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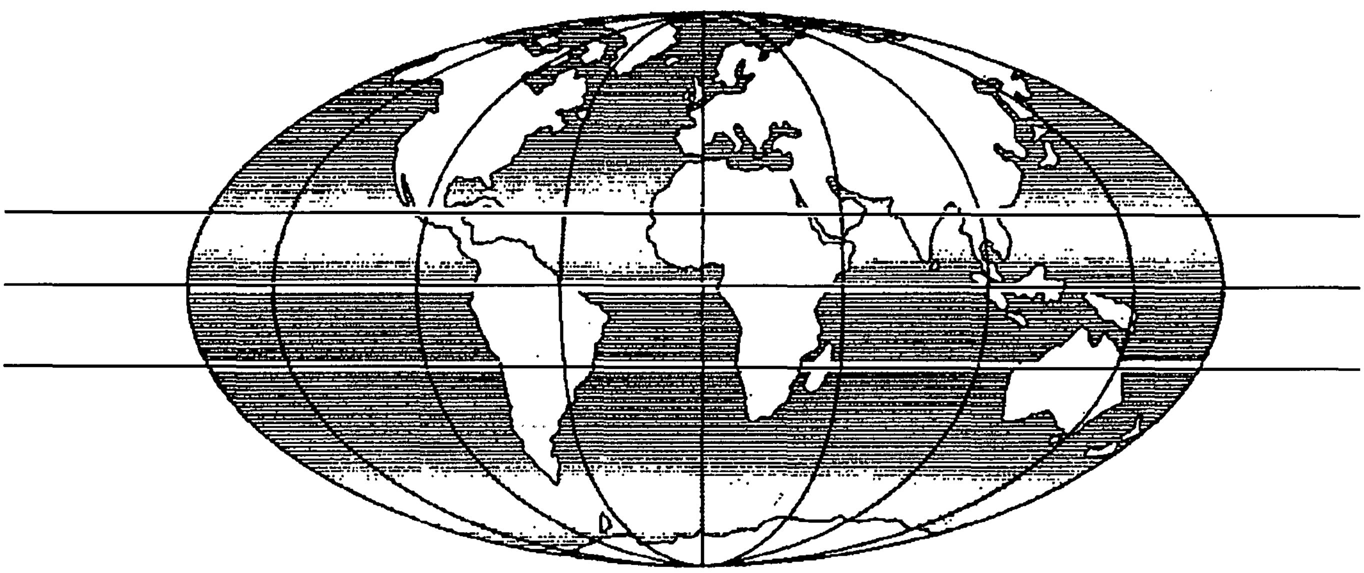

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RESEARCH ON THE SPECIFICATION AND DESIGN OF HOT-MIX ASPHALT SURFACINGS IN INDONESIA

by

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ABSTRACT

A research programme to evaluate the types of road strengthening overlay used in Indonesia has been underway for the last six years (1988-1994). The studies have been carried out jointly by the Indonesian Institute of Road Engineering (IRE) and the Transport Research Laboratory (TRL) of the United Kingdom. The general objectives of the research were to improve material specifications and mix designs, performance predictions and structural design methods.

This paper is primarily concerned with the specification and design of hot-mix asphalt surfacings and contains a review of selected specifications and design methods; summarises the results of performance studies, with particular reference to high durability mixes subject to heavy traffic; and describes a new mix design method and preliminary results of its application in practice.

Recommendations are given for the revision of exising specifications and mix design which-

1. Identify target compositional requirements based on performance in Indonesia,
2. minimise the amount of Marshall tests and introduces a refusal density approach to mix design,
3. simplify the data interpretation stage, and
4. enable a practical target range of bitumen content to be identified, which takes into account the requirements of strength, durability and production tolerances.

1. INTRODUCTION

A collaborative research programme on road engineering was initiated in 1988 between the Institute of Road Engineering (IRE) and the Transport Research Laboratory (TRL). The studies have concentrated on hot-mix asphalt technology since these mix types comprise the surfacing of approximately 56% of the National and Provincial road network (in 1991).

The research embraces overlay design, asphalt mix performance, specifications, quality control and construction practices, the development of road deterioration models for planning purposes and data collection methodologies.

The primary aim of the research is to provide a definitive comparison of alternative asphalt surfacings and overlays, so that the Directorate General of Highways (DGH) cam make rational decisions on future road betterment and mainteance options.

