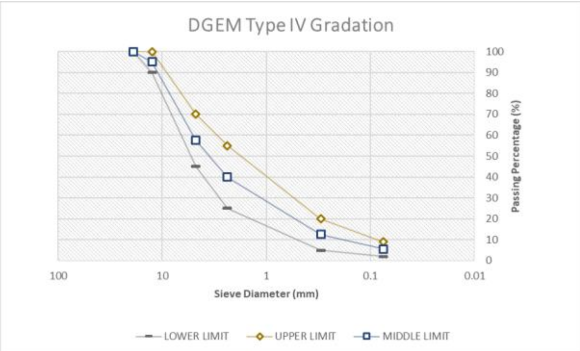

Figure 1. DGEM Type IV

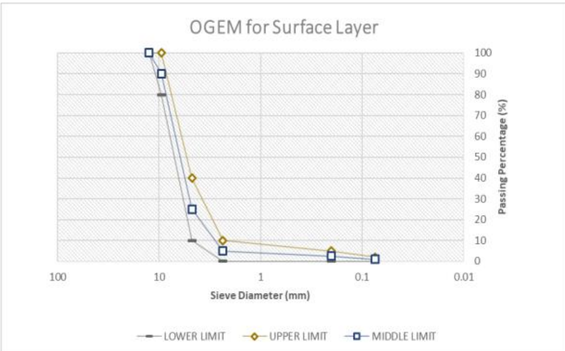

Figure 2. OGEM for Surface Layer

3.1. Material Properties

Materials used in this study were aggregates, water, and bitumen emulsion. The aggregates used were from Pasuruan, East Java, Indonesia. Bitumen emulsion used was CQS produced by Triasindomix company, Indonesia. CQS is a cationic quick setting bitumen emulsion designed to set quickly when in contact with aggregates. Table 1 and Table 2 show the properties of CQS bitumen emulsion and aggregates respectively.

3.2. Experimental Procedure

Marshall Mix design for DGEM were applied to determine the optimum residual bitumen content (ORBC). Three samples with an average diameter of 101.6 mm and a height of 63.5 mm were prepared for each of bitumen content varying from 5.4% to 7.4% with a 0.5% increment. Each sample was mixed and compacted at ambient temperature with compaction energy 2x75 blows for each side of sample [11]. The sample was then put in the oven at 40°C for 24 hours. Sample then stored at room temperature for 24 hours and continued with water capillary soaking condition.

Table 1. Properties and specifications of CQS bitumen emulsion

Properties	Units	Method	Results	Specifications
		Test on Emulsions		
Viscosity, Saybolt-Furol at 25° C	second	ASTM D244	30	20-100
Storage stability, 24 hours	%	ASTM D244	0.21	1 max.
Particle charge	-	ASTM D244	Positive	Positive
Distillation				
Residue	%	ASTM D244	60.74	57 min.
Test on Residue from Distillation test				
Penetration at 25° C, 100g, 5 sec	0.1 mm	ASTM D244	64.8	40-90

Table 2. Properties and specifications of coarse and fine aggregates

Properties	Units	Method	Results		Specifications
			Coarse(1)	Fine(2)	
Specific gravity, bulk	-		2.71	2.45	-
Specific gravity, SSD	-	SNI 1969:2008	2.76	2.48	-
Specific gravity, apparent	-		2.84	2.52	2.5 min.
Water absorption	%		1.72	1.01	3 max.
Los Angeles Abrasion	%	SNI 2417:2008	32.09	-	40 max.

(1) Coarse aggregate is retained on sieve No. 8 (2.36 mm); (2) Fine aggregate is passing sieve No. 8 (2.36 mm)

In this condition, sample were soaked in water at half the height of sample for 24 hours for each side. Marshall Test are then conducted to obtain soaked stability, flow, and also volumetric parameter. ORBC is determined by optimizing these parameters; soaked stability, porosity and density. Marshall Samples at ORBC were kept indoor at room temperature for 7 days prior to Marshall Test to obtain the effect of curing process for cold mixtures.

The procedure for producing OGEM sample to determine the ORBC was similar as the procedure for DGEM sample. Three samples of OGEM were prepared for each of bitumen content varying from 5% to 7% with a 0.5% increment. Unlike DGEM sample, OGEM sample was placed one day longer inside the mold before being placed in the oven because it takes more time to form [12].

4. Data and Analysis

4.1. Optimum Residual Bitumen Content (ORBC) Analysis

From the results of laboratory test, the relationship between Marshall Stability, porosity, and density with bitumen content for DGEM and OGEM are as shown in Figure 3 to Figure 8.

