A STUDY OF POLYMER MODIFIED BINDER ETHYLENE VINYL ACETATE (EVA) ON THE HOT ROLLED ASPHALT

Leksminingsih

RINGKASAN

Pemakaian modified binder telah lama digunakan di dalam campuran pembuatan perkerasan jalan guna menanggulangi pertambahan jumlah dan beban dari kendaraan pemakai jalan. Pemakaian thermoplastic polymer di dalam campuran bahan pengikat sebagai modified binder pemakaiannya meningkat setiap tahunnya, bahan polymer ini berfungsi untuk memperbaiki sifat dari bahan pengikat terutama dengan pemakaian material yang baik sehingga memperlihatkan penampilan yang baik pula di dalam masa pelayanannya terutama pada beberapa tempat yang perlu penanganan khusus.

Di dalam laporan penelitian ini dibahas 3 campuran dari hot rolled asphalt type wearing course, untuk negara bertemperatur rendah BS 594 dan untuk negara tropis ; Road Note 31 dan TRH - 878. Untuk HRS BS 594 dipakai aspal pen 50 dan untuk campuran lainnya dipakai aspal pen 70. Pemakaian agregat jenis Limestone dan granite.

Selanjutnya, laporan membahas pemakaian EVA (Ethylene Vinyl Acetate) di dalam HRA Type wearing course TRH - 8-78. Tujuan dari pemakaian additive ini adalah untuk meningkatkan sifat dari campuran di dalam percobaan Marshall, menambah ketahanan campuran terhadap surface rutting dan bleeding akibat kelebihan bahan pengikat dan untuk memenuhi tuntutan perkerasan yang baik dan tahan terhadap beban lalu-lintas yang berat. Percobaan dilakukan di laboratorium aspal Laing Technology Group di Inggris.

SUMMARY

Modified binder are increasing by being used in asphalt pavements to against the ever growing numbers and weight of vehicles using the roads.

The use of thermoplastic polymer to modify the bitumen is increasing year by year as this versatile and high perfomance material continually demonstrate its performance under the most difficult of service conditions.

The report discusses three mixes of hot rolled asphalt type wearing course for cold country, HRA BS 594 and for tropical country; road note 31 and T.R.H-8-1978. For HRA 594 using 50 pen grade and the others 70 pen grade bitumen and using the limestone and granite aggregate. Further more, the report discusses the use of polymer additive EVA (Ethylene Vinyl Acetate) in the HRA type wearing course T.H.R-8-1978.

the aims by using additives are to improve the properties of binder to the marshall mix design, and to improve resistance surface rutting and bleeding to excess of binder content to meet the demand for better surfacing materials to very heavily trafficked roads.

The experiment have been done in the asphalt laboratory at Laing Technology Group in the UK.

1. INTRODUCTION

For many years additives have been used with the aim of improving the rheological properties of bitumen, but few have found a permanent place in road engineering practice. There are several reason for this. Improvement in the rheological properties of the binder have often not been reflected in road perfomance and sometime additives have introduced more problem than they have solved. To physically add additives into the binder or mix and restrictions on traditional handling and laying techniques are typical examples of the problem that can arise.

Many problem have made it very difficult to demontrate that additives can improve road perfomance consistently and to a degree sufficient to justify the extra cost or inconvenience involved.

This report discusses three mixes of hot rolled asphalt (HRA) one for a cold country HRA BS 594 type wearing course using granite coarse aggregate and 50 pen grade bitumen, and two for a tropical country,the first HRA type wearing course for tropical country has been suggested by TRRL (Road Note 31) and the second TRH -8-78, using a typical Indonesia grading, both two HRA for tropical country using limestone coarse aggregate and 70 grade bitumen.

Further more, the report discusses the use of organic polymer in the HRA type wearing course TRH-8-78. The aims of using additives are to improve the properties of bituminous binders and to describe the effect of selected modified binders on the Marshall Mix design Process.

2. BACK GROUND

For a tropical country like Indonesia the use of medium grade penetration bitumen such as 60/70 pen grade is very useful in order to prevent the pavement from excessive rutting. However, this solution gives only a benefit in the short term. In the long term, use of this pen grade bitumen will result in more rutting, due to the rapidity of the ageing process. The normal maximum temperature at the road surface in Indonesia is more than 40 C, with the air temperature around 35 C. At these temperature the bitumen becomes softer and subsequently some defects, such as deformation, rutting and stripping appear.

Further more, these defects reduce the life time of the pavement. The problem is not only temperatur. Heavy traffic can also be a problem. To solve these problem, Indonesia needs to increase the quality of the pavement. Additional bonding of the bitumen to the aggregate or sand is theoretically possible by adding an additive. EVA thermoplastic polymer, for example, is known to give a benefit, compared to using extra bitumen in the asphalt pavement, in temperate climates.

3. OBJECTIVE

The overall objective of the present work to asses the potential of EVA polymer additives as means to achieve these desired improved properties in HRA designed for use in tropical climates.

The effect on Marshall Mix design properties has been measured together with the effect on the properties of the binders themselves.