The types of asphalt surfacing being examined include asphaltic concrete produced according to Marshall principles (ASPHALT INSTITUTE 1984) and hot rolled sheet (HRS) mixes introduced into Indonesia in the mid nineteen eighties in response to the premature failure through cracking of many AC mixes, this being ascribed to their sensitivity to small changes in composition which gave rise to poor durability and flexibility. The variable and weak nature of many pavements which were being overlaid at the time warranted a more flexible overlay system.

The HRS materials were designed to accommodate a larger amount of bitumen than AC mixes, to give better flexibility and durability. The material possesses similar properties to the gap-graded Rolled Asphalts (RA) used in United Kingdom (BSI, 1992) and South Africa (NITRR, 1978) and is more tolerant of minor changes in composition and easier to make successfully. The basis for the adoption of HRS was fully described by Corne (1983).

This paper is primarily concerned with the specification and design of hot-mix asphalt surfacings and in particular describes progress on the following:

a) the compositional and physical properties of satisfactory mixes, and
b) modifications to mix design practice.

Emphasis is placed on the performance and design of hot rolled sheet asphalts for use in conditions of heavy traffic.

2. REVIEW OF REQUIREMENTS FOR ASPHALT SURFACINGS

2.1 Typical requirements

Various authorities have developed mix design methods and specifications which are often based on long experience. Most methods use the Marshall test and incorporate the recommendations issued by the Asphalt Institute (1984).

The objective of design testing is to determine an economical blend and grading of aggregates (within the project specifications) and asphalt that yields a mix which has

i) **Sufficient asphalt** for good durability.
ii) **Sufficient mix stability** to withstand traffic forces without distorting.
iii) **Sufficient voids** to prevent bleeding and loss in stability, yet low enough to reduce binder hardening.
iv) **Sufficient workability** to permit efficient placement.

Trial mixes and final job mixes are chosen with the following considerations in mind:

a) The aggregate gradation should be within the specification limits that the asphalt mixing plant is capable of producing.
b) Extremely high stability should not be sought at the expense of lower durability, or vice versa. A compromise is necessary.

Emphasis is placed on the coordination of all stages of mix design testing within a project. Four stages are defined, the purpose of which are outlined below:

<u>Preliminary design testing.</u> This is done to identify satisfactory aggregates and asphalt and to examine trial mixes with a particle size distribution (PSD) approaching the <u>median</u> of the specification limits. This first stage serves to ensure the supplier that the design requirements can be obtained economically.

<u>Source acceptance testing.</u> This is done after award of contract to assure both parties in a contract that the proposed sources will yield a satisfactory mix. The main objective is to determine the most economical blend in order to set the Job Mix Formula (JMF).

<u>Job-mix control testing.</u> This is performed at the start of plant production using samples taken from the plant's hot-bins after calibration of the mixing plant for the proposed JMF to ensure that the plant can provide material which fully meets the requirements of the specification.

<u>Construction control testing.</u> This testing is done on a routine basis to check compliance with the JMF and overall specification requirements, and comprises determination of mix composition and field density. Results may indicate a need to re-evaluate the accepted JMF. Compliance should be checked on a daily basis and whenever there is a hint that the mix is outside the job tolerance.

The optimum binder content is established using the results of Marshall tests by taking the average of the binder contents (BC) which give (i) maximum stability, (ii) the maximum unit weight and (iii) the median of the air voids (VIM) limits. The approved mix should also comply with the specified limits for Marshall flow and the minimum voids in the mineral aggregate (VMA). In addition, the combined grading of the material should fall within the particle size distribution limits for the particular mix. The Marshall results should also be checked for consistency, eg. the stability-BC and density-BC relationships should exhibit a peak.

Criteria may also be given for a minimum bitumen film thickness (BFT), or a maximum filler:binder (F/B) ratio, to ensure adequate durability.

2.2 <u>TRL Overseas Centre (1993)</u>

The TRL has incorporated it's extensive experience in the design of asphalt mixes for tropical conditions into the 4th edition of Road Note 31 (TRL 1993).

The TRL guidelines emphasise the difficulty of meeting the conflicting requirements necessary to provide a durable yet deformation resistant mix. The need for strict tolerances and a high level of quality control is advised.

