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Properties of Cold Asphalt Emulsion Mixtures (CAEMs) using materials from old road pavement milling

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Abstract

Cold Asphalt Emulsion Mixtures (CAEMs) can be produced at room temperature. CAEMs can incorporate milled old road pavement. Some virgin aggregate and rice husk ash as filler material and cement was added into the mixture. The samples were subjected to compaction delay for up to 24 hours and cured at room temperature for up to 8 days and cured to full curing condition. The samples required more pronounced compaction effort. The cured samples met the minimum stability of 3 KN. The increased strength at early aged at tropical room temperature was found more dominant due to the water evaporation than cement content.

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Keywords:properties; cold; emulsion; old; pavement

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1. Introduction

Efforts to use of less heat energy in road construction have been attempted by applying the cold asphalt mixture technology; it can save up to 40% heat energy[1]. In order to do this, the viscosity of the asphalt has to be reduced either by diluting it into solutions (cutback asphalt), by foaming (foamed asphalt) or by emulsification (asphalt emulsion) [2]. This paper describes an experiment on Cold Asphalt Emulsion Mixtures (CAEMs) that can be produced at room temperatures, incorporating milled old road pavement as the main aggregate material and rice husk ash as filler. Research had been done on cold mixes in Europe with promising results [3], and can incorporate various waste materials [4]. Natural aggregates were added to modify the aggregate grading to meet specification. There have been few CAEMs full scale trials carried out in Indonesia, therefore limited data is available.

The strength of CAEMs largely depends on the evaporation of the water content in the compacted mix, therefore warmer weather is more suitable for CAEMs application [5]. There have been variations on the design procedure on CAEMs and its specifications [6]. The design procedure used in this experiment was a modification of the available procedures. The main modification was done on the determination of the water content at compaction and the determination of the compaction level to meet porosity. As the production of CAEMs require pre-wetting of aggregates with water the fact that and the asphalt emulsion contain some amount of water, the evenly mixed materials and emulsion were air dried until they were in a loose condition (neither too wet nor too dry) before compaction [7, 8]. Compaction level was achieved until the sample reached a certain density degree, hence resulting in the required porosity 5-10 % [9].

It is well-known that at their early age CAEMs were weak. In order to improve their early life strength, an addition of maximum 2% cement [6] into the mixture was made, and their strength increase was evaluated. CAEMs in Indonesia have been mostly used as patching materials in potholes on road pavements. The potholes may be located at different locations; therefore the delay of compaction is inevitable. In order to simulate this situation, the loose CAEMs were stored for some time before compaction, and compacted at a different time after mixing. Such studieshave been done and gave satisfactory results [10].

The objective of the experiment was to evaluate the Properties of Cold Asphalt Emulsion Mixtures (CAEMs) from Old Road Pavement Milling, with and without the addition of cement and compaction delays.

2. Material and method

2.1. The materials used, its properties and the aggregate grading

The materials used were coldly-milled old road pavement (reclaimed asphalt pavement-RAP) from a road section at Tabanan regency, Bali. The asphalt emulsion has cationic slow setting (CSS) which had been known to be more popular than other type [11]. The asphalt content of the emulsion was 60.8%. The base asphalt penetration of the emulsion was 100 penetration units. The rice husk ash was taken from a local fired clay brick industry using rice husk as material burner.

The asphalt content of the milled old road pavement was 5.7 % (tested using a centrifuge extractor). The properties of the materials are shown in Table 1.

Table 1. Properties of aggregate materials.

Aggregate	SG			Abs
	Bulk	SSD	App	
RAP Coarse agg	2.004	2.089	2.190	2.83%
RAP Fine agg	2.074	2.131	2.200	2.75%
Coarse natural agg	2,680	2,730	2,815	1.77%
Fine natural agg	2,595	2,675	2,815	2.98%
Rice husk ash	2,121			

The aggregate grading of the RAP (after extraction test), the spec limit and targeted gradation are shown in Fig.

1.The tabulation of the aggregate to meet specification is presented in Table 2.

