ARAHAN TEKNIK (JALAN) 5/85

JABATAN KERJA RAYA

MANUAL ON PAVEMENT DESIGN

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INTRODUCTION

This manual consists of the thickness design method, materials specification and the mix design for asphaltic pavements.

The structural design has been based on the AASHO (American Association of State Highway Officials) Road Test results but the design method is developed using the multi-layered elastic theory through the use of the Chevron N-layer computer program.

The mix design and material requirements are based on the existing specifications with modifications to incorporate local experience.

The reports pertaining to the development of this manual are as listed in references 10 & 11.

1.0 SCOPE

1.1 This manual is to be used for the design of flexible pavements for roads under the jurisdiction of JKR. It comprises of details for the thickness design, materials specification and the mix design requirements.

1.2 When using this manual, the designer should take into account other relevant factors such as soil properties, economy of design and practical considerations with regard to the suitability of materials on site.

1.3 This manual is suitable for the design of major roads i.e. where the traffic is medium or heavy.

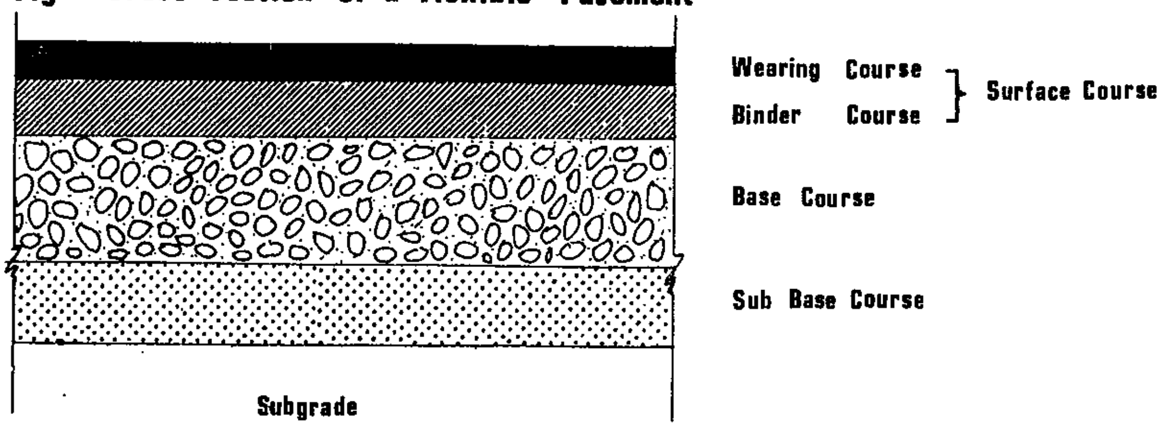
2.0 PAVEMENT STRUCTURE

2.1 Designation of each layer

2.1.1 A flexible pavement is a layered structure consisting of a subbase course, base course, binder course and wearing course. (Fig. 1)

2.1.2 In case there are two or more layers for the binder course, the lowest layer is referred to as the binder course and the other courses as the intermediate course.

Fig.1 Cross-section of a Flexible Pavement



2.2 Definition and Function of Each Layer

2.2.1 Subgrade

The uppermost part of the soil, natural or imported, supporting the load transmitted from the overlying layers.

2.2.2 Subbase Course

The layer(s) of the specified material built up to the required designed thickness immediately overlaying the subgrade. It serves as an aid to disperse the load from the base course before transmitting it to the subgrade. (This layer may be absent in some designs.)

2.2.3 Base Course

The layer(s) of specified material built up to the required designed thickness normally overlying the subbase course. This layer plays a prominent role in the support and dispersion of the traffic loads.

2.2.4 Surface Course

All the bound layer(s) within the pavement i.e. wearing course, intermediate course and binder course are embodied under this general terminology. This layer(s) forms an impermeable and flexible lining of high elastic modulus.

2.2.5 Binder Course

The bound layer(s) overlying the base course. Apart from supporting and dispersing the traffic load, it also resists shear.

2.2.6 Wearing Course

The topmost layer of the surface course. It is in direct contact with the traffic and consequently, it must resist abrasion and prevent skidding.

3.0 THICKNESS DESIGN

3.1 General

The thickness design of the pavement shall be based on the design CBR (California Bearing Ratio) of the subgrade and the total number of 8.16 tonne standard axle applications for a specific design period.

