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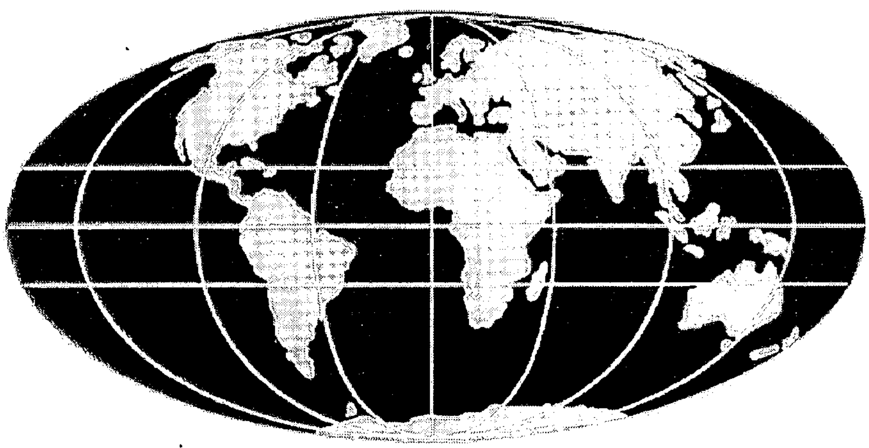

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THE PERFORMANCE OF ASPHALTIC PRE-MIX SURFACINGS IN INDONESIA

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ABSTRACT

Studies have been undertaken over the past three years of the performance of asphaltic overlays in Indonesia. The overlay materials were designed to accomodate a higher than normal bitumen content to improve mix durability and flexibility. The mixes are similar to the UK gap-graded Rolled Asphalt rather than continuously graded Asphaltic Concrete.

The studies have involved an evaluation of performance, for which detailed condition surveys were carried out on more than 300 km of roadway. Subsequently, twenty five sections were selected for long-term study. The sections were chosen to cover the range of standard design parameters, including design traffic, overlay thickness and structural strength, road geometry and mix type and properties.

The paper describes the evaluation methodology used and the preliminary results of the performance studies, including the relation between mix type and mix properties and behaviour.

Recommendations are given to improve the current Indonesian specifications for asphaltic surfacings.

1. INTRODUCTION

A comprehensive research programme to evaluate the performance of road strengthening overlays used in Indonesia has been underway for over three years. The objectives of the studies are to enable improvements in mix design and specifications, construction practice and structural design and to produce road deterioration relationships relevant to the Indonesian environment. Early results from the studies and details of their design and implementation were reported (TOOLE et al, 1990 and 1991).

The types of overlay being evaluated include mixes produced to the 1986 "Specification for High Durability Asphalt" (DGH 1986), known as Hot Rolled Sheet (HRS), and Asphaltic Concrete (AC) mixes produced according to Marshall- design principles (ASPHALT INSTITUTE, 1983).

The basis for the adoption of HRS in Indonesia was first described by Corne (1983). He described an alternative composite overlay system comprising an asphalt treated base (ATB) and HRS wearing course. These materials are designed to accommodate a larger amount of bitumen than AC-type mixes, the aim being to increase flexibility and durability. The HRS is similar to the gap-graded rolled asphalt (RA) used in the UK (BSI, 1985) and Southern Africa (NITRR, 1978). Two classes of HRS are specified, Class A is used for light and medium traffic and Class B is used for heavy traffic and steep grades.

Since the mid-nineteen eighties many thousands of kilometres of road have been overlaid but no quantitative comparison between HRS and AC overlays has been made. Such a comparison is of paramount importance to the Directorate General of Highways (DGH) so that rational decisions can be taken on future road betterment and maintenance schemes. A cooperative research programme between the Indonesian Institute of Road Engineering (IRE) and the Transport and Road Research Laboratory (TRRL) of the United Kingdom has been undertaken to achieve this and is described in this paper.

2. EVALUATION METHODOLOGY AND PERFORMANCE ASSESSMENT

2.1 Evaluation methodology

The scale of the road betterment programme meant that a wide variety of roads had been overlaid under a wide range of conditions. It was anticipated that a study of road betterment projects completed by 1988 would enable the range of the key variables required by the study to be covered. This necessitated "window-monitoring", whereby observations are taken over a limited period of time on sections of varying age. Any factors which could not be examined in this way could be investigated in studies of new overlays or specially constructed trial sections.

The evaluation has so far involved 7 main stages:-

(i) A desk study of design and construction procedures.

(ii) Condition surveys of a sample of road-links to identify general performance trends and mechanisms of failure.

(iii) Selection of a sample of short stretches of road (or monitoring sections) for detailed investigation.

(iv) Determination of the effects of traffic, mix properties and road geometry on mix performance.