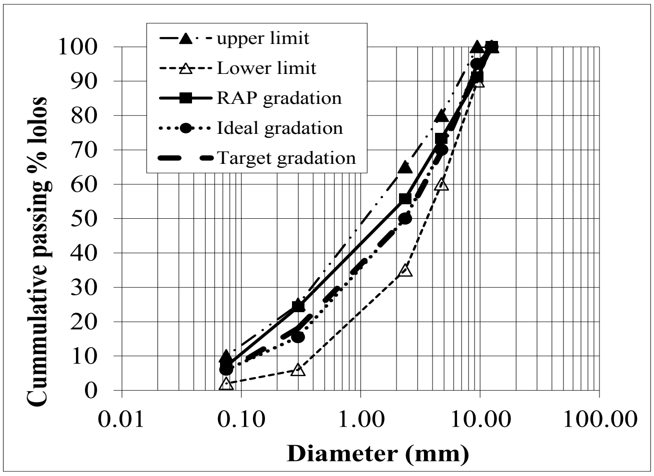

Fig. 1.The aggregate gradation of the RAP, and the CAEM specification (Mix type V).

Table 2.Tabulation of the aggregate to meet specification.

Sieve (mm)	Spec limit of CAEM	Ideal point	RAP agg grad	RAP Retain		Added by trial	Retain on each sieve		Cumulative passing (%)
				(%)	gram	gram	gram	%	
B	c	c	f	g	h=f×g/100	I	j=h+i	k	l (%)
12.500	100	100	100	0.00	0.00		0	0.00	100.00
9.500	90-100	95	91.15	8.85	57.94		57.94	6.44	93.56
4.750	60-80	70	73.32	17.83	116.71	99.81	216.51	24.06	69.50
2.360	35-65	50	55.79	17.53	114.76	62.18	176.93	19.66	49.85
0.300	6-25	15.5	24.32	31.47	205.99	79.36	285.34	31.70	18.14
0.075	2-10	6	7.09	17.22	112.74		112.74	12.53	5.61
Pan	-	-	-	7.09	46.44	4.09	50.53	5.61	
			Sum	100.00	654.57	245.43	900	100	
		Percentage to total			72.73%	27.27%	100 %		

2.2. Production of mixtures and samples

Before producing mixtures, the residual asphalt content was initially estimated using the formula from the Asphalt Institute [12].

$$P = (0.05A + 0.1B + 0.5C) \times (0.7) \tag{1}$$

Where: P=% of initial residual asphalt content. Referring to the cumulative passing of the aggregate in Table 2, A= % coarse aggregates (retain on 2,36 mm) =50,15%; B = % fine aggregates (passing 2,36 mm retain on 0,075 mm) = 44,24%; C=% of filler = 5,61%. It was found that P = 7% (rounded).

The initial emulsion content (IEC) was calculated as below:

$$IEC = \left(\frac{P}{X}\right) \times 100\% \quad (2)$$

Where X =% of asphalt content of the emulsion (0.608%), and IEC was obtained to be 11.5 %.

The production of the mixtures was carried out by proportioning the aggregates in line with the aggregate grading specification CAEMs type V [9], the aggregates were then dry mixed and pre-wetted with water and evenly mixed. After that, the required asphalt emulsion was added and mixed further until the emulsion evenly coated the aggregates. The loose mixture should be observed: if the mixture is too wet, air drying may be required until the mixture is sufficiently loose, neither too dry nor too wet, before being compacted. Afterward, the samples were compacted at the correct compaction level to meet porosity. After compaction the samples were left inside the mold for 24 hours at room temperature, and were then taken out.

The samples were then heat cured in oven at 40 ^{o}C for 24 hours and cooled down. For the soaked stability test, the samples were first exposed to capillary soaking, where they were soaked in water at half of their height for 24 hours and for another 24 hours for the other half of the samples' height (the samples were up-sided down) [9, 13].

Compaction delay was done by producing samples at its ORAC. Before compaction the loose mixture was kept in a sealed container to avoid the loss of the water content for 2, 4, and 24 hours. This treatment was applied to simulate delay of compaction during site works. Finally, the samples were cured at 20-30 ^{o}C and tested for their stabilities after 2, 4 and 8 days.