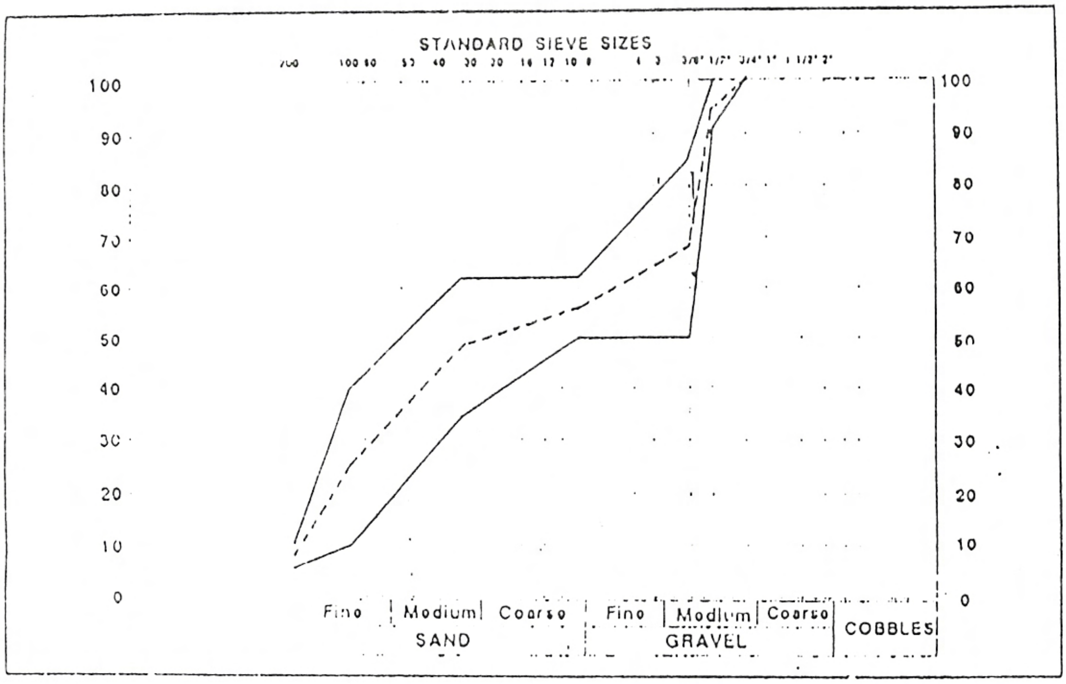
4. HOT ROLLED ASPHALT

One of the most important characteristic of HRA is that the aggregate is "Gap graded" i.e it contains very little medium size aggregate in the 2.36 mm to 10 mm range but consists of a matrix of sand, fine mineral filler and bitumen into which coarse aggregate, usually nominal 14 mm (in HRA, UK) is mixed. The gap-grading gives HRA wearing courses their characteristic weather resistance and durable surface which can accomodate heavy loads without cracking. Its stability derives from the stiffness of the binder-filler-fine aggregate mortar and not from interlocking of the coarse aggregate.

A typical composition of HRA:

- Coarse aggregate retained on a 2.36 mm sieve may be crushed rock gravel ;
- Fine aggregate passing a 2.36 mm retained on a 75 m sieve;
- Natural sand or crushed rock fines ;
- Filler passing a 75 m sieve-cement or limestone dust, and
- Bitumen 35, 50, 70 or 100 pen.

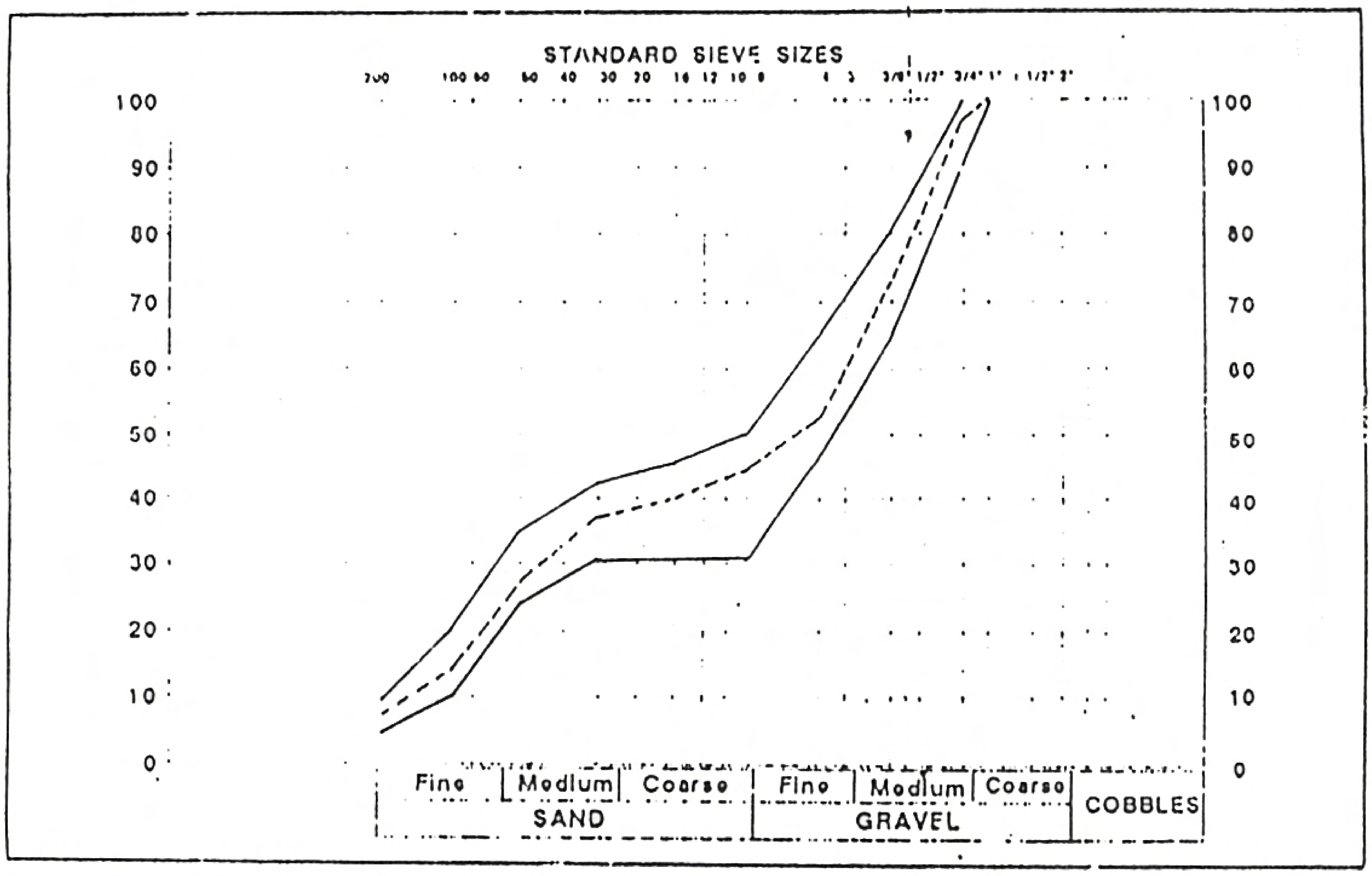
4.1. HRA type wearing course specification for cold country (BS 594).



