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MODIFICATION OF ASPAHLT CONCRETE USING FLY ASH AND WASTE PLASTIC

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ABSTRACT
The effect of modifying asphalt concrete using fly ash and recycled HDPE plastic is reported. This was added to 60/70 penetration grade bitumen and its effect on penetration at 25, 30, 35 and 40^{0}C, softening point and Penetration Index determined. This showed that addition of both wastes could be used to modify these properties. Marshall design was used to evaluate the effect of the waste / bitumen blends on mix properties. The mix data showed that the addition of both waste materials could improve performance of the asphalt concrete. Greatest improvement was with the addition of waste HDPE plastic. The paper concludes that simple bitumen and Marshall design values can be used to determine the probable effect of waste addition. This is important as these methods are still widely used in many countries.

KEY WORDS: Fly ash, HDPE waste plastic, Marshall design.

1. INTRODUCTION

Wearing course asphalt concrete is widely used in many countries around the world. In countries such as Indonesia it can suffer from problems of permanent deformation in the wheel track due to increased traffic volume, overloading and the high ambient temperature. Its resistance to permanent deformation is particularly affected by the binder properties with modifiers such as fly ash or polymer to improve stability and strength [1].

This paper compares the effect of fly ash and polymer addition on bitumen and mix properties. The polymer used was a HDPE plastic derived from waste milk cartoons. Disposal of solid waste such as plastic containers is a major problem in developing countries where rapid development and changing lifestyles in growing cities has changed the waste composition from being mainly organic to mainly being composed of plastics, paper and packaging materials.

Disposal of waste becomes more challenging as greater amounts of land are needed for the disposal of such waste streams [2, 3]. Using waste as a construction material offers an answer not only to the environmental problems and but in certain cases may improve pavement properties [1]. With approximately 100 million tonnes of fly ash and 150,000 tonnes of waste plastic produced annually [3] in Indonesia alone, they offer a less expensive means of modifying asphalt materials and formed the basis for the research reported in this paper.

The data reported in this paper formed part of a larger investigation into the use of these materials [4]. This paper considers use of the simple bitumen and Marshall design values to determine the effect of waste addition as these methods are still widely used in many countries.

2. MATERIALS USED

Table 1 summarises the properties of the fly ash used in the study. The waste plastic was derived from high-density polyethylene (HDPE) milk cartoons collected from household waste. These were simply cut into small pieces approximately 2 x 2 mm^2 in size. The thickness, density, melting point, tensile strength and elongation at break were 0.5mm, 0.94 – 0.97gm/cc, 120 – 130^{0}C, 31.4MPa and 100% respectively. The fly ash and waste plastic was used to modify a 60/70 penetration grade bitumen widely used in Indonesia for asphalt concrete. The aggregate was Tertiary basalt from Northern Ireland. Table 2 summarises the main aggregate properties. A <0.075mm limestone dust was used as filler.

Table 1: Properties of the fly ash used

Property	Fly ash used in the study
Moisture Content	0.25%
Fineness (45μm sieve residue)	9%
Particle Density	2350kg/m³
Water Requirements	94%
Loss on Ignition	4%
Chloride	0.00%
Sulphuric Anhydride (SO3)	0.8%
Calcium Oxide (CaO)	4.5%

Table 2: Properties of the basalt aggregate used

Property	Aggregate size		Indonesian requirement
	Coarse	Fine	
Apparent Particle Density	2.97	2.92	> 2.5
Oven Dried Particle Density	2.87	2.79	> 2.5
Saturated Surface Dry Particle Density	2.91	2.84	> 2.5
Water Absorption	1.22	1.54	< 3%
Flakiness Index	24		< 25%
Aggregate Impact Value	9.60		< 30%
Los Angeles value	19		< 40%
Magnesium Sulphate Soundness	9		
Aggregate Abrasion Value	6.30		
Polished Stone Value	58		

