HIGHWAYS DEPARTMENT

GUIDANCE NOTES

MIX DESIGN OF BITUMINOUS MATERIALS

Research & Development Division

RD/GN/022

June 1996

GUIDANCE NOTE

THE PROCEDURE FOR THE DESIGN OF BITUMINOUS MATERIALS

Foreword

1. Scope

This document describes the procedure for designing bituminous materials in accordance with the Marshall Method of Mix Design stated in the Asphalt Institute Handbook "MS-2 Mix Design for Asphalt Concrete and other Hot-mix Types,"1984 Edition, with modifications. The purpose of this Guidance Note is to ensure that a standardized method is applied to the design procedure.

2. Purpose

The objective is to produce a design for a bituminous material which will satisfy the specified design criteria, and which can be produced and laid by experienced operators to the requirements of the specification. The design is to be conducted at an approved laboratory by personnel experienced in this type of work.

Procedure

3. Preparation of Aggregates

3.1 Wash aggregates over a 75 μm sieve and dry to a constant weight at 105 C-110 C in an oven. Separate the dried aggregates into the desired coarse and fine fractions by dry sieving, using the same sieve sizes as those given in the grading specification.

3.2 Reproportion the aggregates for each test specimen in accordance with the desired gradation by following the steps below :

(a) Calculate the individual percentage of each size fraction retained from the selected design grading curve.

(b) Weigh into separate containers the amount of each size fraction required to produce a batch that will result in a compacted specimen 63.5±1.3 mm in height. The mass of this batch shall be between 1000 and 1200g.

(c) Prepare one standard aggregate blend by weighing the mass of each fraction onto an aggregate container to the nearest 0.1g.

(d) Determine the grading of the standard aggregate blend by wet sieving. Compare the result to the selected design grading curve and correct the individual proportioned fraction by adding to or subtracting from the mass of each fraction, whichever is appropriate.

3.3 Estimate the number of standard aggregate blends to be prepared as below:

(a) Minimum of four specimens for each binder content.

(b) Minimum of five binder contents.

(c) Duplicate samples for determination of the maximum theoretical specific gravity with a minimum of two selected binder contents.

(d) Minimum of three standard aggregate blends as spare samples.

3.4 Prepare and weigh the standard aggregate blends, corrected in accordance with 3.2(d).

4. Mixing

4.1 Plot a graph of bitumen viscosity against temperature. From the graph, determine the temperatures for mixing and compaction, taking into account the viscosity requirements stipulated in Table 1.

Table 1 Mixing and Compaction Criteria

Type of mix	Temperature	Viscosity of bitumen
Normal mixes :	Mixing temperature	170±20 centistokes
	Compaction temperature	280±30 centistokes
Friction Course :	Mixing temperature	900±100 centistokes
	Compaction temperature	2000±200 centistokes
Modified mixes :	In accordance with Suppliers' recommendations.	

4.2 Place all the standard aggregate blends in an oven and heat to a temperature of approximately 28 C above the mixing temperature. Place the bitumen in an oven at a temperature not higher than the required mixing temperature.

4.3 Mould cylinders, bases, extension collars and hammer foot shall be heated in an oven kept at 93 C-149 C. If the hammer foot is of such design that it cannot be detached from the hammer, it may be heated by other means, e.g. a hot plate.

4.4 Calculate to the nearest 0.1g the mass of the binder to be added to each standard aggregate blend. Five binder contents at intervals of 0.5% shall be calculated. In the case of Friction Course or Cushion Course the interval may be reduced to 0.3% if found necessary.

Binder content is defined as the mass of binder expressed as a percentage of the mass of a mixture of aggregates and binder.

Mass of Binder in grams required = $A \times b/(100 - b)$

Where A = Mass of standard aggregate blend in grams.
b = Binder content(%)

4.5 Transfer the bitumen from the oven to a container and heat to the required mixing temperature on a hot plate with a baffle plate approximately 5 minutes prior use. Reject all the bitumen being held at the mixing temperature for more than one hour before use.

4.6 Charge the mixer bowl with heated aggregate, mix thoroughly with the spatula and form a crater to receive the binder. Tare the charged mixer bowl.

4.7 Stir the binder in its container, weigh the required amount of binder into the mix. Mix the aggregates and binder with a mechanical mixer, or hand mix with a trowel, as quickly and thoroughly as possible giving the mixture a uniform distribution of binder throughout.

4.8 Take a mould assembly from the oven, place a filter paper disk in the bottom of the mould. Transfer all the mixed material into the mould, spade the mixture with a heated spatula 15 times round the perimeter and 10 times over the interior of the mould and form the top of mixture into a dome.

4.9 Measure and record the temperature of the mixture with a digital thermometer midway between the centre and the perimeter of the mould. The thermometer should be maintained at a temperature approximate to that of mixed material prior to use.

5. Compaction

5.1 When the temperature lies at the compaction temperature ±2 C, place another paper disk on top of the material, transfer the mould assembly to the compaction pedestal and locate it in the mould holder. Should the temperature of the material be found to be below the minimum required compaction temperature prior to compaction, the material shall be discarded.

5.2 Apply 75 blows to each side of the mixture.

5.3 Remove the collar, base and paper disk, and allow the briquettes to cool in air.

5.4 Place the collar on the mould and extrude the briquette with an extruder. Remove burrs on the briquettes with a spatula. Examine each briquette and reject any that have been damaged during extrusion or have obvious defects.

6. Determination of the Bulk Specific Gravity, Stability and Flow Value and Theoretical Maximum Specific Gravity

6.1 Measure bulk specific gravity of the briquettes in accordance with ASTM D2726 for dense mix; the height of specimens in accordance with ASTM D3549;and the air voids content in accordance with ASTM D3203, or using equivalent in-house test method accepted by HOKLAS or other recognised accreditation agencies in Hong Kong.