Sieve Size	Percentage Passing
20 mm	100
14 mm	90 - 100
10 mm	50 - 85
6.3 mm	-
2.36 mm	50 - 62
600 µm	35 - 62
212 µm	10 - 40
75 µm	6.0 - 10.0

Bitumen Grade		50 pen
Traffic Category		Heavy
Number of compaction blaws		50
Marshall Stability		6 - 10 KN
Flow ;	Minimum	2 mm
	Maximum	5 mm
Void in Mix ;	Minimum	3 %
	Maximum	5 %
Void Filled Bitumen		
	Minimum	75 %
	Maximum	85 %
Bitumen Content		6.3 %

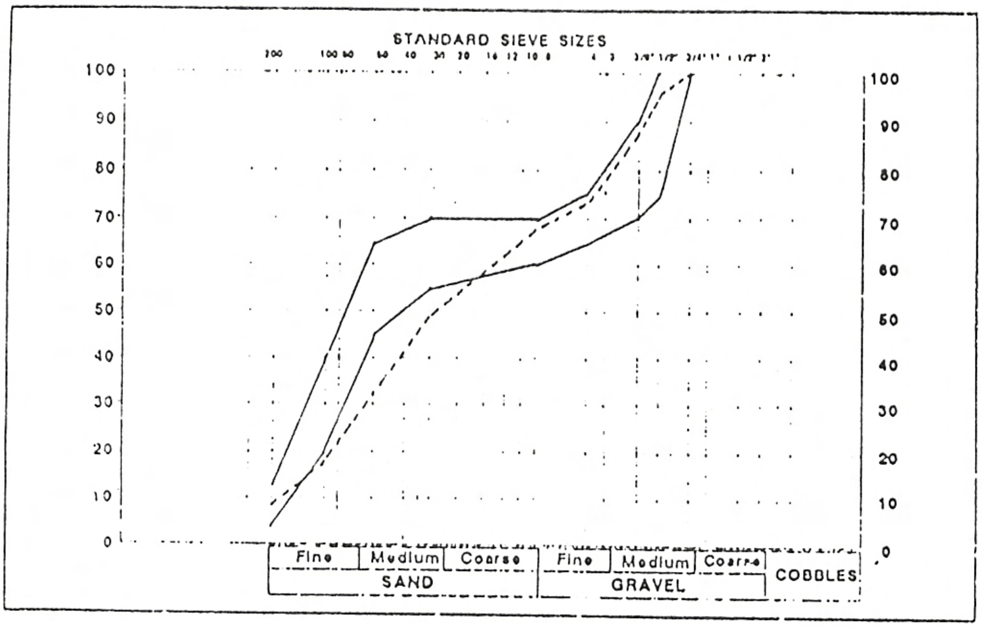
4.2. HRA specification for tropical country suggested by TRRL (Road Note 31).



Sieve Size	Percentage Passing
28 mm	100
21 mm	90 - 100
10 mm	66 - 80
5 mm	47 - 65
2.36 mm	30 - 50
1.18 mm	30 - 46
600 µm	30 - 42
300 µm	24 - 35
212 µm	16 - 27
150 µm	10 - 20
75 µm	5.5 - 9.5

Bitumen Grade		60/70 pen
Traffic Category		Heavy
Number of compaction blaws		50
Marshall Stability Minimum		3.4 KN
Flow ;	Minimum	2 mm
	Maximum	6 mm
Void in Mix ;	Minimum	4 %
	Maximum	10 %
Void Filled Bitumen		
-	Minimum	-
	Maximum	-
Bitumen Co ntent		5.5 ± 0.3

4.3. HRA specification for tropical country from TRH-8-78 using Indonesian Typical grading.



Sieve Size	Percentage passing suggested for Indonesia.		Percentage passing according Indonesia's aggregate grading
	Specification	Mean Grading	Typical Mean Grading
3/4" (20mm)	100	100	100
1/2" (14mm)	75 - 100	87.5	97
3/8" (10mm)	70 - 90	80	90
No.4 (5mm)	65 - 75	70	75
No.8 (2.36mm)	60 - 70	65	68
No.30 (600µm)	55 - 70	62.5	47
No.50 (300µm)	45 - 65	55	32
No.100(150µm)	20 - 40	30	17
No.200(75µm)	4 - 12	8	9

Bitumen Grade		70 pen
Traffic Category		Heavy
Number of compaction blaws		50
Marshall Stability Minimum		6 - 10 KN
Flow ;	Minimum	2 mm
	Maximum	5 mm
Void in Mix ;	Minimum	3 %
	Maximum	5 %
Void Filled Bitumen	Minimum	75 %
	Maximum	85 %
Bitumen Content		7 %

5. MODIFIED BITUMINOUS BINDER

5.1. General

The use of modified bitumens offers one solution to reduce the frequency of maintenance required at "Blacks-pots" and provides much longer service life for maintenance treatments at difficult sites. To optimize the cost effectiveness of modified bitumens, they are best used in combination with high quality aggregates in area requiring exceptional resistance to fatique and surface rutting. The degree of improvement required, and hence the cost, will depend upon the needs of the site to be treated by using a variety of additives such as-

* Various organic polymers to improve the properties of bituminous binders;
* Reclaimed tyre rubber to improve deformation resistance;
* Sulphur, Organomanganese compounds and thermoplastic polymer can improve both the workability of asphalt during compaction and resistance to surface rutting in service;
* Thermoplastic rubber to improve deformation resistance and fatique characteristic.

5.2. Properties required in polymer additives.

For the modifier to be effective and for its use to be practicable and economic it must -

i. be readily available ;
ii. resist degradation at asphalt mixing temperature ;
iii. mix easily with bitumen ;
iv. improve resistance to flow at high road temperature without making the bitumen too viscous at mixing and laying temperature or too stiff or brittle at low road temperature ;
v. be cost effective.

The modifier, when blended with bitumen, should have the following characteristics;

i. Maintain its good properties during storage, application and in service;
ii. be capable of being processed by conventional equipment;
iii. be physically and chemically stable during storage, application and in service;
iv. achieve a coating or spraying viscosity at normal application temperature.

5.2. The modification of bitumen by the addition of EVA.

EVA is a thermoplastic polymer which has been examined in modified road binder. As it is a thermoplastic , it is characteristised by softening on heating and hardening on cooling. Thermoplastic polymer, when mixed with bitumen associate at ambient temperature, increasing the viscosity of the bitumen.

EVA copolymer are thermoplastic materials with a random structure produced by the copolymerisation of ethylene and vinyl acetate. The properties of EVA copolymer are controlled by molecular weight and vinyl acetate content.

1. Molecular weight : the molecular weight of many polymer are defined in terms of an alternative property. Standard practice for EVAs is to measure the Melt Flow Index (MFI) which is a viscosity test related to molecular weight. The higher the MFI, the higher the molecular weight and viscosity, the higher the penetration the lower average molecular weight and viscosity of the bitumen.
2. Vinyl Acetat Content.
   In order to appreciate the main effect of vinyl acetate on the properties of the modified binder, it is useful to consider a simple illustration of its structure as shown in fig.1. This shows how the regular polyethylene segment of the chain can pack closely together and form what are known as crystalline regions.
   The crystalline regions are relatively stiff and give a considerable reinforcing effect.