3.1.1 The design CBR of the subgrade and the total equivalent standard axle are the main factors in the structural design of the pavement.

3.1.2 The design chart (Fig. 2) is based on the AASHO Road Test relationship between thickness index and axle load applications at terminal servicability of 2.5, 18-kip single axle, for subgrade CBR of 3%. The thickness for other subgrade CBR is obtained through the use of Chevron, a multi layer elastic theory computer program. The input for the computer program is based on the following material properties :-

	Surface	Base	Subbase
Elastic Modulus E kg/cm^2	30,000	1,000	800
Poisson's Ratio ν	0.45	0.40	0.40

Subgrade is assumed semi infinite, with E of

80 - 800 kg/cm^2 and ν of 0.35

3.2 Design Period

A design period of ten years shall be used. Also refer 3.2.3

3.2.1 The design period refers to the span of time between the initial passing of user traffic until the fatigue limit of the pavement whereby a strengthening overlay is required.

The design period should not be confused with the pavement life for the pavement life can be extended by strenghtening overlays.

3.2.2 Currently, a design period of twenty years is stipulated in the Road Note 29.

A design period of only ten years is to be specified, however, as an initial study (ref.10) has indicated that it would be economical in terms of initial capital outlay and also with respect to the total cost.

3.2.3 The calculation for the traffic estimation for the ten year design period shall be based from the expected year of completion of construction, onwards.

The designer is to project the initial traffic for the year he expects the road to be opened to traffic, and in turn treats the projected year as the base year for the calculation of traffic over the design period. The projection of traffic is given in 3.3.7.

In the absence of exact information on the time of opening to traffic, the designer shall project the initial traffic to another five years.

3.3 Traffic Estimation

The equivalent 8.16 tonne standard axle load applications shall be obtained through the following procedure:

3.3.1 Estimate the initial Average Daily Traffic ADT (both ways).

3.3.2 Estimate the percentage of commercial vehicles Pc. The commercial vehicles referred to are the medium and heavy goods vehicles with unladen weight exceeding 1.5 tonne.

3.3.3 Estimate the rate of annual traffic growth (r). If there are different rates of annual growth over the design period, then the different rates of annual traffic growth are applied for the calculation of traffic volume for each period.