Three main types of asphalt surfacing are specified, namely:

- i) Asphaltic concrete (AC),
- ii) Bitumen macadams (BM) (with surface dressing), and
- iii) Rolled asphalt (RA).

Bitumen macadams are continuously graded mixes similar to asphaltic concretes but usually with a less dense aggregate structure. They have been developed in the United Kingdom from empirical studies but have performed well in the tropics under heavy traffic and at severe sites provided they have received a surface dressing soon after laying to prevent embrittlement.

Compliance with both compositional limits and mix design criteria is required for all mixes and each can be used in a wide range of situations although preferences are indicated, including-

- a) Bitumen macadams designed using Marshall procedures and with a surface treatment added after a few months are recommended at all sites sites. On severe sites AC mixes are likely to be too sensitive to errors in proportioning and mix tolerances are likely to be too narrow and RA mixes are likely to lack stability.
- b) In open terrain or under conditions of light traffic, rolled asphalts are likely to be suitable. These latter mixes when produced using natural fine aggregates are generally more workable and more tolerant of proportioning errors than AC.
- c) For conditions of heavy traffic and severe sites a refusal density design, preferably using a modified version of the BS Percentage Refusal Density test (BSI 1989), is recommended to ensure that the refusal (or in-place) voids are greater than 3 per cent. For other situations the minimum VIM can be reduced to 2 per cent. The aim is to prevent the occurrence of plastic flow.

TRL suggest that the optimum bitumen content is established by determining the range of bitumen content (BC) over which all properties are acceptable and identifying a target binder content at the centre of this range as the job mix value. This procedure reduces problems encountered in interpreting Marshall test data and has the added advantage in that it clearly identifies the actual range of production tolerances for a particular mix.

Production and compaction trials are considered as essential final stages in the development of a job mix.

2.3 Directorate General of Highways of Indonesia

In recent years the following mixes have been used, namely:

i) high durability HRS asphalts (DGH 1986), and
ii) dense graded asphalt mixtures (Asphaltic Concrete) incorporating Marshall design (DGH, 1992).

2.3.1 High durability asphalts

Two types of HRS were specified and used almost exclusively throughout the period 1986-92. Class A was used on more lightly trafficked roads and Class B was for heavy traffic and steep grades. Requirements are summarised in Table 1.

Adopting the HRS specifications was an important departure from convention requiring, in particular, a minimum effective bitumen content (EBC). The need to attain satisfactory air voids (VIM) and bitumen film thickness (BFT) was emphasised whilst other requirements were considered to be of secondary importance. Compositional limits for an all-in combined grading were not given. Instead, by a process of 'trial-and-error', starting with a nominal recipe, the various proportions of coarse aggregate (CA), fine aggregate (FA), filler (FF) and binder were to be optimised to achieve the best formula that met the end-product requirements of the Specifications. The best recipe was selected as the JMF based on the following order of priority:

a) air voids at the centre of the specified range
b) maximum bitumen film thickness
c) Marshall Quotient within specified range
d) Marshall stability within specified range
e) lowest effective bitumen content within specified range

It was then intended that the chosen JMF would be used as the job specification with allowable tolerances applied to take into account production variability and testing reproducibility.

2.3.2 Dense Graded Asphalt

Asphaltic concrete (AC) designed by the Marshall method was reintroduced in 1992 by the Directorate General of Highways for use on heavily trafficked roads, intersections and other areas where the surfacing is subject to severe wheel loadings, ie. conditions similar to where HRS B was used earlier.

The requirements for AC surfacings are summarised in Tables 1 and 2.

The design approach involves preparing a provisional job mix (PJM) based on the compositional limits and then subjecting this to the full range of specified tests. Thereafter the mix is altered until a satisfactory and economic design is obtained. The provisional optimum binder content is determined using Asphalt Institute procedures. Additional test specimens are then prepared to assess the susceptibility of the PJM to variations in combined grading and binder content and the mix which satisfies the specification requirements for all mix variations is then chosen as the Job Mix.

In practice, tolerances are applied to the job mix for quality control testing.