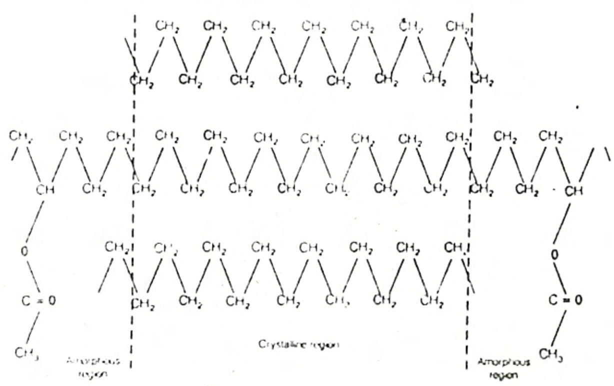


Figure.1 - Packing of the polyethylene in EVA

There is a wide range of EVA copolymer available which are specified by MFI and vinyl acetate content. For example, EVA with an MFI of 150 and a vinyl acetate content of 18 is the 18/150 grade.

From the wide range available the 18/150 and to a lesser extent the 33/45 grade are the most popilar, usually blended in 70 pen bitumen. Eva copolymers are easily dispersed in, and have good compatibility with bitumen. They are thermally stable at normal asphalt mixing temperature.

For this research two types of EVA bitumens containing 5% EVA by weight with 70 pen bitumen grade, were used in HRA TRH-8-78 using Indonesia typical grading.

1. Standard grade, know as "S" grade, which contained 18/150 EVA granules.
2. Flexible grade know as "F" grade which contained 33/45 EVA granules.

Type "F" grade EVA modified bitumen, being more flexible in the preferred choice for asphalt overlays on concrete surfaces, as it provides greater resistance to reflective cracking.

Table. 1. Given effect of EVA on the properties of bitumen.

No.	Binder	Pen 25°C	R&B °C	Temperatur °C		After RTFO	
				For Viscosity of 2 poise	For Viscosity of 50 poise	Pen 25°C	R & B °C
1.	Conventional bitumen (A)	56	52	174	112	37	61
2.	(94 % A + 6 % pen 300) + 5 % EVA	42	68	184	115	33	74
3.	78 % A + 22 % pen 300 + 5 % EVA	51	63	178	109	38	70
4.	A + 2 % EVA	52	60	181	117	32	68
5.	A + 3.5 % EVA	41	64	186	116	29	71
6.	A + 5 % EVA	35	70	195	120	26	78

(Adopted from TRRL Report LR 989, 1981)

6. SCOPE OF LABORATORY WORK

6.1. Testing of binder properties ; -

- 70 pen grade
- EVA type S
- EVA type F

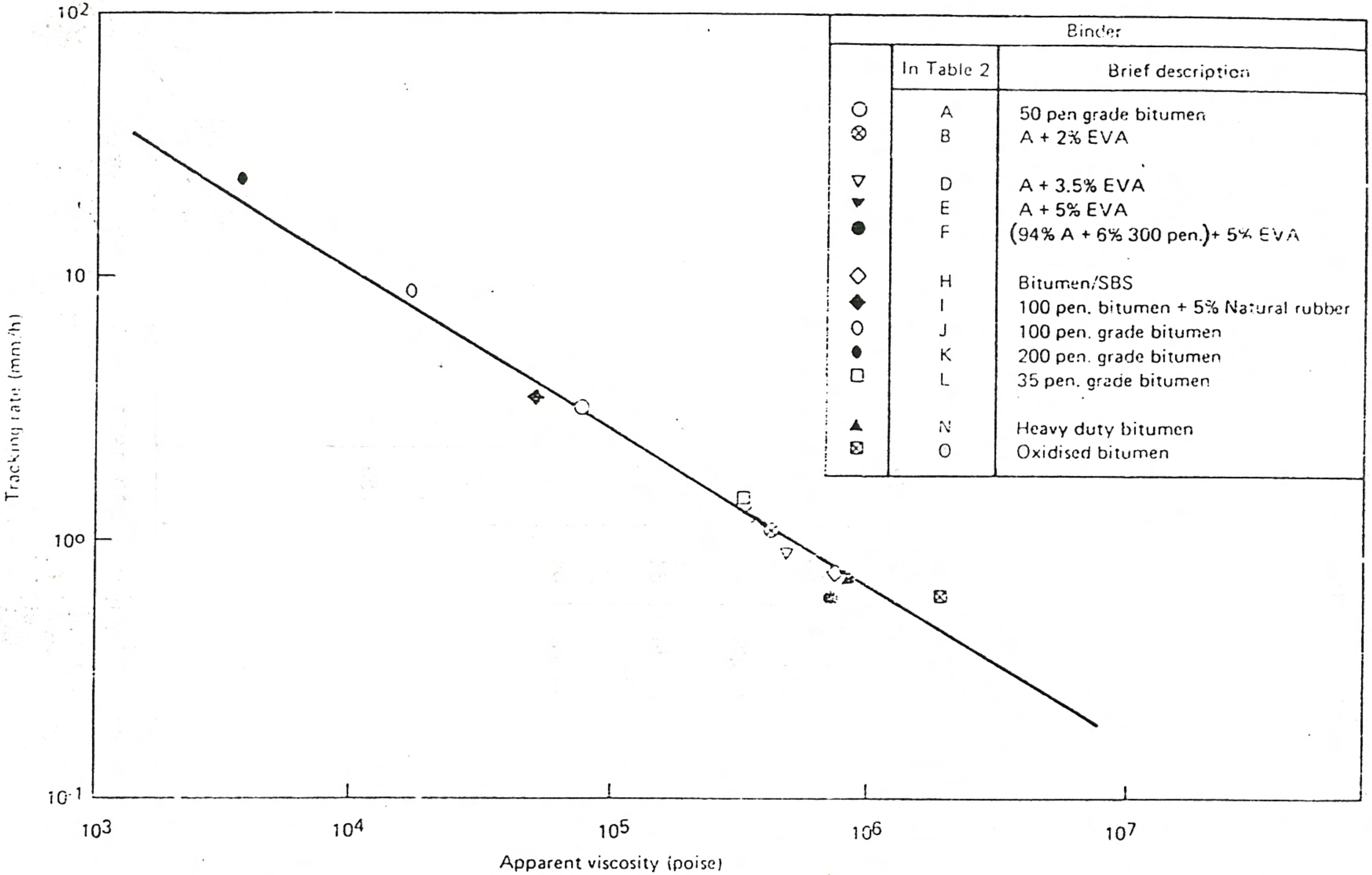
6.2. Testing of aggregate grading and relative density.