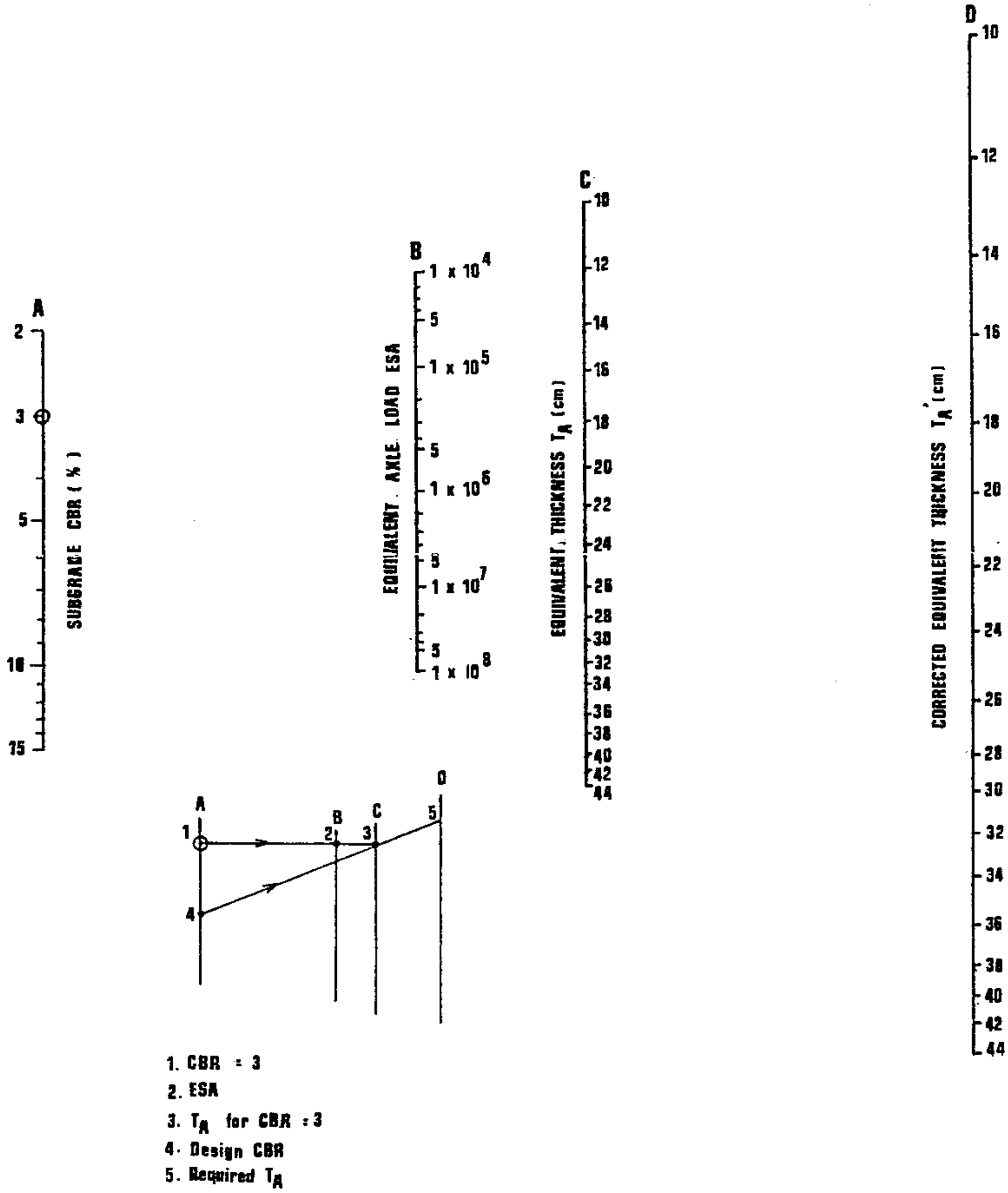


FIG-2 THICKNESS DESIGN NOMOGRAPH

3.3.4 The initial annual commercial traffic for one direction, V_o ,is obtained by :

$$V_o = ADT \times 0.5 \times 365 \times Pc/100$$

where

ADT = Average Daily Traffic

Pc = Percentage of commercial vehicles

3.3.5 The total number of commercial vehicles for one direction (V_c) is obtained by :

$$V_c = \frac{V_o [(1 + r)^x - 1]}{r}$$

where

V_c = total number of commercial vehicles for x years

V_o = initial yearly commercial traffic

r = rate of annual traffic growth

3.3.6 The total traffic volume at the end of the design period should be checked as per 3.3.13 -3.3.14 to ensure that the maximum capacity has not been exceeded.

3.3.7 The total daily one-way traffic flow of both non-commercial and commercial vehicles at the end of the design period (V_x) is calculated as follows

$$V_x = V_1 (1 + r)^x$$

where

V_x = volume of daily traffic after x years in one direction.

V_1 = initial daily traffic in one direction.

x = design period (year)

3.3.8 Estimate the Equivalence Factor (e)

In the absence of an axle load survey, Table 3.1 below shall be used as a guide.

Table 3.1 Guide for Equivalence Factor

Percentage of selected heavy goods vehicles*	0-15%		16-50%	51-100%
Type of road Equivalence Factor	local 1.2	trunk 2.0	3.0	3.7

* Selected heavy goods vehicles refer to those conveying timber and quarry materials.

3.3.9 The total equivalent Standard Axles (ESA) applications is given by :-

$$ESA = V_c \times e$$

3.3.10 The traffic information necessary for design shall be obtained from the publication by Unit Perancang Jalan, Kementerian Kerja Raya entitled 'Traffic Volume-Peninsular Malaysia'.

3.3.11 For highways with three or more lanes per direction, the values on traffic estimation shall be based on 80% of ADT as referred in 3.3.4 . This is to accomodate the distribution of traffic over the whole carriageway.