2.3. Conditioning samples to full curing condition

CAEMs samples produced according to the design procedure may still contain some water content. In order to achieve full curing condition, the water content within the samples needs to be evaporated. To achieve a full curing condition where all water had evaporated, the samples need to be heat cured in oven at 40 ^{o}C until they achieve constant weight.

3. Results and discussion

3.1. Compaction level and porosity

It was found that the samples require 2×(2×75) Marshall blow to meet the required 5-10% porosity, as shown in Table 3. This had also been experienced by [14]. This is because the mixture became stiffer as the compaction applied due to the setting of the asphalt globule within the emulsion [11]. It was found that the milled RAP material acts as an inert material.

Table 3. Compaction level to meet porosity

Compaction blow	Soaked Stability (kN)	Porosity (%)	Specification
2 × 75	4,838	11,373	5 – 10 %
2 × (2 × 75)	9,356	8,424	5 – 10 %

3.2. Marshall properties and the optimum residual asphalt content

For a variationin residual asphalt content, the relation between the residual asphalt content and the Marshall properties are shown in Fig. 2 to Fig. 8.

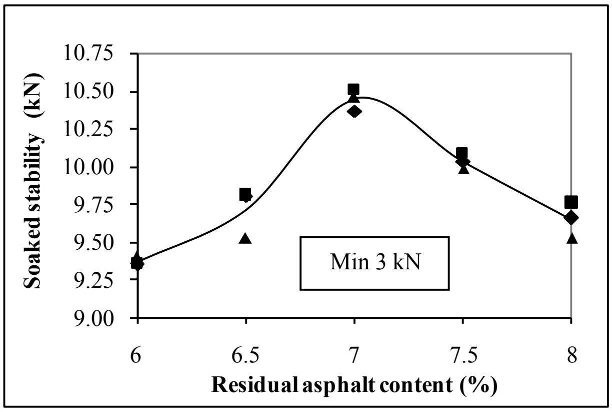

Fig. 2. Residual asphalt content vs. Soaked stability.

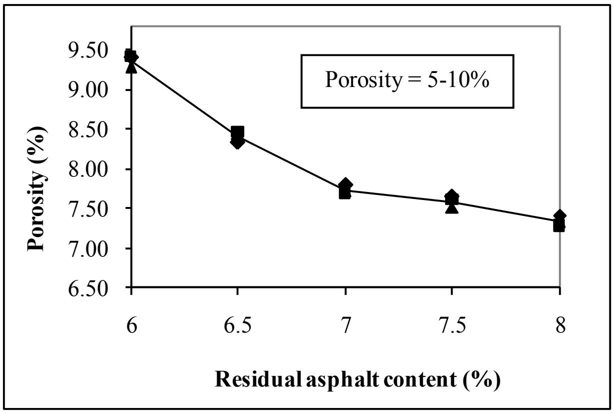

Fig. 3.Residual asphalt content vs. Porosity.

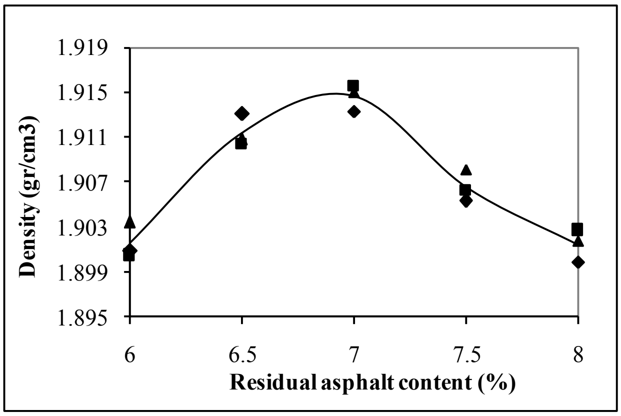

Fig. 4.Residual asphalt content vs. Density.