3. RESULTS OF RECENT PERFORMANCE STUDIES IN INDONESIA

3.1 Summary of main findings

Evidence from this research programme (IRE, 1992, 1993a and 1993b) has quantified the performance of a wide variety of asphalt mixes. The main findings were as follows:

i) A large proportion (> 70 per cent) of mixes laid on heavily trafficked roads which did not pass existing specifications have performed satisfactorily.

ii) The performance of nominal HRS mixes was strongly related to mix type. For gap-graded, intermediate and continuously-graded types the percentage of mixes in a satisfactory condition after five years service was 94 per cent, 70 per cent and 50 per cent respectively.

iii) Satisfactory performance was highly correlated with a number of individual mix and compositional properties. In order of importance these included the percentage material retained between the 0.6mm and 2.36mm sieves (for nominal HRS mixes only), in-place voids and bitumen film thickness.

iv) The in-place voids after heavy trafficking was approximately equal to the voids determined in the modified refusal density (RD) test (Edwards and Mulyadi, 1992). For a sample of mixes examined, the 50 blow and 75 blow Marshall tests produced voids up to 4% higher than the RD test at similar bitumen contents hence, in all likelihood, for HRS mixes the Marshall test over estimates the bitumen content which gives safe voids (3 to 5% VIM).

v) The specified range of binder content and of combined aggregates was only met in 22 per cent and 54 per cent of the cases examined respectively and, hence, the allowable tolerances were considered unrealistic in comparison with plant capability, and typical international requirements.

The coverage of different mix types in the research was not uniform, for instance most gap-graded mixes occurred on heavily trafficked roads and continuously graded types, including true AC's, were only represented on light and medium trafficked roads. Mixes with an intermediate gradation were represented in most situations. In the continuation of the research this imbalance will be improved. However, it is important that the results are taken into account in the revision of specifications since they best represent the composition of mixes which can be produced by Indonesian Contractors.

3.2 Discussion and recommendations

3.2.1 Mix composition.

Comments on the effect of changes in compositional properties on the performance of gap and semi-gap (or intermediate) graded HRS mixes under heavy traffic are presented in Table 3 together with target values for key properties. Mixes with these properties have performed satisfactorily over a period of 5 to 7 years on some of the most heavily trafficked roads in Indonesia, and have carried more than 6 million ESA. Average post overlay Benkelman beam deflections were up to 1.0 mm under an 80 kN load. The average thicknesses of the asphalt overlays were in the range 110 mm to 170 mm. The suggested stone content of the mixes is higher than previously recommended and the minimum bitumen film thickness is lower, but is comparable with limits originating from studies in the United States (FORD 1988 and NAPA 1989). In line with the earlier HRS philosophy it would not appear essential to specify a combined aggregate grading envelope.

Evidence of the performance of asphaltic concrete overlays designed to Marshall methods is limited, this being a consequence of the change to HRS mixes in the mid nineteen eighties. It is suggested that the present DGH (1992) limits are applied for most circumstances. However, for severe sites a refusal density approach is essential.

3.2.2 Mix design criteria

The recommended mix design criteria for asphalt surfacings for use in heavy traffic have been reviewed and differences between Indonesian practice and recommendations of the Asphalt Institute and TRL have been identified. A few points are worthy of mention.

Firstly, only the DGH Specification for HRS requires the Marshall stability of a mix to be within a specified range. This restriction coupled with a specified Marshall quotient range was intended to ensure that the designed mix was sufficiently flexible to cope with the expected high tensile strains which could occur in overlays of a medium thickness (50 - 125 mm thick) on weak Indonesian pavements (mean 80 kN design deflection > 1.0 - 2.0 mm). This is the basis of the HRS overlay design method of which mix design is an integral part (CORNE 1983). Under these circumstances a controlled strain regime occurs and placing limiting values on mix stiffness is necessary to reduce the stress on the asphalt and to improve fatigue life. However, at lower in-service deflections and with thick bituminous layers (> 125 mm) a controlled stress regime will exist. Under these conditions fatigue life will increase with the use of higher stiffness mixes (SHELL, 1990). Thus the selection of mix specification is inextricably linked with design conditions and from a practical viewpoint separate requirements are needed for the design of thin overlays and for thick overlays.

Taking the above into consideration new recommended requirements for HRS mixes in Indonesia are given in Table 4. Further studies are however required to extend the application of the Refusal Density Test to light and medium trafficked roads.

A notable feature of the refusal density test is that it can be used to predict refusal density at any bitumen content. Hence, if adopted, it would clearly identify mixes with potentially low voids, which the present HRS design method fails to do.