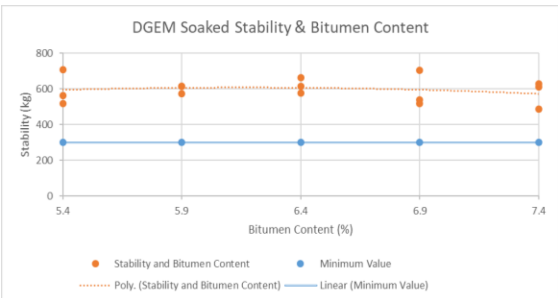

Figure 3. Relationship between DGEM Marshall Stability and Bitumen Content

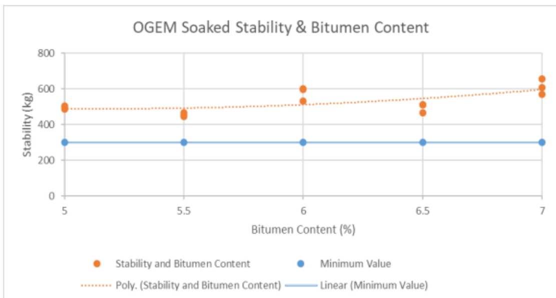

Figure 4. Relationship between OGEM Marshall Stability and Bitumen Content

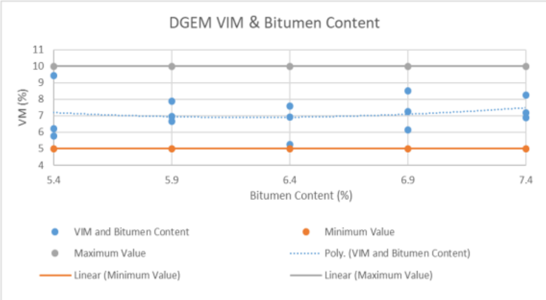

Figure 5. Relationship between DGEM VIM (Porosity) and Bitumen Content

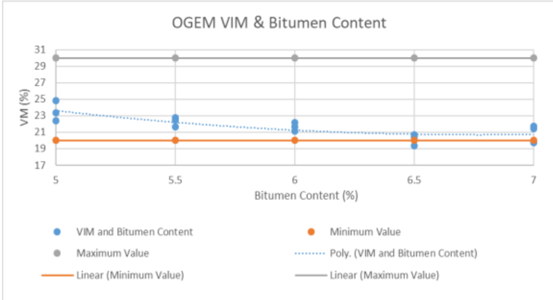

Figure 6. Relationship between OGEM VIM (Porosity) and Bitumen Content

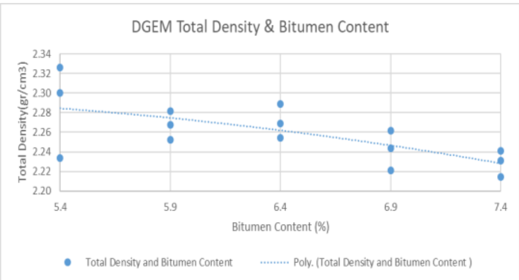

Figure 7. Relationship between DGEM Total Density and Bitumen Content

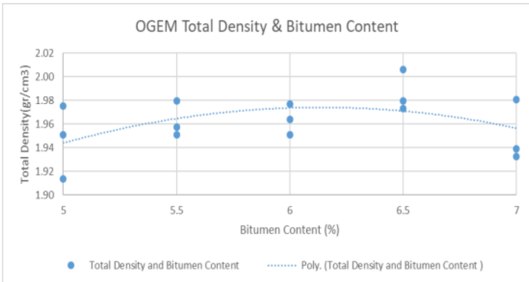

Figure 8. Relationship between OGEM Total Density and Bitumen Content

For DGEM, the highest stability was at asphalt content of 6.4% with an average value of 618.24 kg., while for OGEM, at the asphalt content of 7% with an average value of 680.15 kg. Stability will be the main parameter for determining the Optimum Residual Bitumen Content (ORBC) value. Considering that all parameters have met the maximum and minimum values of the standard, the ORBC value were at 6.4% for DGEM and at 7% for OGEM.

4.2. Effect of Curing on DGEM and OGEM

The results of tested samples at ORBC values for DGEM and OGEM at 7 days of curing time are shown in Figure 9 to Figure 12.