(v) Evaluation of problems from the design stage through to construction.

(vi) Identification of inadequate data sets and selection of relevant additional test sections on other completed or new projects.

(vii) Development of improved specifications and design procedures.

2.2 Performance assessment

Pavement condition surveys have been carried out at the following levels of detail (Toole et al, 1991):

LEVEL 1 (PCS1). Visual assessment and measurements within a 100m length of road and for each lane.

LEVEL 2 (PCS2). Detailed visual assessment and measurements within 10m sub-sections.

LEVEL 3 (PCS3). Measurements taken at 10m intervals at specific chainage and wheelpath positions.

The results given in this paper relate to the PCS2 and 3 surveys in which the structural and compositional properties of ten metre lengths of roadway have been related to performance.

The principal performance measurements were rut depths measured at the test points and wheelpath cracking in each ten metre sub-section.

The criteria used are given below:

Rutting	:	Sound	< 10mm
		Critical	10-20mm
		Failed	> 20mm
Cracking	:	Sound	No cracks
		Initiated	< 10% of length affected
		Critical	10-30% of length affected
		Failed	> 30% of length affected

3. GENERAL DESCRIPTION OF THE STUDY SAMPLE

The sample of roads included in the research comprises a total length of 360 km of road-link located in West Java from which twenty five representative sections, most of which were 500m in length, were selected for detailed study. The road-links have been surveyed at intervals of two to three years whilst the monitoring sections were assessed at six monthly intervals.

The types of overlay investigated include 22 sections of nominal HRS and 3 sections of AC laid on asphalt base layers constructed to a common specification. Subsequent analysis of mix properties has shown that 35% of the surfacings are of an AC-type, 50% are of an intermediate gradation and 15% are of an RA-type.

The thicknesses of the composite overlay ranged from 50mm to more than 200mm. The original surface prior to overlay was Penetration Macadam on 21 sections and natural granular materials for the remaining sections. Subgrade CBR's were between 1 and 6 per cent.

4. PROPERTIES OF THE ASPHALTIC SURFACINGS

The properties of the asphaltic surfacings taken from each homogeneous road section, divided by mix specification, are given in Table 1. It is clear that mixes produced to the same target specification cover a wide spectrum and possess grading characteristics ranging from continuously- graded to gap-graded mixes.

In order to distinguish between mixes a method of classifying them into gap-graded or continuously- graded types has been devised and involves determining the amount of material retained between the 2.36mm and the 0.6mm sieves. The method is based on the BS 594 Specification for RA (BSI 1985) in which an upper limit is placed on this amount. The limit is set according to coarse aggregate content (CA) and ranges from 9 to 14 per cent for CA of 55 and 30 per cent respectively. The following three classes of mix were identified in relation to the BS 594 upper limit:

Gap-graded : where the amount retained is less than the upper limit.

Intermediate : where the amount retained is up to 5% above the upper limit.

Continuous : where the amount retained is more than 5% above the upper limit.

Nearly 70% of all mixes laid on medium and lightly trafficked roads are of the continuous type, the remainder are mainly intermediate. On heavily-trafficked roads, gap-graded, intermediate and continuos type mixes account for 30, 50 and 20 per cent respectively.

Table 1

Properties of the asphaltic surfacings by target specification

Contract package	TBC (%)	EBC (%)	CA (%)	FA (%)	FF (%)	VIM (%)	Ft (um)	f/b Ratio
HOT-ROLLED SHEET CLASS A								
Specification	> 7.3	> 6.8	20-40	47-67	5-9	3-6	>8	> 0.73
CP 39	8.1 (1.00)	7 (1.00)	53 (3.9)	30 (3.2)	8.4 (2.3)	2.4 (1.4)	7 (2)	1.2 (-)
CP 40	7.0 (0.48)	5.8 (0.54)	54 (2.7)	30 (2.4)	8.9 (2.1)	6.1 (2.5)	7 (1)	1.5 (0.4)
HOT-ROLLED SHEET CLASS B								
Specification	> 6.7	> 6.2	30-50	39-59	4.5-7.5	3-6	>8	> 0.73
CP 11	7.4 (0.37)	6.2 (0.47)	44 (5.6)	40 (5.5)	8.0 (2.4)	6.4 (3.2)	6 (1)	1.3 (0.45)
CP 12	7.6 (0.40)	6.3 (0.40)	54 (2.8)	30 (2.5)	7.7 (1.7)	2.0 (1.9)	8 (1)	1.2 (0.30)
CP 21	6.7 (0.56)	5.6 (0.62)	55 (3.6)	30 (2.9)	7.8 (1.0)	1.7 (1.9)	7 (1)	1.4 (0.25)
CP 38	7.2 (0.52)	6.1 (0.67)	56 (4.7)	29 (4.7)	7.9 (1.7)	5.4 (2.5)	6 (2)	1.3 (0.4)
CP 39	7.2 (0.58)	5.8 (0.42)	52 (3.5)	30 (3.6)	10.2 (3.6)	5.2 (1.5)	5.4 (1)	1.9 (-)
CP 40	7.4 (0.42)	5.8 (0.35)	52 (8.2)	33 (7.1)	7.8 (2.1)	5.7 (2.9)	7 (1)	1.3 (0.3)
ASPHALTIC CONCRETE								
CP 21	5.9 (0.39)	48 (0.50)	58 (2.8)	28 (2.7)	8.1 (0.5)	3.5 (2.3)	6 (1)	1.7 (0.19)