3.2.3 **Other considerations**

Three further areas warrant consideration, namely-

i) allowable production tolerances,
ii) trends in mix design data, and
iii) requirements for component materials.

The present tolerance limits for bituminous materials (0 to plus 0.5 per cent) and filler content (±1.5 per cent) appear unrealistic. Typically, the standard deviation within a day's production for projects investigated during this study was of the order of 0.3 per cent bitumen content and 1.1 per cent filler content respectively, thus the range of acceptable values based on 1 in 20 samples falling outside the limits would be ± 0.6 per cent and ± 2.2 per cent respectively. It is recommended that the interpretation of mix design data takes into account the likely range of bitumen content when a target value is determined for a job mix.

It has also been found from analysing a large number of mix designs covering a variety of compositions that only in approximately 30 per cent of cases did the expected ideal trends in design data occur, such as peaks in the stability and density-bitumen content relationships. In all cases the expected trend of reducing air voids against increasing bitumen content occurred. Given that there is considerable uncertainty in interpreting Marshall data it is suggested that the bar chart approach recommended by TRL is adopted. The method is fully compatible with the HRS design approach. It has the added advantage of identifying the range of bitumen content for which all specified properties are satisfied and this can be compared with the expected production variability.

Revisions to present requirements for fine aggregates for HRS mixes are also suggested to ensure that a gap will occur in the combined grading. This can be acheived by limiting the amount of overlap in the grading of the fine and coarse aggregate fractions and choosing fine aggregates with only a small amount retained between the 0.6 mm and 2.36 mm sieves.

4. THE IRE-TRL "TRIAL" MIX DESIGN METHOD

A new mix design approach has been developed which incorporates key elements of the Asphalt Institute, the TRL and existing DGH procedures and recent experience in Indonesia. The method and an example of its application is described below.

4.1 Description of the "trial" mix design method

The proposed new procedure includes the following six stages:

Stage 1 Selection of suitable component materials.

Stage 2 Selection of a suitable blend of aggregates and bitumen which satisfy a target composition and a number of key properties.

Stage 3 Preliminary design testing, incorporating use of a modified version of the British Standard Refusal Density Test (BSI, 1989) to supplement the Marshall Test, using stockpile or supplied aggregates.

Stage 4 Evaluation of the results and selection of a trial production mix making use of a bar chart method of presentation to define the common range of bitumen content over which all requirements are met.

Stage 5 Production trials to calibrate the plant, to determine production variability and a suitable compaction procedure.

Stage 6 Repeat design testing using aggregates from the plant.

For Stage 2 a customised spreadsheet-based calculation procedure has been developed which comprises the following steps:

a) Entering the properties of the fine and coarse crushed aggregates (CA) and natural fine aggregates (FA);
b) Entering selected target values for key properties of the combined mix, including for CA , filler content (FF) and target effective bitumen content (EBC);
c) Choosing a number of mix variants by varying the coarse aggregate content of the total mix by increments (eg. 30, 40, 50 per cent, etc.) and the ratio of crushed to natural fine aggregate (eg. 1:2, 1:1, 2:1, etc.);
d) Determining the consequences of (c) above, by calculating the composition of combined mixes and the values of additional key properties, such as the bitumen film thickness (BFT), the per cent material retained between the 2.36mm and the 0.6mm test sieves (for HRS mixes) and the combined grading, the required amount of added filler and the required blending proportions for manufacturing the trial mix;
e) Selecting potential trial mixes for laboratory examination by comparing the results of (d) with the specification limits.

In Stage 3 specimens are prepared at intervals of 0.5% bitumen content from one per cent below the target effective bitumen content to two per cent above.

Following Stage 4, if the mix is satisfactory in all respects it can then be selected as a potential production trial mix. If not, the target composition should be altered using the available component materials or new materials sought.

Final confirmation of a satisfactory job mix formula (JMF) can only occur after completion of Stages 5 and 6.

4.2 Example application of the "trial" mix design method

The new mix design method was applied in an extensive laboratory programme and a recently constructed asphalt surfacing trial. In the full scale trials two mixes were evaluated, namely a high stone content HRS and an AC. Each mix was designed to withstand heavy traffic. Refusal density tests were also conducted to determine whether the mixes satisfied the requirements for severe sites.