- Limestone coarse aggregate
- Limestone dust
- Granite coarse aggregate
- Granite dust
- Asphalt sand
- Filler (lime)

6.3. Trial test

- Marshall Mix Design HRA wearing course BS 594, using granite aggregate and 50 pen grade bitumen.
- Marshall Mix Design HRA wearing course for tropical country (Road Note 31) using limestone aggregate and 70 pen grade bitumen.
- Marshall Mix Design HRA wearing course for tropical country (TRH-8-78) with Indonesia typical grading using limestone aggregate and 70 pen grade bitumen.

Fig. 2. Relationship between the Whell Tracking rate of Rolled Asphalt Containing 30 percent course aggregate and the apparent viscosity of the binder, at 45 oC.



(Adopted from TRRL Report LR 989, 1981)

- Marshall Mix Design HRA wearing course for tropical country (TRH-8-78) with Indonesia typical grading using limestone aggregate and EVA Type S and type F.

6.4. Calculation - to measure
- Marshall stability
- Density
- Marshall flow
- Void in Mix
- Void filled with bitumen
- Optimum binder content.

7. RESULT AND DISCUSSION

7.1 For binder and modified binder properties.

Table. 3. Gives the results of binder properties.

No.	Testing	Result		
		70 pen Bitumen	E.V.A Type S	E.V.A Type F
1.	Penetration, 25°C 200 gr (0,1 mm)	72	53	62
2.	Softening point (°C)	50	51	48
3.	Ductility (Cm)	>140	>140	>140
4.	Flash Point (°C)	298	314	318
5.	Specific grafity	1.0276	1.0257	1.0139
6.	Loss on heating (TFOT) (%)	0.0139	0.0192	0.0122
7.	Penetration after (LOH) (%)	90	84	80
8.	Softening point after (LOH) (°C)	51	55	53
9.	Ductility after (LOH)(Cm)	>140	>140	>140

Type "F" grade EVA modified binder being more flexible to resistance to reflective cracking as shown in table 3. has lower softening point and higher penetration

7.2. Hot rolled asphalt.

7.2.1. HRA Type wearing course from BS 594

Table. 4. Gives the specification for HRA type wearing course for cold country and the Marshall Mix Design result from the experiment

No.	Marshall Result	Spesification	Result	
			Granite Aggregate	Limestone Aggregate
1.	Stability (KN)	6 - 10	9.0	6.4
2.	Flow (mm) min max	2.0 5.0	3.4	2.9
3.	Void in mix (%) min max	3 5	3.8	4.3
4.	Void filled (%) min max	75 85	78.0	76.0
5.	Bitumen content 50 pen grade (%)	6.3	6.15	5.8
6.	Nominal aggregate size (mm)	14	14	14
7.	Density (kg/mm^3)	-	2.336	2.360
8.	Number of compaction (blows)	50	50	50

By using the granite aggregate shows stability is higher than using limestone aggregate, using a limestone aggregate need more bitumen content + 0.5 % to comply with the specification.

7.2.2. HRA type wearing course for tropical country from Road Note 31.

Table. 5. Gives the specification for HRA type wearing course for tropical country from Road Note 31 and the Marshall Design result from the experiment

No.	Marshall Result		Spesification	Result
				Limestone Aggregate
1.	Stability (KN)		3.4	12.2
2.	Flow (mm)	min	2.0	
		max	6.0	2.8
3.	Void in mix (%)	min	4.0	3.4
		max	10.0	
4.	Void filled (%)	min		
		max		77.0
5.	Bitumen content (%)			
	50 pen		-	-
	70 pen		5.5 + 0.3	5.0
6.	Nominal aggregate size (mm)		20	20
7.	Density (kg/mm^3)		-	2.428
8.	Number of compaction (blows)		50	50

The air void in mix was too low, and did not comply with the specification which required an air void in mix between 4 to 10%.
If the void content is too low the aggregate will be unable to retain sufficient bitumen and the mix will lack durability.

7.2.3. HRA type wearing course for tropical country from TRH-8-78.

Table. 6. Gives the specification for HRA type weaaring course for tropical country from TRH-8-78 at typical Indonesian grading, and the Marshall Mix design result from the experiment

No.	Marshall Result		Spesification	Result
				Limestone Aggregate
1.	Stability (KN)		6 - 10	13.0
2.	Flow (mm)	min	2.0	
		max	5.0	3.1
3.	Void in mix (%)	min	3.0	3.6
		max	5.0	
4.	Void filled (%)	min	75	
		max	85	80.0
5.	Bitumen content (%)			
	50 pen		-	-
	70 pen		7 + 0.3	6.2
6.	Nominal aggregate size (mm)		14	14
7.	Density (kg/mm^3)		-	2.380
8.	Number of compaction (blows)		50	50

The objective of designing mixes is to achieve a dense mix of high stability but with sufficient voids between the aggregate particles, ensuring that sufficient bitumen is added to achieve flexibility, durability and workability without sacrificing resistance to rutting or permanent deformation.

For stability up to 8 KN the maximum flow value should be higher for resistance to cracking.

7.3. HRA type wearing course TRH-8-78 + EVA modified binder.

7.3.1. HRA TRH-8-78 + EVA type "S" and type "F"

Table. 7., Gives the specification for IIRA type wearing course for tropical country from TRH-8-78 and the Marshall Mix Design result at typical Indonesian grading and by adding 5% EVA type S and 5% EVA type F. Full detail of graph are given in Appendix. 3

No.	Marshall Result		Spesification	Result		
				Limestone Aggregate		
				Control	Type S	Type F
1.	Stability (KN)		6 - 10	13.0	12.8	9.3
2.	Flow (mm)	min	2.0	3.1		
		max	5.0		3.5	4.0
3.	Void in mix (%)	min	3.0	3.6	4.3	4.1
		max	5.0			
4.	Void filled (%)	min	75	80	76	82
		max	85			
5.	Bitumen content (%)					
	50 pen		-			
	70 pen		7 + 0.3	6.2	6.1	6.3
6.	Nominal aggregate size (mm)		14	14	14	14
7.	Density (kg/mm^3)		-	2.380	2.369	2.365
8.	Number of compaction (blows)		50	50	50	50

Examination of table 7. Show that there is no significant advantage between using modified binder and unmodified binder except in the stability. By using modified binder lower stability and higher flow leading to resistance to rutting and deformation were expected.

8. CONCLUSIONS

8.1 The are three specifications for HRA type wearing courses one for cold country from British Standard, and two specification HRA type wearing courses for tropical countries.
The specifications are modified from HRA in British Standard according to aggregates that are available in the particular country and the climate.

8.2 Specification suggested for use in Indonesia are difficult to achieve due to many variations of available aggregate and tendency for the aggregate to be continuously graded.