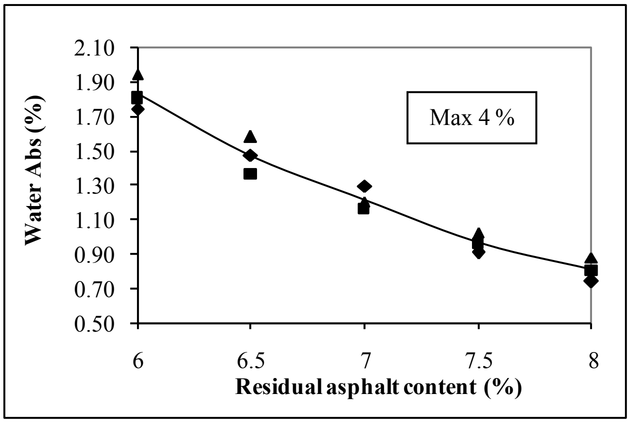

Fig. 5.Residual asphalt content vs.Water absorption.

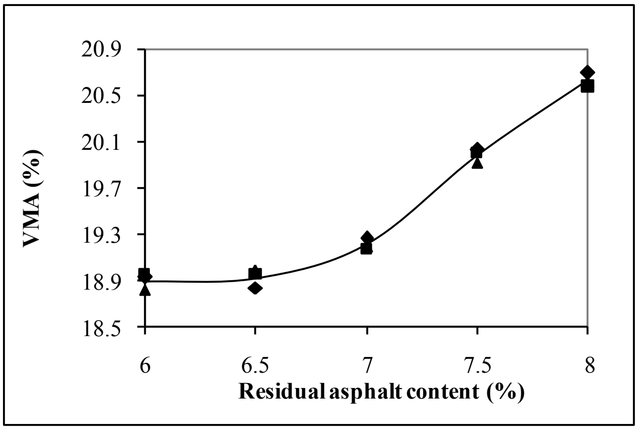

Fig. 6.Residual asphalt content vs. VMA.

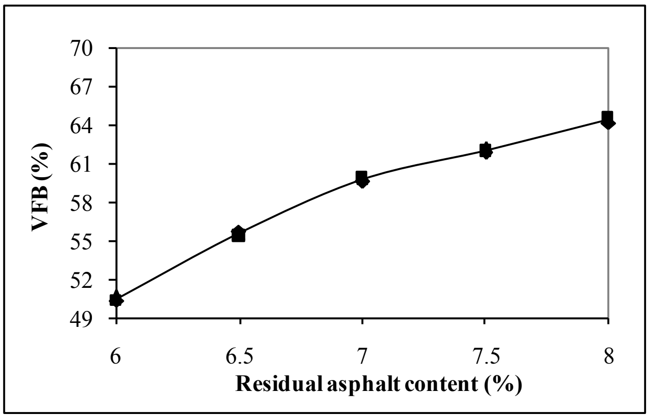

Fig. 7.Residual asphalt content vs. VFB.

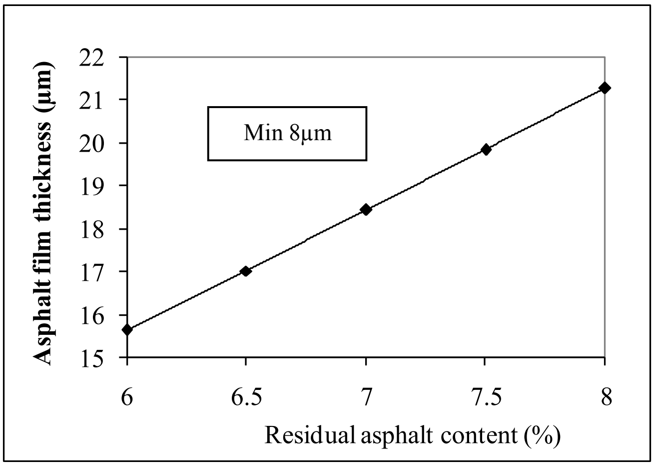

Fig. 8.Residual asphalt content vs. Asphalt film thickness.