Preliminary and final trial mixes were produced using stockpile and hot-bin aggregates respectively. The results of these were used to -

i) confirm whether the results of the two stages of testing (3 and 5) were similar, and

ii) compare the results of applying different methods for selecting an optimum, or target, bitumen content.

The trial mixes were prepared by blending a crushed coarse aggregate and fine aggregate, a natural fine sand and Portland cement filler with bitumen. The values of key properties, design fractions and added filler requirements based on stockpile and hot-bin materials and the properties of samples taken during the production trial and during full-scale production are summarised in Table 5.

Mix design results were interpreted using Asphalt Institute procedures, the TRL bar chart method and the new recommendations for high stone content HRS. An example of the bar chart method is given in Figure 1 and the results of using alternative methods to determine the target bitumen content are summarised in Table 6.

The compositon of the trial mixes, including values of mix variability, were well within acceptable limits with the exception of the design EBC and the CA content for the HRS and the amount of added filler. The low EBC was not considered critical since other key properties, particularly BFT and F/B, were satisfied. The CA was at the extreme limit of the suggested range (see Table 3) beyond which the enhanced workability of Rolled Asphalt-type materials can be lost. However, with this particular mix satisfactory in place densities were readily acheived during the compaction trial. The high added FF was compensated for by the BFT and F/B values and the low overall filler content.

For the AC, use of both the Asphalt Institute and TRL procedures resulted in a similar target TBC for heavy traffic. For the HRS mix the target TBC's were only slightly different. The clear difference between the methods is the identification of a range of satisfactory values which results from applying the bar chart method. In most cases the tolerance band for HRS was twice that of the AC. For the latter mix, with the exception of the severe sites, the tolerance band is within the capability of a typical production plant. The particular HRS design is relatively insensitive to variations in

TBC (up to ± 1.0 per cent) and is suitable for both heavy traffic and severe sites. The AC is unsuitable for severe sites, since it's tolerance range is ± 0.2 per cent, which is too narrow for normal production. In such circumstances TRL would suggest use of a bitumen macadam with a surface dressing. Alternatively, a new mix design could be attempted but may not be successful.

Finally, the differences in target TBC between designs using stockpile and hotbin aggregates were small. Therefore, the results of the preliminary design were a good indication of final requirements.

5. SUMMARY AND CONCLUSIONS

1) A review of the specification and design of hot-mix asphalt surfacings highlighted key requirements of different authorities. The review complemented the IRE-TRL road performance study which has provided local evidence for recommending a new high stone content HRS mix for use in heavy traffic conditions. Revised criteria for compositional properties and mix design, including refusal density requirements, have also been established.
2) A trial mix design method was developed which incorporates a computer programme operated on a spreadsheet which is used to identify suitable mixes based on compositional analysis. These are then subject to full design testing, including use of a modified version of the British Standard refusal density compaction method, and the results presented in bar chart form to identify the common range of bitumen contents over which the key compositional and design properties are satisfied. The method enables likely production tolerances to be considered in selecting a suitable mix.
3) The trial design method was applied in an extensive experimental programme which included the design and construction of a full scale asphalt trial to evaluate the new HRS mix.
4) The results of using the various methods to determine the target, or optimum, bitumen content for the different trial mixes were similar. However, use of the bar chart method was clearly advantageous since it defined the tolerance range of the mixes in relation to all specification and design requirements. The particular HRS mix investigated in the surfacing trial was found to have a wide tolerance to changes in bitumen content (up to ± 1 per cent) whereas an AC selected as the control material was less tolerant, varying between ± 0.5 and ± 0.2 per cent for heavy traffic and severe sites respectively.
5) The experimental programme will be continued to evaluate the trial design method and the refusal density method in a wider range of design conditions at a full-scale level.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

ASPHALT INSTITUTE (1984). Mix design methods for asphalt concretes and other hot-mix types. Manual Series No. 2 (MS-2).

BSI (1989). Sampling and examination of bituminous mixtures for roads and other paved areas. British Standard 598: Part 104. Methods of test for the determination of density and compaction.

BSI (1992). Rolled asphalt for roads and other paved areas. British Standard 594 Part 1: 1992. Specification for constituent materials and asphalt mixtures.

CORNE, C.P. (1983). Optimising pavement overlay design for Indonesia. Proc. Fourth Conference of Road Engineering Association of Asia and Australia, Jakarta, Indonesia.