8.3 Using EVA modified binder extended the visco elastic range of the binder, decrease the penetration thus improving the properties of the HRA in comparison with modified bitumen.
The result, however the stability decrease but in wheel Tracking test expected that the rate decrease is significantly than the conventional bitumen

9. RECOMENDATIONS

On the basis of the practical work in this experiment, three recomendations can be made.

9.1 The mix of HRA type wearing courses for tropical countries (Road Note 31) needs to be redesigned to improve the air void in order to comply with the specification.

9.2 The HRA type wearing courses from TRH-8-78 using Indonesia typical grading would also redesign to reduce the high stability, before being used to design mixes in Indonesia with the hot climate and high humidity.

9.3 Further work is necessary in order to establish the optimum modification of binder necessary to improve the performance of Indonesia HRA against rutting and current skidding tendencies due to the use excess binder.

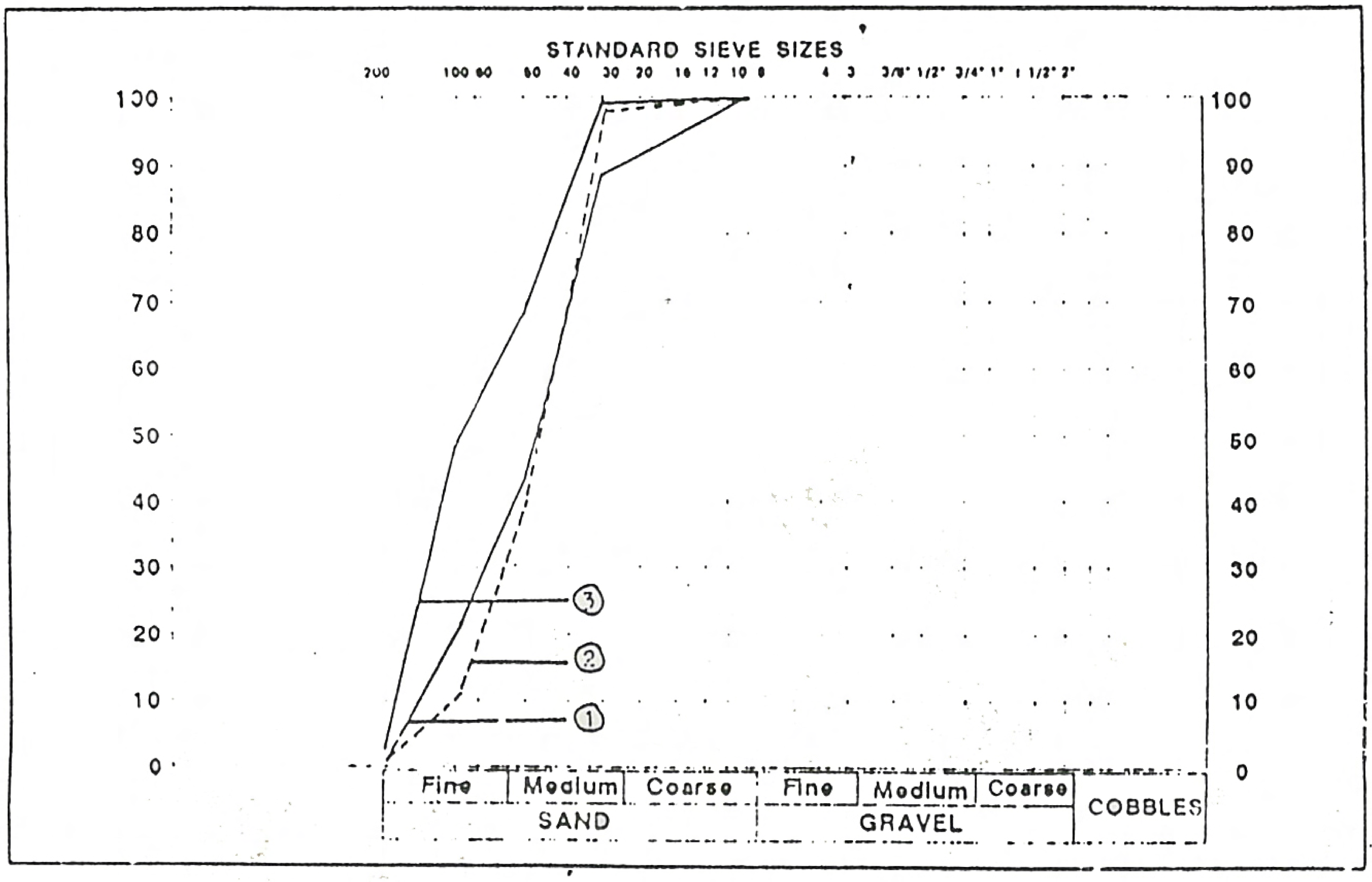
10. REFERENCES

1. Transport and Road research laboratory, A guide to the structural design of bitumen surfaced roads in tropical and sub tropical countries. Departement of the Environment, Road Note 31, London 1977 (HM Stationery office).
2. The Asphalt Institute. Method for asphalt concrete and other hot mix type. Manual series no. 2 (MS-2) college Park, Maryland 1969 (the Asphalt Institute)
3. British Standard Institution. Rolled asphalt (hot process) for roads and other paved areas. British Standard 594; 1973, London 1973 British Standard Institution).
4. Shell bitumen; the shell bitumen Handbook Surrey 1990 (Shell bitumen).
5. Denning J.H. and J.Garswell Improvement in rolled asphalt surfacings by the addition of organic polymers. Department of Environment. Departement of Transport. TRRL report LR 989 1981 (TRRL).
6. George N.Guendaru : Bituminuous mix design for tropical climate. Project report in construstion material training course. Laing Technology Group March 1987.
7. British Standard Institution Method of test for the determination of the composition of design wearing course rolled asphalt. British Standard 598 part 107 1990. London 1990 (British Standard Institution).