3.3.12 The maximum hourly traffic volume, as per 3.3.6 is calculated as follows:

$$c = I \times R \times T$$

where

c is the maximum one way hourly capacity

I is the ideal hourly capacity as in Table 3.2

R is the roadway factor as in Table 3.3

T is the traffic reduction factor (Table 3.4)

Table 3.2 Maximum Hourly Capacity under ideal conditions

Road Type	Passenger Vehicle Units per hour
Multi lane	2000 per lane
Two lanes (bothways)	2000 total for bothways
Three lanes (bothways)	4000 total for bothways

Table 3.3 Carriageway Roadway Reduction Factor

Carriageway Width	Shoulder Width			
	2.00m	1.50m	1.25m	1.00m
7.5m	1.00	0.97	0.94	0.90
7.0m	0.88	0.86	0.83	0.79
6.0m	0.81	0.78	0.76	0.73
5.0m	0.72	0.70	0.67	0.64

Table 3.4 Traffic Reduction Factor

Type of Terrain	Factor*
Flat	T = 100/(100+Pc)
Rolling	T = 100/(100+2Pc)
Mountainous	T = 100/(100+5Pc)

* Nota Bene: Pc is as per 3.3.2

3.3.13 Assuming that maximum hourly capacity, c as per 3.3.12 reflects 10% of the 24 hrs. capacity, then the one way daily capacity is as follows:

$$C = 10 \times c$$

where

C is the 24 hrs. one way traffic capacity

c is as per 3.3.12

3.3.14 If the traffic estimate for the design period exceeds the daily capacity, C, then the number of years, n, required to reach the daily capacity is as follows:

$$n = \frac{\log C/V}{\log (1 + r)}$$

where

n is the period required to reach capacity

C is as per 3.3.13

V is as per 3.3.7

r is the rate of annual traffic growth

3.4 Subgrade California Bearing Ratio (CBR)

3.4.1 The CBR of the subgrade shall be taken as that of the layer(s) underlying within 1 m below the subgrade surface.

3.4.2 In the case of varying CBR within the 1 m depth of the subgrade, especially when soil stabilisation has been undertaken, the mean CBR is determined as follows :

$$CBR = \left(\frac{h_1 CBR_1^{1/3} + h_2 CBR_2^{1/3} + \ldots + h_n CBR_n^{1/3}}{100} \right)^3$$

where

$CBR_1, CBR_2, \ldots CBR_n$ is CBR of soil strata 1,2...n

$h_1, h_2, \ldots h_n$ is thickness of soil strata 1,2...n

in cm whence $h_1 + h_2 + \ldots + h_n = 100$ cm

3.5 Design

3.5.1 After determining the mean CBR as per 3.4.2 and ESA as per 3.3.9, the equivalent thickness T_A, is obtained from fig. 2.

3.5.2 The thickness of the various layers shall be obtained using

$$T_A = a_1 D_1 + a_2 D_2 + \ldots + a_n D_n$$

where

$a_1, a_2 \ldots a_n$ are the structural

coefficients of each layer as shown in Table 3.5

$D_1, D_2 \ldots D_n$ are the thickness of each

layer as shown in Table 3.6

Table 3.5 Structural Layer Coefficients

Component	Type of Layer	Property	Coefficient
Wearing and Binder Course	Asphalt Concrete		1.00
Base Course	Dense Bituminous Macadam	Type 1: Stability > 400 kg	0.80
		Type 2: Stability > 300 kg	0.55
	Cement Stabilized	Unconfined Compressive strength(7 days) 30-40 kg/cm2	0.45
	Mechanically Stabilized crushed aggregate	CBR ≥ 80%	0.32
Subbase	Sand, laterite etc.	CBR ≥ 20%	0.23
	Crushed aggregate	CBR ≥ 30%	0.25
	Cement Stabilized	CBR ≥ 60%	0.28

Table 3.6 Minimum Layer Thickness

Type of layer		Minimum thickness
Wearing Course		4 cm
Binder Course		5 cm
Base Course	Bituminous	5 cm
	Wet Mix	10 cm
	Cement treated*	10 cm
Subbase Course	Granular	10 cm
	Cement treated	15 cm

* Nota Bene

For cement treated base course, the total bituminous layers overlaying it should not be less than 15 cm

3.5.3 In determining individual layer thickness, the practical aspects of construction shall be taken into account as per Table 3.7.

Table 3.7 Standard & Construction Layer Thickness

Type of layer		Standardard thickness	One layer lift
Wearing course		4-5 cm	4-5 cm
Binder course		5-10 cm	5-10 cm
Base Course	Bituminous	5-20 cm	5-15 cm
	Wet mix	10-20 cm	10-15 cm
	Cement treated	10-20 cm	10-20 cm
Subbase Course	Granular	10-30 cm	10-20 cm
	Cement treated	15-20 cm	10-20 cm

3.5.4 The minimum thickness of bound (bituminous) layer in order not to exceed the critical tensile strain at the base of the bituminous layer, shall be based on Table 3.8.