DGH (1986). Specifications for high durability asphalts. Directorate General of Highways, Jakarta, Indonesia.

DGH (1992). Specification for dense graded asphalt (asphaltic concrete). Jakarta: Directorate General of Highways.

EDWARDS, A. and MULYADI, M. (1992). An investigation of compaction levels in Indonesian asphaltic mixes. IRE Research Report 11.TJ.062.92. Bandung: Institute of Road Engineering.

FORD, M.C. (1988). Pavement densification related to asphalt mix characteristics. Transportation Research Record 1178, p. 9-15. Washington D.C.

IRE (1992, 1993a and 1993b). Reports on the TARP II Road Strengthening and Rehabilitation Research Programme. Technical Assistance and Research Training Project, Second Phase. Bandung: Institute of Road Engineering.

NAPA (1989). Development of Marshall procedures for designing asphalt paving mixtures. NAPA Information Series 84. National Asphalt Pavement Association, USA.

NITRR (1978). Selection and design of hot-mix asphalt surfacings for highways. National Institute for Transport and Road Research, Technical Recommendations for Highways, TRH 8. Pretoria, South Africa.

SHELL BITUMEN UK (1990). The Shell Bitumen Handbook. Shell Bitumen UK, Chetsey, Survey.

TRL (1993). A guide to the structural design of bitumen-surfaced roads in tropical and sub-tropical countries. Overseas Road Note 31 (4th Edition). Crowthorne: Transport Research Laboratory.

Table 1
Specification Requirements for Hot Rolled Sheet (DGH, 1986) and Asphaltic Concrete (DGH, 1992)

Property	HRS		AC
	Class A	Class B	
Coarse Aggregate, %	20 - 40	30 - 50	-
Filler Fraction, %	5 - 9	4.5 - 7.5	-
Effective Bitumen, %	> 6.8	> 6.2	-
Absorbed Bitumen, %	0 - 1.7	0 - 1.7	0 - 1.7
Total Actual Bitumen, %	> 7.3	> 6.7	4 - 7
Air Voids, %	3 - 6	3 - 6	3 - 6
Voids Filled with Bitumen, %	-	-	70 - 80
Bitumen Film Thickness, (micron)	> 8	> 8	> 8
Filler Binder Ratio (F/B)	> 0.73	> 0.73	-
Marshall Quotient (kN/mm)	1.0 - 4.0	1.8 - 5.0	-
Marshall Stability, (kg)	450 - 850	550 - 1250	>750
Marshall Flow, (mm)	-	-	2 - 4
Immersion Index, %	>75	>75	>75
Compaction Level, (blows)	2 x 50	2 x 50	2 x 75

Table 2
Particle Size Distribution of Asphaltic Concrete Wearing Course (DGH, 1992)

Combined Grading		
Sieve Size		Percentage Passing
1"	25.0 mm	100
3/4"	19.0 mm	100
1/2"	12.7 mm	75-100
3/8"	9.5 mm	60-85
4#	4.75 mm	38-55
8#	2.36 mm	27-40
30#	0.60 mm	14-24
50#	0.30 mm	9-18
100#	0.15 mm	5-12
200#	0.075 mm	2-8

Table 3

Effect of Mix Properties on the Performance of Gap and Semi-gap Graded Asphalt Surfacings for Heavily-trafficked Conditions

Mix Property	Range	Effect	Comments	Suggested Limits
Voids in Mix, (%)	0 - 12	Rutting at low values. Cracking at high values.	i) 50 blow Marshall test underestimates traffic compaction. Use 75 blow test. ii) Use the PRD test to supplement the Marshall test.	3 - 6 2 - 6 (PRD)
Bitumen Film Thickness (micron)	4 - 12	Rutting at high values. Cracking at low values.	-	>6
Effective Bitumen content, (%)	3.5 - 8.9	Rutting at high values. Cracking at low values.	Rutting at low values coincided with continuously graded mixes. Cracking at high value related to very high F/B ratio.	> 6.2 % after allowing for plant tolerances.
Total Bitumen Content, % content (%)	5.2 - 9.5	No clear trend.	TBC value to be based on EBC plus allowance for bitumen absorption.	>6.2
Coarse Aggregate, %	40 - 65	No clear trend.	CA > 55% may lead to compaction difficulties.	40 - 55
Filler, %	2.9 - 14.2	More than 10 per cent equates with cracking.	-	4.5 - 10
Filler to Binder Ratio.	0.4 - 2.5	More than 1.5 equates with cracking.	-	0.7 - 1.3
Material 2.36 to o.6mm.	5.7 - 26.1	Good performance at low values. Variable performance at high value.	-	<13 (preferably <8)