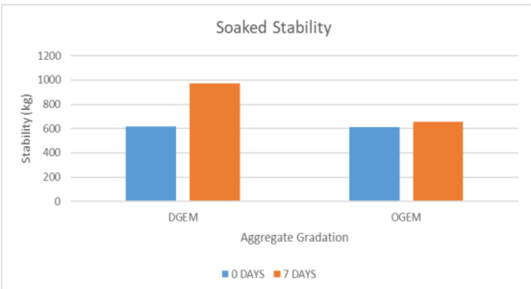

Figure 9. Effect of Curing Duration on DGEM and OGEM Soaked Stability

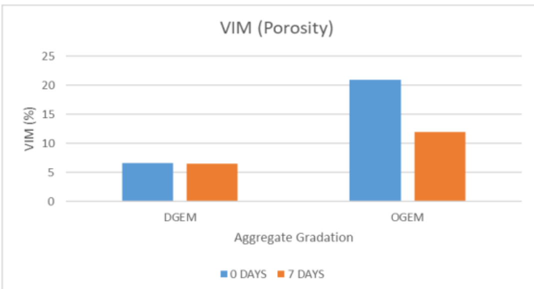

Figure 10. Effect of Curing Duration on DGEM and OGEM VIM (Porosity)

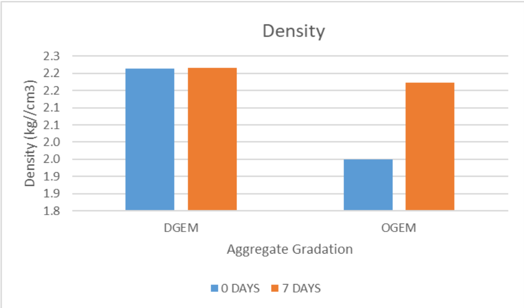

Figure 11. Effect of Curing Duration on DGEM and OGEM Density

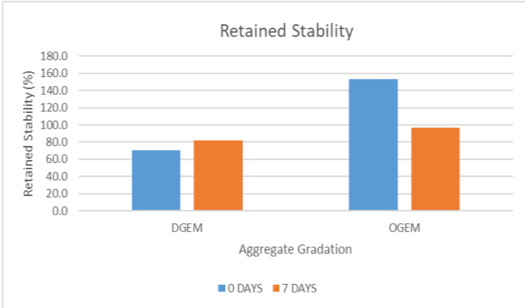

Figure 12. Effect of Curing Duration on DGEM and OGEM Retained Stability

Table 3. Characteristics of DGEM and OGEM after curing process

No	Characteristics	DGEM		Standard	OGEM		Standard
		0 days	7 days	DGEM	0 days	7 days	OGEM
1	Soaked Stability (kg)	618.24	974.49	300 kg min.	611.39	654.49	300 kg min
2	Flow (mm)	10.84	7.87	-	9.82	8.72	-
3	Porosity (VIM) (%)	6.60	6.48	5%-10%	20.99	12.00	20%-30%
4	VMA (%)	24.00	25.57	-	32.70	25.05	-
5	VFB (%)	72.61	74.66	-	35.85	54.67	-
6	Water Absorption (%)	2.51	1.09	4% max.	1.55	10.19	4% max.
7	Density (gr/cm^3)	2.21	2.22	-	1.95	2.17	-
8	AFT (µm)	19.40	19.40	8µm min.	49.52	49.52	20µm min.
9	MQ (kg/mm)	57.05	123.76	-	62.25	75.05	-
10	Retained Marshall Stability	70.29	81.93	50 min.	153.53	96.92	-

For DGEM and OGEM, the stability increased after a period of curing. For DGEM, the porosity slightly decreased after 7 days curing and the density was almost not changed. Retained stability was increased at 7 days of curing. For OGEM, the porosity significantly decreased after 7 days curing and the density increased. The retained stability decreased after 7 days of curing time. The summary of mixtures characteristic is shown in Table 3.

From these results, it can be seen that DGEM has an advantage in stability. This is indicated by a higher and more stable stability value. Meanwhile, OGEM has the advantage of high porosity (VIM). With high porosity, application in rainy weather will provide better durability because of its resistance to water flow. This is indicated by the higher retained stability for uncured sample. It is because OGEM can absorb water under immersion conditions and reduce voids in the mixture.

5. Conclusion

Based on this study, it can be concluded that:

1. The ORBC value obtained in DGEM (6.4%) is lower than OGEM (7%). It is because of the aggregate composition in DGEM which tends to be finer so that the bitumen content requirement can be lower. Meanwhile, OGEM has a lot of coarse aggregate so that the value of the surface area factor is lower which has an impact on the need for more bitumen content. In addition, the lower percentage of voids in DGEM and high density also minimizes the need for bitumen content compared to OGEM.

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2. The stability value in DGEM is higher than OGEM in a similar range of bitumen content. The high percentage of voids and porosity in OGEM causes the mixture to be less dense thus lowering the Marshall stability value. Otherwise, higher porosity made OGEM more permeable which has benefit regarding to the drainage.

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