Table 3.8 Minimum thickness of Bituminous Layer

T_A	Total thickness of bituminous layer
< 17.5 cm	5.0 cm
17.5 - 22.5 cm	10.0 cm
23.0 - 29.5 cm	15.0 cm
> 30.0 cm	17.5 cm

3.5.5 Worked example

The following conditions are given :-

Class of road	JKR 05
Initial daily traffic volume (ADT)	6,600
Percentage of commercial vehicles	15%
Annual growth rate	7%
Equivalence factor	2.0
Subgrade CBR	5%
Rolling terrain	

Initial annual commercial traffic for one way V_o (Ref. 3.3.4)

$$V_o = 6.600 \times 0.15 \times 0.5 \times 365 = 181,000$$

Accumulative sum of commercial traffic one way for 10 year design period (Ref. 3.3.5 & 3.2.3).

$$V_c = \frac{181,000\ [(1 + 0.07)^{10} - 1]}{0.07}$$

$$= 2.50 \times 10^6$$

Total Equivalent Standard Axles (Ref. 3.3.9)

$$ESA = 2.0 \times 2.5 \times 10^6$$

$$= 5.0 \times 10^6$$

Maximum Hourly One Way Traffic Flow (Ref. 3.3.12)

$c = I \times R \times T$

$c = 1000 \times 1.0 \times 0.77 = 770$ vehicles per hour

Assuming hourly capacity is ten per cent of daily capacity.

$C = 7700$ veh/day/lane

The estimated daily traffic V after 10 years is given by

$$V = \frac{6,600\ (1 + 0.07)^{10}}{2}$$

$= 6490$ veh/day/lane

Hence capacity has not been reached after 10 years.

From fig. 2, the chart shows that for an ESA of 5.0×10^6, the required T_A is 26 cm.

Design of Layer Thickness (Ref. 3.5.2)

$$T_A = a_1D_1 + a_2D_2 + \ldots + a_nD_n$$

Layer	Material	Coefficient	Minimum Thickness
a_1	Asphalt Concrete	1.00	9 cm
a_2	Mechanically Stabilized Crushed Aggregate	0.32	10 cm
a_3	Sand	0.23	10 cm

1st Trial

Nominate $D_1 = 12.5$ cm
$D_2 = 18.0$ cm
$D_3 = 20.0$ cm

Then $T_A = 1.0 \times 12.5 + 0.32 \times 18 + 0.23 \times 20$
$= 25.36 \text{ cm} < T_A'$

2nd Trial

$D_1 = 15.0$ cm
$D_2 = 20.0$ cm
$D_3 = 20.0$ cm

Then $T_A = 1.0 \times 15 + 0.32 \times 20 + 0.23 \times 20$
$= 26.0$ cm

Taking into consideration the minimum thickness requirements, the pavement structure then comprise of the following layer thicknesses

Wearing - 5 cm

Binder - 10 cm

Base - 20 cm

Subbase - 20 cm

4.0 SUBBASE COURSE

4.1 General

Sand gravel and laterite are amongst the various types of subbase course materials. When these materials do not have the required quality, cement stabilisation of these material or crushed aggregate is to be used.

From an economic point of view, locally available materials such as sand, gravel, laterite, etc. should be utilised for subbase course materials.

4.2 Material Requirements

The quality of materials shall conform to the following standards and shall not include a deleterious amount of organic materials, soft particles, clay lumps etc.

4.2.1 Locally available materials, such as sand, gravel, soft rocks, laterite etc should be utilised for subbase course materials, from an economic point of view. When these materials do not meet the required standard, stablisation with cement should be considered. When a suitable and economic natural material is not available crushed aggregates (crusher run) are commonly used.

4.2.2 The quality of materials shall conform to the following standards and not include a deleterious amount of organic materials, soft particles, clay lumps etc.