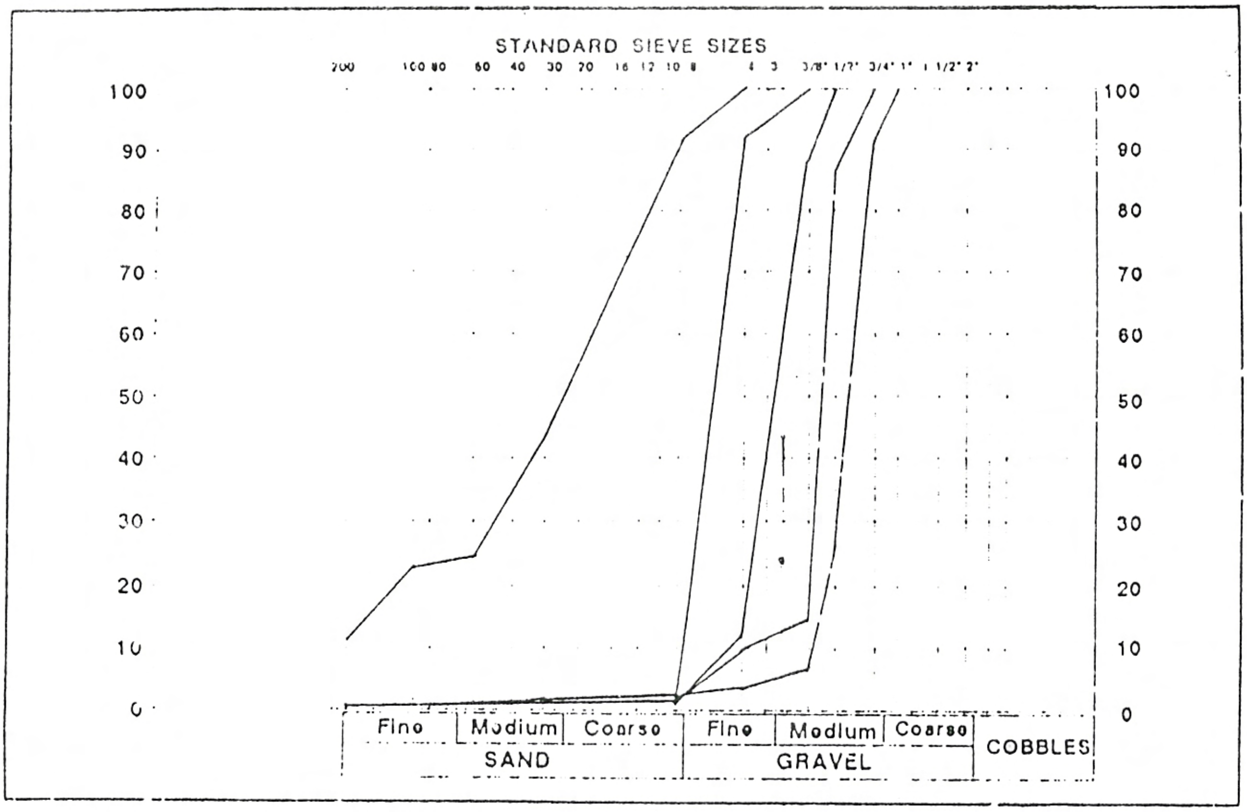
Penulis :
Dra Leksminingsih, Alumni Jurusan Biologi FIPPA UNPAD 1975, Peneliti muda, aktif dalam penelitian aspal, cat dan kimia bahan jalan

Table . 8 Specipic gravity and absorption of aggregate (BS 812 part 2).

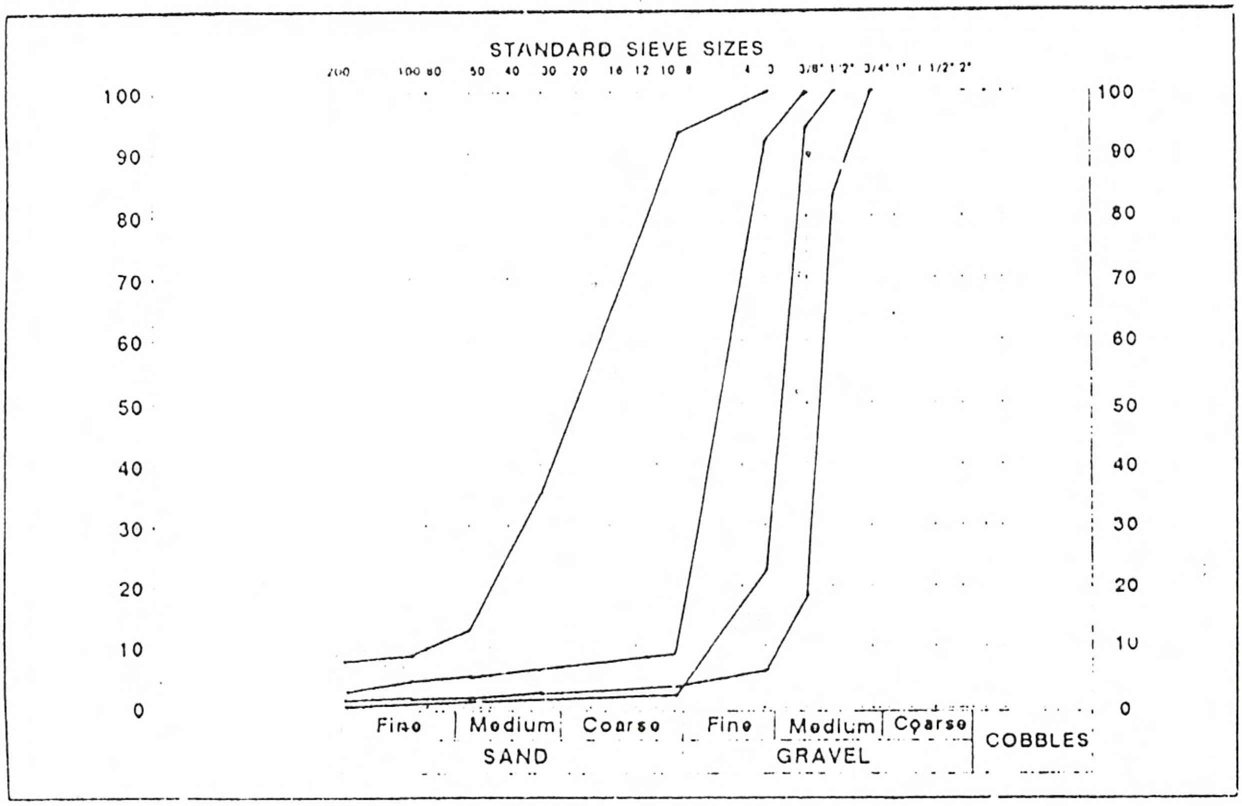
No.	Aggregate Source	Size	Relative Density			Absorp-tion
			Apparent	Oven dry (%)	Saturated Surface Dried (SSD)	
1.	Aggregate ex Foster Yeoman Somerset	20	2.74	2.71	2.72	0.44
		10	2.74	2.70	2.71	0.49
		6	2.74	2.70	2.71	0.68
		Dust	2.78	2.74	2.76	0.47
		Sand filler lime	-	-	2.72	-
2.	Aggregate ex Croft Leicester shire	14	2.68	2.59	2.63	1.20
		10	2.68	2.62	2.64	0.91
		6	2.73	2.64	2.67	1.20
		Dust	2.72	2.66	2.68	0.77