Table 4
Proposed Marshall and Refusal Density Requirements for High Stone Content Semi-gap and Gap-graded Asphaltic Surfacings

Mix Property	Design Traffic Level (Millions 80 kN axles)			Severe Sites
	< 1 Light	1-5 Medium	> 5 Heavy	
Marshall stability (kg)	450-850	550-1250	> 700	> 900
Flow (mm)	-	-	> 2	2 - 4
Quotient (kN/mm)	1.0-4.0	1.8-5.0	-	-
Compaction Level (blows)	2 x 50	2 x 75	2 x 75	2 x 75
Air Voids (%)	3 - 6	3 - 6	2 - 6 (Note 1)	3 - 6 (Note 1)
Immersion index (%)	75	75	75	75

Notes:
1. Based on refusal density voids. It is essential to compare this with Marshall values during design testing.
2. The requirements for heavy traffic and severe sites assume controlled stress conditions.
3. The compositional properties for light and medium traffic should comply with HRS A and HRS B.

Table 5
Composition of the Trial Mixes

High Stone Content HRS.

Property	Specification		Design		As built	
			Stockpile Aggregates	Hotbin Aggregates	Production Trial	Full scale Trial
	Min	Max				
CA, % (Total Mix)	40	60	55.0	53.6	57.1 (1.61)	56 (0.45)
FF, % (Total Mix)	4.5	10	6.0	6.0	5.7 (1.28)	6.1 (0.27)
EBC, % (Total Mix)	5.7	-	5.7	5.6	5.7 (0.25)	5.7 (0.22)
BFT (micron)	6	-	9.1	9.8	10.2	10.0
F/B Ratio	0.73	1.3	1.0	1.0	1.0 (0.18)	0.9 (0.01)
#8 - #30, %	-	13	7.2	10.3	8.4 (0.20)	10.9 (0.04)
Added FF, %	-	3	1.2	3.7	-	-

Asphaltic Concrete

Property	Specification		Design		As built	
			Stockpile Aggregates	Hotbin Aggregates	Production Trial	Full scale Trial
	Min	Max				
CA, % (Total Agg)	60	73	66.0	67.1	61.0 (0.32)	64.7 (1.60)
FF, %	2	8	6.0	6.0	5.9 (0.77)	6.3 (0.35)
TBC, %	4	7	6.4	6.5	6.7 (0.32)	6.3 (0.34)
BFT (micron)	8	-	10.0	10.1	10.5	9.8
Added FF, %	-	3	2.9	3.1	-	-

Note: ( ) = Standard Deviation

Table 6

Comparison of Different Target Bitumen Contents for the Trial Mixes

Authority/Method	Preliminary Trial Mix using Stockpile Aggregates						Final Trial Mix using Hotbin Aggregates		
	Heavy Traffic Sites			Severe Sites			Heavy Traffic Sites		
	Satisfactory Range of TBC (%)	Target TBC (%)	Tole-rances (%)	Satisfactory Range of TBC (%)	Target TBC (%)	Tole-rances (%)	Satisfactory Range of TBC (%)	Target TBC (%)	Tole-rances (%)
Asphaltic Concrete									
Asphalt Insitute	-	6.4	-	-	-	-	-	6.5	-
TRL Road Note 31 (1993)	6.0 - 7.0	6.5	0.5	6.0 - 6.4	6.2	0.2	6.0 - 7.0	6.5	0.5
High Stone content HRS									
IRE/TRL Trial Method	6.2 - 8.2	7.2	1.0	6.6 - 8.2	7.4	0.8	6.2 - 8.0	7.1	0.9
Asphalt Insitute	-	7.2	-	-	-	-	-	6.8	-
TRL Road Note 31 (1993)	6.2 - 8.2	7.2	1.0	6.2 - 8.2	7.2	1.0	6.4 - 7.4	6.9	0.5

Figure 1. Example Bar Chart Presentation of Mix Design Data for High Stone Content HRS