Table 4.1 Standard Properties of Subbase

Quality	Test Method	Crushed Aggregate	Sand Laterite etc
CBR (%)	BS 1377:75	Not less than 30	Not less than 20
Plasticity Index (P.I)	BS 1377:75	Not greater than 6	Not greater than 6
Los Angeles Abrasion loss (%)	ASTM C 131	Not greater than 50	-
Cement Stabilised CBR (%)	BS 1377:75	-	Not less than 60

Table 4.2 Standard Gradation Limit for Crushed Aggregates*

Sieve size mm	50	40	25	10	5	2.4	0.420	0.075
Percentage by weight passing	100	90-100	65-100	40-80	25-65	15-50	9-30	0-10

Note* :- 1. Sieve analysis should be done according to BS 1377:75

2. For sand, laterite etc. nominal size shall not be greater than 1/3 of the compacted layer thickness.

4.2.3 Natural materials vary from place to place throughout the country. Generally, natural sand and laterite give a strength of CBR 20% or more. However, the strength of some materials may be lower in certain regions. These materials can be stabilised with cement. A CBR of not less than 30% for crushed aggregates can normally be obtained from the quarries.

4.2.4 A cement content of 2% to 4% by weight is recommended for stabilisation with cement. Higher cement content will usually produce a stiff mix which consequently would fail due to stress concentration.

4.2.5 For maximum utilisation of suitable local materials, no gradation is specified. Gradation is required only for crushed aggregates to avoid seggregation and to obtain better workability for construction.

For construction purposes, the nominal size of local material is specified.

4.2.6 A sand layer of 10 cm thick is required to be placed on top of the subbase course, extending from edge to edge of the formation width.

5.0 BASE COURSE

5.1 General

Base course shall be selected materials such as crushed stones and sand, or a combination of these materials. It may be stabilised with cement, bitumen or lime.

In the AASHO road test results, it was found that stabilised base courses especially bituminous stabilised base gave the best performance with respect to strength and durability. Therefore bituminous treated base course are recommended to be used whenever suitable.

Three types of base courses are specified here. They are crushed aggregates, cement stabilised and bitumen stabilised base courses.

5.2 Requirements for materials and mixtures

The quality of both materials and mixtures shall conform to the following requirements:-

Table 5.1 Material Properties of Base course

Quality	Test Method	Crushed Aggregates	Cement Stabilised	Bitumen Type 1	stabilised Type II
CBR (%)	BS1377:75	Not less than 80	-	-	-
Plasticity Index	BS1377:75	Not greater than 4	Not greater than 8	Not greater than 6	Not greater than 8
L.A Abrasion Loss (%)	ASTM C131	Not greater than 40	Not greater than 40	Not greater than 40	Not greater than 40
Water Absorption (%)	M.S. 30	-	-	Not greater than 4	Not greater than 4

Table 5.2 Gradation for Base Course

Sieve size (mm)	Percentage by weight passing			
	Crushed aggregates	Cement stabilisation	Bitumen stabilised	
			Type I	Type II
40	100	Nominal size of material used shall not be greater than 1/3 of compacted layer thick ness	100	Nominal size of material used shall not be greater than 1/3 of compacted layer thick ness
25	70-100		70-100	
10	40-65		40-65	
5	30-55		30-55	
2.4	20-45		20-45	
0.420	10-25		10-25	
0.075	2-10		2-10	

Note: Sieve analysis shall be done according to BS 1377:75

Table 5.3 Mixture requirements for Base Course

Requirement	Cement Stabilised	Bitumen stabilised	
		Type I	Type II
Unconfined Compressive strength (7 days) kg/cm^2	30 to 40	-	-
Stability (kg)	-	Not less than 400	Not less than 300
Flow (1/100cm)	-	15-45	15-45
Air Voids(%)	-	3-10	3-12
Marshall residual stability immersed(%) (60°C ,24 hrs)	-	Not less than 75	Not less than 50

5.2.4 Since the base course is placed directly beneath the binder course, it is therefore essential to use good quality materials. Generally, crushed aggregates (wet-mix macadam) are used. However, when suitable good quality materials are available but are of inadequate strength at natural condition, they should be stabilised.

5.2.5 The L.A. abrasion loss test is used to determine the soundness of coarse aggregates. The test is specified in AASHTO T 96-97(1982). For the grading of test samples, Grading A from Table 1 of AASHTO T 96-97(1982) shall be used since the nominal size of aggregate used is 40 mm.