3. PREPARATION OF BITUMEN BLENDS

Fly ash / bitumen blends were prepared using 3, 6 and 9% of fly ash by mass of binder. The fly ash was first pre-heated at 170^{0}C for 24 hours. The 60/70 penetration grade bitumen was heated to 150^{0}C, the fly ash added and then blended for 15 minutes at 150^{0}C. The chopped HDPE was added slowly as 2 x 2mm pieces to the bitumen and mixed at low speed for about 5 minutes until all of the plastic had been added. The blend was maintained at 160 to 170^{0}C and mixed at high speed for about 1 hour. Three HDPE blends were made i.e. 0.75, 1.5 and 3% by mass of binder. Based on previous studies and observed that a uniformly dispersed binder formed only if the temperature and time of blending exceed 160°C and 1 hour respectively.

4. PREPARATION OF ASPHALT CONCRETE TEST SPECIMENS

The optimum bitumen content was determined using the Marshall mix design method as used in Indonesia. The coarse aggregate, fine aggregate and the filler material were proportioned to meet the requirements of Indonesian specification [5] as shown in Figure 1. Mixing and compaction was carried out at 170^{0}C (a viscosity of 170 ± 20 cSt) and 140^{0}C (a viscosity of 280 ± 30 cSt) respectively. Marshall compaction with 75 blows each side was used. This found the optimum bitumen content of the asphalt concrete mix to be 6%. Subsequent test specimens were prepared using these test conditions.

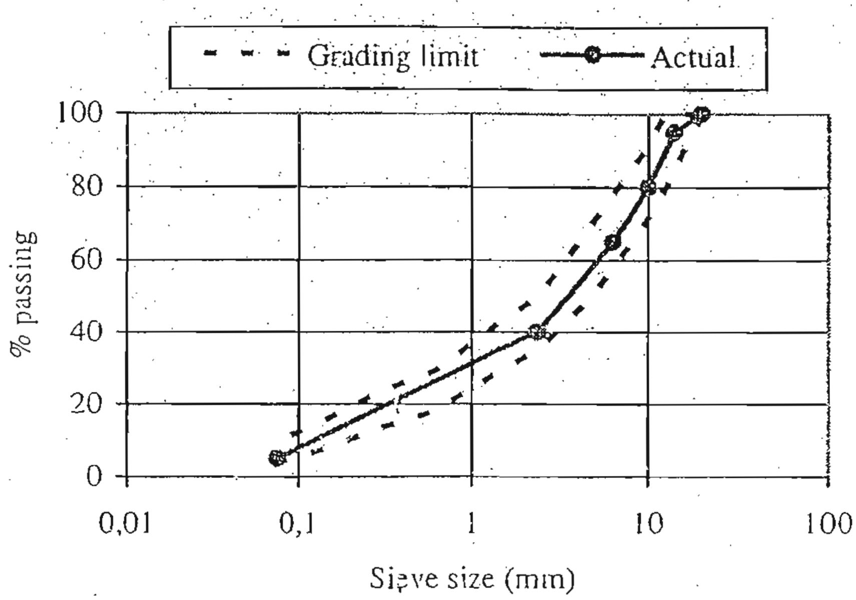

Figure 1: Asphalt concrete grading curve

4. EFFECT OF MODIFICATION ON BITUMEN PROPERTIES

The results of modified penetration testing at 25, 30, 35 and 40^{0}C are shown in Table 3. This shows that the addition of both fly ash and HDPE caused penetration to decrease. The addition of HDPE had more effect on penetration than fly ash. Figure 2 shows the addition of small amounts of HDPE had a marked effect of softening point.