6.2 Immerse the briquettes into the water bath, one by one, with an interval of one minute and maintain at 60±1 C for 30 - 40 minutes prior to test.

6.3 Thoroughly clean the inside surface of the testing head and lightly oil the guide rods and check whether the upper platen of the testing head slides freely over them. Maintain the temperature of the assembly between approximately 21 C and 38 C.

6.4 Remove the briquettes from the water bath and dry the surface with a damp towel, place centrally on its sides in the lower segment of the testing head. Place the upper half firmly on the briquette and transfer the whole assembly to the compression machine.

6.5 Clamp the flow gauge or transducer onto the assembly, then start the test.

6.6 Measure and record the peak load and flow value. The entire procedure for both stability and flow test, starting with removal of the briquette from water bath shall be completed within a period of thirty seconds.

6.7 Repeat the steps 6.2 to 6.6 for the remaining briquettes.

6.8 Calculate the corrected stability by the measured stability of the briquette multiplied by the correlation ratio for the corresponding volume of the briquette as listed in Table 2.

Table 2 Stability Correlation Ratio

Volume of specimen (ml)	correlation ratio
471--482	1.14
483--495	1.09
496--508	1.04
509--522	1.00
523--535	0.96
536--546	0.93
547--559	0.89

6.9 Determine the theoretical maximum specific gravity of the mix in accordance with ASTM D2041, or equivalent in-house test method accepted by HOKLAS or other recognized accreditation agencies in Hong Kong for at least two binder contents on mixes at or near the optimum binder content. Prior to the test, determine the optimum de-airing time for the mix, unless optimum de-airing times are available from similar mixes at similar binder contents (Optimum de-airing time is the minimum de-airing time required to yield the maximum specific gravity).

7. Determination of Design Binder Content.

7.1 The design binder content shall be determined by the producer of the design, or the supplier of the material, ensuring that the specified criteria for mix properties are complied with.

Appendix 1

List of Modifications to the MS 2 Design Procedures adopted by the Bituminous Material Suppliers

(Anderson Asphalt Ltd., Pioneer Asphalts HK Ltd., and Wimpey Asphalt HK Ltd.)

1) The use of aggregates in excess of 25mm (1 in.). MS2 clause 3.01.

2) The use of a mechanically operated compaction hammer, for the compaction of test specimen. MS2 clauses 3.04(n) and 3.05(g).

3) The use of plain paper instead of waxed or filter paper. MS2 clause 3.05(d).

4) The use of load cell and flow transducer, instead of dial gauges and proving rings for the determination of stability and flow values. MS2 clause 3.09.

5) The test specimen is not agitated during de-airing in the determination of the theoretical maximum specific gravity (ASTM D2041). MS2 clause 3.10(e).

6) The use of test sieves complying with BS410 in place of test sieves complying with ASTM E11 for the grading analysis of the aggregates.

7) The target binder content is selected to achieve the desired air void content, rather than the optimum binder content determined from the numerical average of the binder content for maximum stability, maximum compacted density, and median of air voids limits.

8) Aggregates are dried to constant weight at 105±5 C, instead of 105 C to 110 C.

Appendix 2

Checklist for the Supervision of Bituminous Material Mix Design Testing to G.S. for Civil Engineering Works, 1992 Edition

Name of Testing Laboratory : _____

Location of Testing Laboratory : _____

Name of Testing Laboratory In-charge : _____

Name and Post of Person who Witnessed the Design : _____

Date of Design Testing : _____

Material and Job Mix No. of Supplier : _____

Checklist

1. Can identities of equipment employed for the mix design be found on the updated equipment calibration records, for Asphalt Suppliers, copied from Research & Development Division of Highways Department ? Yes/No

2. Laboratory's proposed mixing temperature : _____ ± ºC

3. Laboratory's proposed compaction temperature : _____ ± ºC

4. Time bitumen held at mixing temperature before use : _____ min.
   (Not exceeding 1 hour)

5. Has aggregate been mixed thoroughly before bitumen is added ? Yes/No

6. Temperature of mixture prior to compaction :

Specimen No.	Temperature C	Remarks

Specimen No.	Temperature C	Remarks

7. Random check of the number of compaction blows per side :

Specimen _____ : _____ blows
Specimen _____ : _____ blows
Specimen _____ : _____ blows

8. Temperature of water for Bulk S.G. determination : _____ºC
(25 ± 0.5 C)

9. Duration specimen was immersed in water for Bulk S.G. determination (3 - 5 minutes) : _____ Minutes

10. Water bath temperature for Marshall Stability and Flow Value test (60 ± 1 C) : _____ ºC

11. Time Marshall specimens immersed in water before test (30 - 40 minutes) : _____ Minutes

12. Was the entire Marshall Stability test procedure for one specimen, starting from removal from water bath, completed within 30 seconds ? : Yes/No.

13. Sample size for Rice's S.G. determination : _____ g

Nominal size (mm)	Minimum Mass (g)
37.5	4000
28	2800
20	2000
10	1000

14. Temperature of water used to cover the Rice's S.G. specimen (22.2 - 26.7 C) : _____ ºC

15. Was a partial vacuum of 30mm Hg (4kPa) maintained ? : Yes/No.

16. Laboratory optimum partial vacuum time used (5 - 15 Minutes) : _____ Minutes

17. Record of optimum vacuum time determination available ? : Yes/No.

18. Time which the Rice's S.G. specimen is immersed in water for the determination of mass of specimen in water (10 ± 1 Minutes) : _____ Minutes

Remarks :

Witnessed By : _____ (Name)

_____ (Post)

Signature : _____