Notes: 1. Mean and standard deviation (in brackets).

2. CA - Coarse aggregate fraction
FA - Fine aggregate fraction
FF - Filler fraction
VIM - Voids in the mix(air voids)
TBC - Total bitumen content
EBC - Effective bitumen content
Ft - Bitumen film thickness (effective)
f/b - Filler:binder ratio (effective)

5. RELATIONSHIP BETWEEN MIX PROPERTIES AND PERFORMANCE

5.1 General

The data for locations where performance has been affected by factors such as poor road widening practice or inadequate pre-treatment of an existing damaged surface have been excluded from the analysis.

The analysis has included the following:

(i) Relationship between mix type and performace.

(ii) The ability of two alternative specifications, namely BS 594 (1985) and TRH 8 (1978) to identify satisfactory mixes.

(iii) Influence of specified mix properties and composition (DGH 1986) on performance.

Analysis (i) and (ii) above included data from all monitoring sections. Analysis (iii) has so far only included data from the most heavily-trafficked roads. These have carried 3,000 to 4,000 ESA per day for a period of five years, equivalent to 5.5-7.5 million ESA since overlay.

The results should be considered as preliminary and their statistical base will be improved following the completion of further sampling and testing which will increase the sample five-fold.

5.2 Effect of mix type

Time-series data for each sampled location has been examined and the percentage of locations giving satisfactory or unsatisfactory performance for each mix type and traffic level determined. The sample comprises 18 gap-graded mixes, 56 intermediate mixes and 45 continuously-graded mixes. The ages of the roads and the cumulative traffic loading correspond with between 35 and 50 per cent of the expected design life. Details are given in Table 2.

Table 2

Performance of the overlays

Traffic	All levels		Heavy only	
Mix	Satisfactory (per cent)	Unsatisfactory (per cent)	Satisfactory (per cent)	Unsatisfactory (per cent)
Gap graded	94	6	94	6
Intermediate	69	31	60	40
Continuously graded	71	29	50	50

The satisfactory category includes locations in a sound condition or where cracking has begun but extends to less than 10 per cent of the sampled location. In such cases normal routine or surfacing maintenance should be sufficient to arrest or retard deterioration.

The incidence of severe cracking by mix type is 6, 16 and 25 per cent for gap, intermediate and continuously-graded mixes respectively. The incidence of severe rutting is 0, 15 and 4 per cent respectively.

The results confirm that gap-graded mixes generally give satisfactory performance. The performance of the other mix types is more variable.

5.3 Alternative specifications

The performance of mixes which conform to two alternative specifications, BS 594 (BSI, 1985) and the South African Guidelines for gap and semi gap-graded bituminous wearing courses (TRH 8) (NITRR, 1978), has been examined.

Both specifications contain a combined grading envelope and recommend that a Marshall-design approach is followed to obtain the optimum binder content. BS 594 allows the use of a recipe approach where experience indicates that the mix will be satisfactory.

Fifteen per cent of all mixes fulfill the BS 594 criteria for combined grading and the overall percentage success rate is the same as that for gap-graded mixes (see Table 2 above). Only in one case has failure occurred.

When compared with the requirements of TRH 8, 39 per cent of all mixes fulfill the combined grading criteria. These comprise all gap-graded mixes and approximately 40 per cent of the intermediate mixes, again these mixes had high ratings for performance.

5.4 Effect of mix properties and composition

The HRS specification requires the mix to conform to specified values for eight mix properties. It also states that the governing criteria should be to ensure that the air voids content lies near the centre of the specified range while the bitumen film thickness should be as high as possible (for maximum mix durability). The Marshall stability and Quotient criteria should also be met (for adequate mix strength). For practical purposes a minimum effective bitumen content and a range of mix design fractions are specified. Trial mixes are produced and adjusted until the criteria are met.