5.2.6 For bituminous stabilised base course. Type I refers to plant mix using selected material of good quality. Type II refers to the utilisation of suitable local material. This is to allow more flexibility in the selection of base course materials.

5.2.7 Unconfined compressive strength value greater than 40 is not recommended, since higher values of unconfined compressive strength may cause stress concentration. Cement content of between 3% to 6% is recommended.

5.2.8 Marshall residual stability requirement for bituminous stabilised base course has been introduced to test the durability of the mixture and the stripping action of aggregates used.

6.0 BINDER COURSE AND WEARING COURSE

6.1 General

Hot-mixed bituminous mixtures shall be used for binder course and wearing course. The compositions of these mixtures shall be designed based on the Standard Marshall Test procedure. Care must be taken in the selection of materials, gradation and bitumen content so as to obtain a mix with the desirable stability, durability, and sufficient skid resistance (in case of wearing course) as well as good workability.

Bituminous mixtures consist of a well graded mixture of coarse aggregates, fine aggregates and filler, bound together with bitumen. Their stability derives both from the interlocking of the well-graded aggregates and from the cohesion provided by the bitumen binder. They are suitable for surfacing heavily trafficked roads in hot climate and for use where an impermeable surfacing is required.

6.2 Material Requirements

6.2.1 Coarse Aggregates

Coarse aggregates shall be material substantially retained on 2.4mm sieve opening and shall be crushed rock or crushed gravel and free from foreign materials. Coarse aggregate shall conform to the following requirements.

Table 6.1 Course Aggregate for Bituminous Mix

Quality	Test Methods	Requirements
Abrasion loss Los Angeles (%)	ASTM C131 -69	Not more than 60
Water absorption (%)	M.S. 30	Not more than 2
Flakiness Index (%)	M.S. 30	Not more than 30

6.2.2 Fine Aggregates

Fine aggregates shall be material passing a 2.4 mm sieve opening. It shall be clean natural sand or screenings or a mixture thereof. Screenings shall be produced by crushing stone and or gravel conforming to the quality requirements for coarse aggregate described in the previous section 6.2.1

Fine aggregate shall be clean, hard, durable and free from clay, mud and other foreign materials. The minus 0.425mm sieve fraction shall be non plactic when tested in accordance with B.S. 1377:1975.

6.2.3 Mineral Filler

Mineral Filler shall be portland cement and shall conform to the following grading requirements:

Table 6.2 Mineral Filler for Bituminous Mix

Sieve openings	Percentage by weight passing
600 m	100
150 m	90-100
75 m	70-100

6.2.4 Bitumen

Bitumen shall be straight-run bitumen (petroleum bitumen) and shall conform to the following requirements :

Table 6.3 Bitumen Properties

Characteristics	ASTM Test Method	Penetration Grades	
		60-80	80-100
Penetration at 25 C (1/100 cm)	D5	60-80	80-100
Loss on heating (%)	D6	not more than 0.2	not more than 0.5
Drop in penetration after heating (%)	D6/D5	not more than 20	not more than 20
Retained penetration after thin-film over test (%)	D1754/D5	not less than 52	not less than 47
Solubility in carbon disulphide or trichloroethylene (%)	D2024	not less than 99	not less than 99
Flash point (Cleveland open cup) (°C)	D92	not less than 250	not less than 225
Ductility at 25°C (cm)	D113	not less than 100	not less than 100
Softening point (°C)	D36	not less than 48 & not more than 56	not less than 45 & not more than 52

6.2.5 One of the requirements of the wearing course mixture is sufficient skid resistance. Therefore aggregates such as limestone, which have been proved to have a tendency to be polished under traffic wear should be avoided for the wearing course especially for high-speed roads. Suitable types of aggregate shall be used for the wearing course.

6.2.6 Some aggregate like granite when coated with bitumen binder produces stripping problems when in contact with water. A stripping test in accordance to ASTM D1664-80 shall be done on such aggregates.

6.2.7 The resistance of aggregates to abrasion is tested by the Los Angeles Abrasion Loss Test in accordance to AASHTO T 96-77(1982). For the grading of test samples, Grading B from Table 1 of AASHTO T 96-77(1982) shall be used since the nominal size of aggregates used is less than 25mm.

6.2.8 Hydrated lime or portland cement may be effective to improve the adhesion between bitumen binder and aggregates, thus reducing the stripping problem.