Graph. 1. Grading of sands
1. Thames Valley Sand
2. Harper Lane Sand
3. Mix Asphalt Sand (40% No. 1 + 60% No. 2)

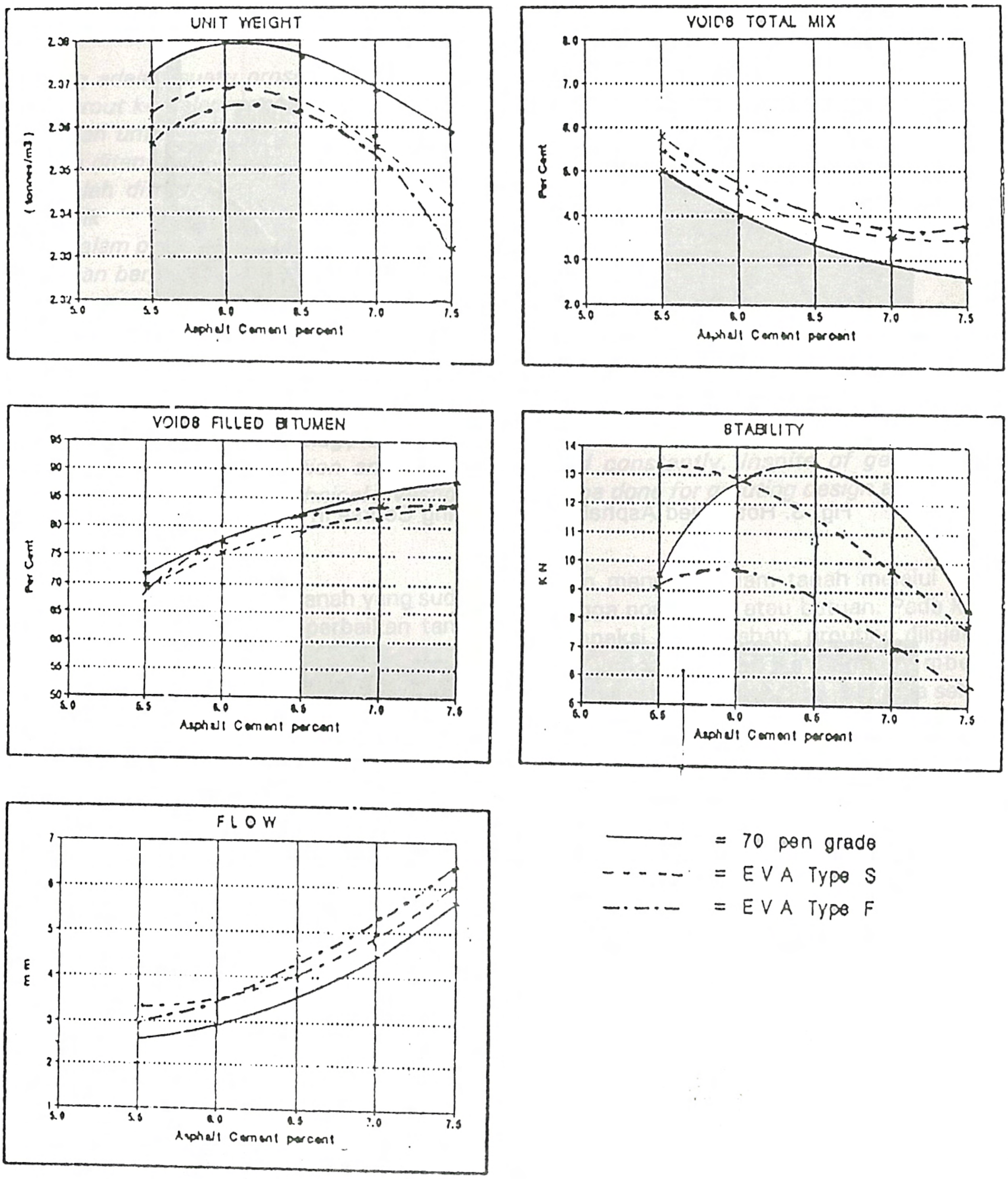


Graph. 2. Grading of limestone aggregate ex. Quarry Foster, Yeoman, Sommerset.



Grap. 3. Grading of Granite Agregate ex Quarry Croft, Leicester Shire.

Graph. 4. Combined Result Mix-Design from HRA type wearing course TRH-8-78 using a mean of Indonesian typical grading and Modified Binder EVA type "S" and EVA type



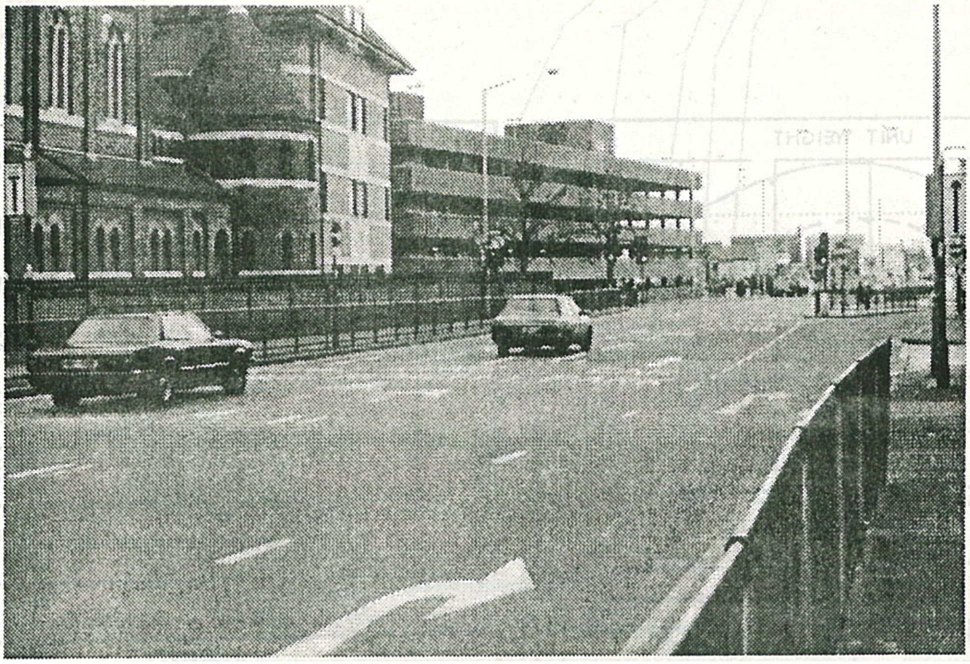


Fig. 3. Hot Rolled Asphalt type Wearing Course in the UK

Fig. 4. Detail HRA type wearing course using lightly chipped(20 m)