It has not been possible to examine the original Marshall test criteria since records are not available but the effect of the following individual properties on performance has been examined

In-place Air Voids Content (ie. After Trafficking)
Bitumen Film Thickness
Effective Bitumen Content
Total Bitumen Content
Coarse Aggregate Fraction (>2.36mm)
Fine Aggregate Fraction (75 um - 2.36mm)
Filler Fraction (<75 um)
Effective Filler : Bitumen Ratio
Per cent retained between 2.36mm and 0.6mm sieves.

Table 3: Relationship between mix properties and performance for heavy traffic: Percentage of samples in each property range

Bitumen film thickness (Microns)	5-6	6-7	7-8	8-9	9-10	10-11	11-12
Sound	77	81	74	77	100	100	100
Cracks	33	13	0	0	0	0	0
Ruts	0	6	26	23	0	0	0

In-place air voids (% by volume)	< 2	2-3.99	4-5.99	6-7.99	8-9.99	> 10
Sound	72	87	80	75	100	0
Cracks	0	0	20	25	0	100
Ruts	28	13	0	0	0	0

Effective bitumen content (% by weight of mix)	4.7-5.19	5.2-5.69	5.7-6.19	6.2-6.69	6.7-7.19	7.2-7.69	> 7.7
Sound	83	50	94	79	80	100	33
Cracks	17	17	6	0	20	0	0
Ruts	0	33	0	21	0	0	67

Total bitumen content (% by weight of mix)	6.2-6.69	6.7-7.19	7.2-7.69	7.7-8.19	8.2-8.69	> 8.7
Sound	60	82	75	92	100	0
Cracks	20	9	5	0	0	0
Ruts	20	9	20	8	0	100

Coarse aggregate fraction (% >2.36mm)	30-39.9	40-49.9	50-59.9	> 60
Sound	-	67	81	80
Cracks	-	0	9	0
Ruts	-	33	10	20

Fine aggregate fraction (% Retained 2.36mm - 0.075mm)	20-29.9	30-39.9	40-49.9	> 50
Sound	74	71	-	-
Cracks	8	18	-	-
Ruts	18	11	-	-

Filler fraction (%< 0.075mm)	4.5-7.49	7.5-9.99	10-12.49	> 12.5
Sound	89	83	50	0
Cracks	0	0	40	100
Ruts	11	17	10	0

Filler:binder ratio	< 0.7	0.7-1.19	1.2-1.49	1.5-1.99	> 2.0
Sound	100	88	79	67	0
Cracks	0	0	0	13	100
Ruts	0	12	21	20	0

% retained 2.36mm-0.6mm	< 6	6-7.99	8-9.99	10-11.99	12-13.99
Sound	100	100	92	75	63
Cracks	0	0	0	12	11
Ruts	0	0	8	13	26

The percentage of sound, cracked and rutted locations have been determined for each property range and the results are shown in Table 3. Comments on these are summarised in Table 4.

Table 4

Effect of mix properties on performance

MIX PROPERTY	EFFECT	COMMENTS	SUGGESTED LIMITS *
Voids in Mix	Rutting at low values. Cracking at high values.	Use of 50 blow Marshall test probably underestimated traffic compaction. Use 75 blow test	2 - 8 per cent
Bitumen film thickness	Rutting at high values. Cracking at low values.	-	>6 microns
Effective bitumen content	Rutting at high values. Cracking at low values.	Rutting at low values coincides with continuously graded mixes. Cracking at high values related to high f/b ratio	>5.7 per cent after allowing for plant tolerances
Total Bitumen content	-	No clear relationships.	>6.2 per cent
Coarse Aggregate	No clear trend	-	45 - 55
Fine Aggregate	Low FA (<30 per cent equates with rutting)	-	30 - 40
Filler	More than 10 per cent equates with cracking	-	4.5 - 10
Filler to binder ratio	More than 1.5 equates with cracking	-	0.7 - 1.3 (0.7 - 1.0 preferred)
Material 2.36 to 0.6mm	Good performance at low values. Variable performance at high values	-	<13. preferably <8.

* for gap or semi-gap graded mixes

6. CONCLUSIONS

The main conclusions drawn from this research are as follows :

1) The performance of overlays laid to a number of target specification has been very variable, with critical conditions being reached at the highest traffic levels within 35-50 per cent of the planned design lives. High variability in mix properties and non-mix related factors have contributed to this result.

2) Relationships between the properties of the asphaltic surfacings and performance have shown that semi-gap to gap-graded mixes are superior to continuously graded asphaltic concretes.

3) Two alternative specifications for gap and semi-gap graded mixes were assessed and found to relate closely to the properties of satisfactory mixes.

4) Further research is required to develop an improved HRS specification for use in the most heavily trafficked design situations. The results of this research will be used as the basis of a trial specification.

7. ACKNOWLEDGEMENTS

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