Table 3: Summary of modified penetration test data for fly ash and HDPE plastic blends

Penetration test temperature (^0C)	Fly ash / bitumen blends				HDPE / bitumen / blends			
	0%	3%	6%	9%	0%	0.75%	1.5%	3%
25	67	66	65	63	78	72	66	55
30	130	117	112	110	149	122	103	85
35	209	207	202	194	239	206	176	133
40	340	310	308	305	350	319	285	223

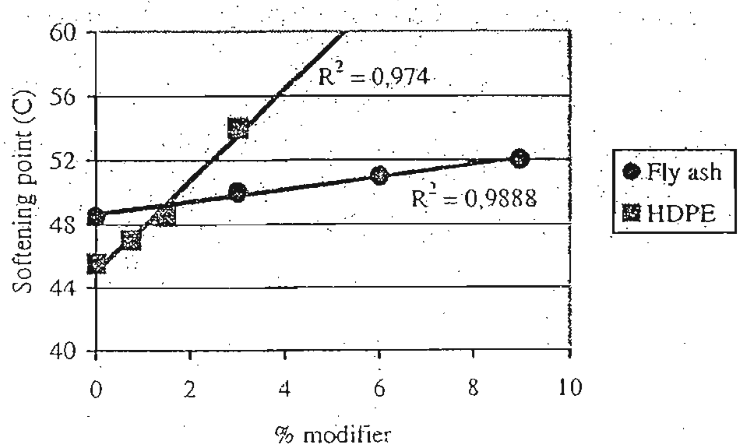

Figure 2: Effect of bitumen modification on softening point

Figure 3 show that both wastes can reduce temperature susceptibility in terms of Penetration Index. Temperature susceptibility for the HDPE blends was found to decrease as the waste plastic content increased. For the fly ash blends, temperature susceptibility decreased and then increased.

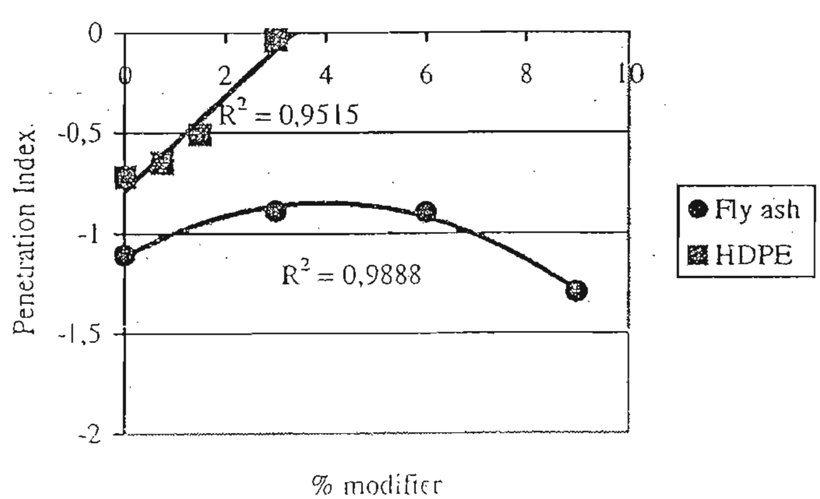

Figure 3: Effect of bitumen modification on Penetration Index

5. EFFECT OF MODIFICATION ON MIX PROPERTIES

The Marshall test protocol was used to assess basic mix properties. The reason why Marshall was chosen for the analysis presented in this paper was because this method is still widely used in many developing countries around the world. One of the aims of the investigation was to determine the ability of Marshall testing to highlight differences between the two waste materials.

Figure 4 shows the effect of bitumen modification on Marshall Stability. This shows that the addition of small amounts of HDPE can have a significant improvement on stability. Increasing the amount of waste HDPE appears to cause the mix to become stiffer with greater shear resistance. The addition of fly ash had a much smaller effect with an optimum content of approximately 4%. Initial addition of fly ash would appear to fill the voids between aggregate grains causing the mix to gain strength. Increased fly ash addition then reduces contact between aggregate particles leading to reduction in stability.