Referring to Fig. 2 to Fig. 8, and Table 4, it can be seen that all specifications were met. There is no specification on VMA and VFB for CAEMs. Based on results in Fig. 2 to Fig. 8 above, the properties of the samples are summarized in Table 4.

Table 4. Summary of the properties of the CAEMs

Properties of mixture	Residual asphalt content (%)					Specification
	6	6,5	7	7,5	8	
Soaked Stability (KN)	9,366	9,713	10,442	10,032	9,648	> 3 kN
Porosity (%)	9,363	8,412	7,729	7,582	7,335	5-10%
Water abs (%)	1,834	1,475	1,221	0,963	0,809	max 4%
Asphalt Film Thickness (µm)	15,721	17,123	18,539	19,970	21,418	>8µm
VMA (%)	18,899	18,925	19,211	19,983	20,628	-
VFB (%)	50,459	55,553	59,767	62,056	64,440	-

For determining the optimum residual asphalt content (ORAC), the relationship between the added residual asphalt content and the Marshall properties of the mixtures were plotted in a bar-chart as shown in Fig. 9. By optimizing soaked stability and the density, the ORAC was determined to be at 7%.

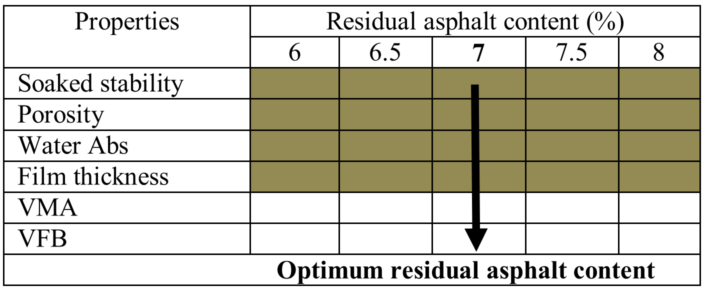

Fig. 9.Determination of optimum residual asphalt content by bar-chart method.

3.3. Properties of CAEMs at its ORAC and subjected to compaction delay and curing at room temperature

The mixtures that had been treated for compaction delay and cured at different durations gave stabilities as shown in Fig. 10. It is shown that the stability of samples were from 9-10 kN, well above minimum 3 kN stability at the earliest 2 days' curing duration. A clear increase of strength (stability) can be seen at 2, 4, and 8 days. If the lines extrapolated to an earlier stage than 2 days' curing, it appears to produce a good trend. However, it would be unreasonable to expect that a stable state would be reached at a minimumof 3 kN at 0 day curing duration (soon after compaction).

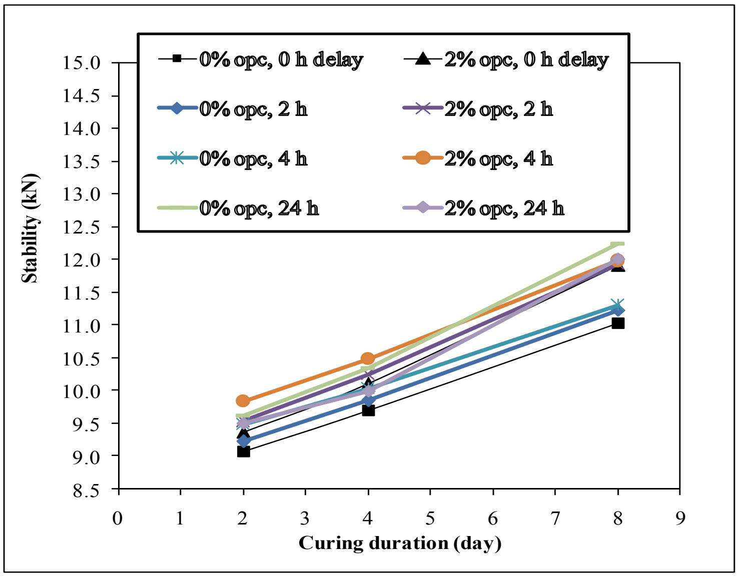

Fig. 10.Stabilites of samples subjected to compaction delay.

A slight higher stability was found on the samples with 2% ordinary portland cement (opc). However, the increase of stability appears to be more dominant due to the evaporation of the water content, as the curing room temperature was warm, i.e. at 28-30 ^{o}C. In cold climates the addition of cement had been found to give a significant increase of stability [6, 10].

3.4. Performance of CAEMs at full curing condition

Achieving a full curing condition where all water content has evaporated requires 30 days of curing in an oven at 40 ^{o}C. The stability and porosity of the samples that had been subjected to compaction delay are shown in Fig. 11 and 12. It is shown that the stability decreases in line with the increase in porosity. The increase in porosity occurred due to the compaction delay, where the loose mixture of CAEMs had become slightly stiffer, hence less workable during compaction. Although the porosity increases, the overall porosities still remain within the spec limit, i.e. 5-10 %.The samples containing ordinary Portland cement (OPC) showed higher stability, as the cement would assist the hardening of the compacted samples.

Although all properties of the CAEMs well meet the specification, further testsarenecessary such as stiffness tests, creep tests, and fatigue tests, in order to attain a broader appreciation on the performance of CAEMs.

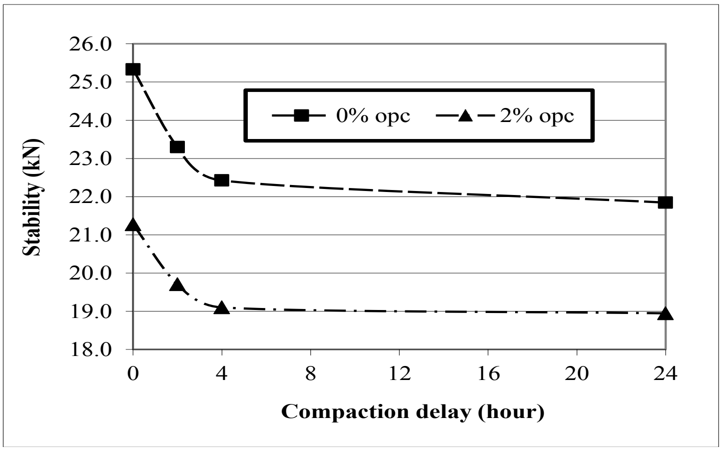

Fig. 11.Stability of CAEMs at full curing condition that had been subjected to compaction delay.

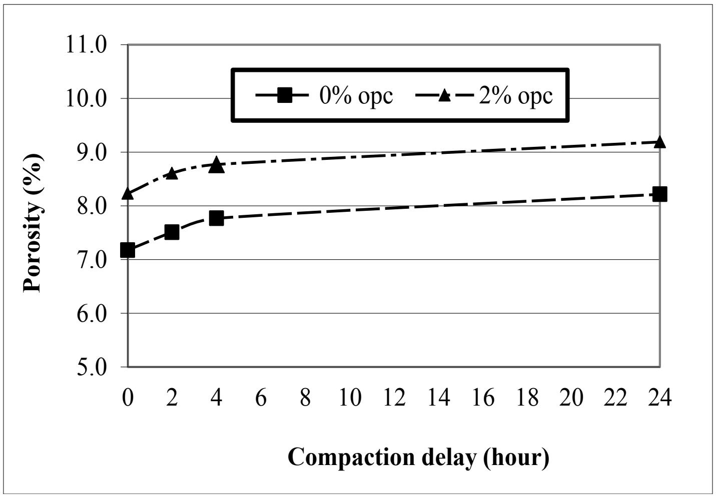

Fig. 12.Porosity of CAEMs at full curing condition that had been subjected to compaction delay.

4. Conclusion

Considering the results and the analysis, it can be concluded that:

- CAEMs can incorporate a high portion (72.73%) of RAP,where their properties well meet the specifications.
- CAEMs can meet their minimum stability 3 kN in less than 2 days of curing at 20-30 ^{0} C.
- Ina warm curing environment, the evaporation of water content is sufficient (more dominant) to increasethe rate of strength gain, without adding OPC.

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