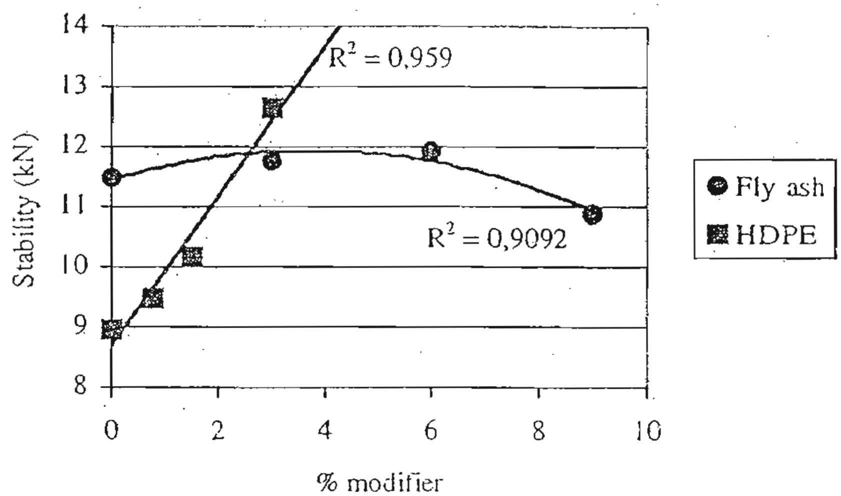

Figure 4: Effect of bitumen modification on Marshall Stability (kN)

Marshall Quotient is the ratio between stability and flow. It is an emperical stiffness value which can be used to evaluate a bitumnious mix. A higher Marshall quotient indicates a stiffer mixture with more resistance to permanent deformation. Figure 4 plots the effect of bitumen modification on Marshall Quotient. This reflects the trend for stability suggesting that the addition of HDPE has a marked effect on this empirical measure of mix stiffness.

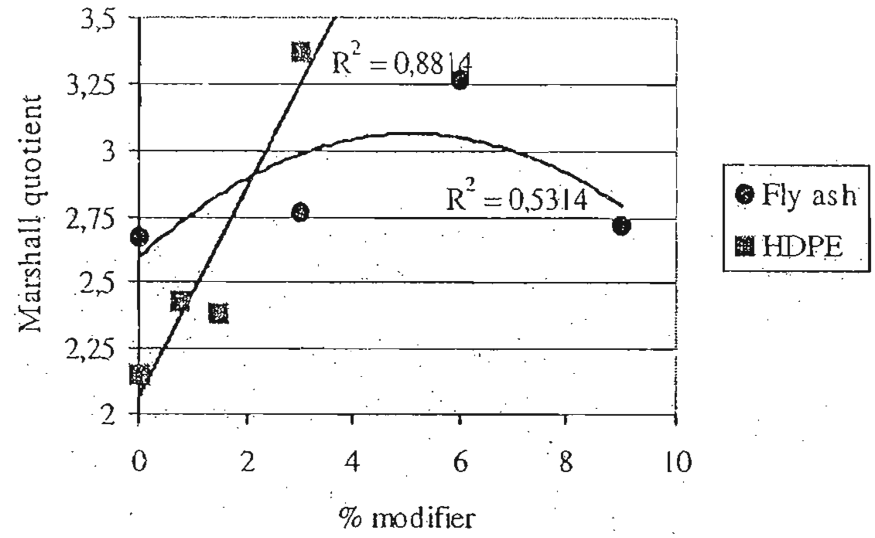

Figure 5: Effect of bitumen modification on Marshall Quotient

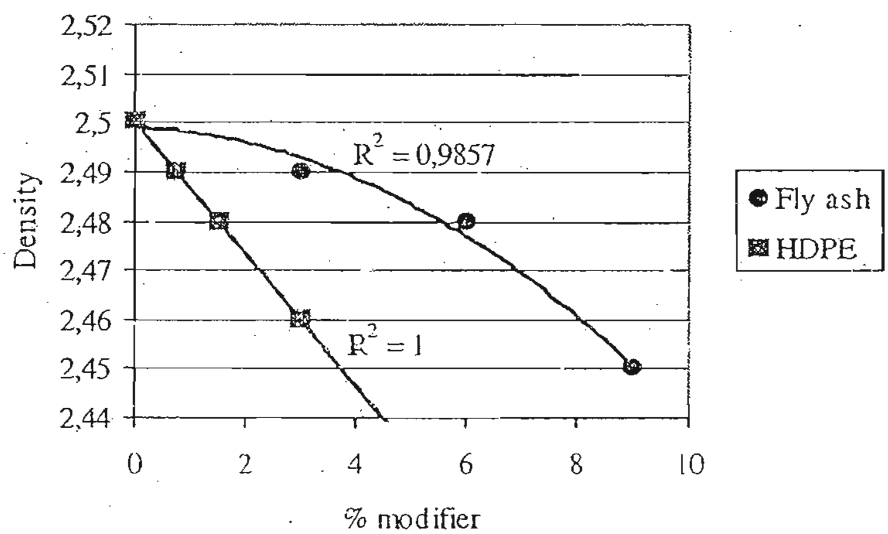

Figure 6: Effect of bitumen modification on compacted mix density

The effect of bitumen modification on compacted mix density is shown in Figure 6. This shows that the increased addition of both wastes causes compacted mix density to decrease. The decrease is greater for the HDPE plastic and reflects the effect of each waste on compaction effort.

The effect of both waste materials on moisture susceptibility is shown in Figure 7 in terms of Retained Stability. The data shows retained stability increased to an optimum value for both materials i.e. 1.5% for HDPE and 3% for fly ash. After this value retained stability decreased. This finding agrees with previous studies that have highlighted the improved moisture sensitivity with he use of filler and polymers as anti-stripping agents.

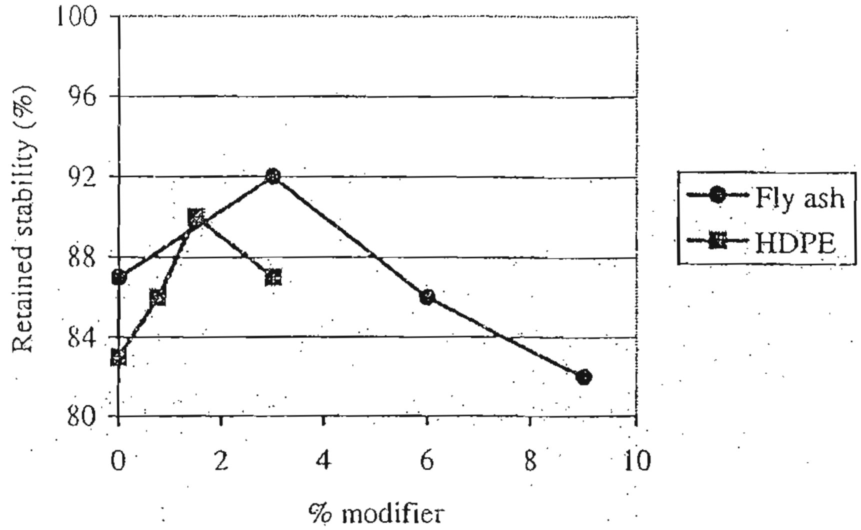

Figure 7: Effect of bitumen modification on Retained Stability

6. CONCLUSIONS

The investigation using simple bitumen and Marshall design has shown that these methods are capable of identifying the increased addition of both waste materials added to the bitumen caused both bitumen properties and Marshall properties to change. Marshall stability was found to increase, however compacted mix density was detrimentally effected due to the stiffening properties of both wastes. Increasing both waste materials content increased VIM and VMA with the plastic having a greater effect.

Both waste materials were found to improve moisture susceptibility. The overall conclusion was that the optimum waste content was 4% fly ash and 1.5% waste HDPE as a percentage of the bitumen content. The research has shown that the use of these waste materials can improve the properties of asphalt concrete and offer a potential solution to high temperature problems of using this type of mix in a hot climate.

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