6.2.9 Limestone quarry dust which does not meet the gradation requirements of mineral filler shall not be considered as mineral filler.

6.2.10 The bitumen of penetration grade 60-80 is recommended to be used for heavy traffic roads as classified under JKR Standard of 05-06. A harder grade bitumen of 60-80 is recommended in order to achieve higher stability of mixture and to lessen the possibility of bitumen bleeding or flushing at high temperatures. The bitumen of penetration grade 60-70 and 80-100 as described in M.S. 124 can also be used.

6.3 Mixture Requirements

6.3.1 Gradation

Gradation of mixtures shall meet the following requirements:

Table 6.4 Gradation for Asphaltic Concrete

Sieve Size (mm)	Percentage by weight passing	
	Binder Course	Wearing Course
25	100	-
20.0	78-100	100
12.5	60-84	78-100
10.0	52-76	68-90
5.0	38-62	52-72
2.4	28-48	38-85
0.600	14-30	20-36
0.300	9-22	12-25
0.150	5-14	7-16
0.075	3-7	4-8

6.3.2 Mix Design Requirements

The mixture shall be designed in accordance to the Standard Marshall Test Method. It shall conform to the following requirements:

Table 6.5 Asphaltic Concrete Mix Design

Quality	Binder course	Wearing Course
Stability (kg)	Not less than 500	Not less than 500
Flow (1/100 cm)	20-40	20-40
Voids in the total mix (%)	3-7	3-5
Voids filled with bitumen (%)	65-75	75-82
Residual Stability (immersed) (%)	Not less than 75	Not less than 75

Note: Number of blows on each side of a Marshall specimen is 50 for binder course and either 50 or 75 for wearing course depending on traffic conditions.

6.3.3 A dense gradation for the wearing course is selected in order to produce a more durable and stable mix.

6.3.4 As rainfall intensity is high, a less permeable layer of binder course is selected at nominal aggregate size of 25mm.

6.3.5 The number of blows on each side of the specimen for the wearing course is either 75 or 50 depending on traffic conditions. It is recommended to use 75 blows for heavily traffic roads to JKR 05-06 Standard. 50 blows is used for medium or light traffic roads i.e. JKR 01-04 Standard.

6.3.6 Standard bitumen contents are 5.0% - 6.0% by weight of the mix for the binder course and 6.0% - 7.0% for the wearing course.

6.3.7 The amount of filler present by weight of the mix shall be in the range of 2% - 3%.

6.3.8 Where the mix is susceptible to the influence of water, the residual stability is to be computed by the following formula and it should not be less than 75%.

$$\text{Residual stability (\%)} = \frac{\text{Marshall stability after 48 hours of } 60^{\circ}\text{C Water immersion (kg)} \times 100}{\text{Standard Marshall Stability (kg)}}$$

This test helps to check the stripping problem of aggregates. If stripping problems occur, a change of gradation to include more filler, or the use of an antistripping agent should be considered.

6.3.9 Temperature-viscosity relationship of bitumen is necessary to determine the mixing and compacting temperatures during the preparation of Marshall stability test speciments. The viscosity test for bitumen shall be done in accordance with ASTM E 102 (Saybolt Furol Test for Asphalt Cement at High Temperature). The temperature to which the bitumen must be heated to produce a viscosity of 85$\pm$ 10 sec Saybolt Furol and 140 $\pm$ 15 sec Saybolt Furol shall be established as the mixing temperature and compacting temperature respectively.

6.3.10 Density of Marshall Stability test specimen shall be determined prior to the stability test conducted. Density is determined using one of the following equations in accordance with the texture of the specimen.

a) When the surface texture of the specimen is dense and absorption is negligible

$$d = \frac{A}{A-C} \times W \ (g/cm^3)$$

b) When the surface texture of the specimen is smooth but absorption is not negligible. The method of test shall be based on ASTM D 1075 (Test for Effect of water on Cohesion on Compacted Bituminous Mixture)

$$d = \frac{A}{B-C} \times W \ (g/cm^3)$$

where

A = weight of specimen in air (g)
B = surface dry weight of specimen in air (g)
C = weight of specimen in water (g)

W = Density of water ($1/gm/cm^3$)

Standard Marshall Test method. In this method, the Marshall properties, which are density, air voids, voids filled with bitumen, stability and flow, are plotted against bitumen content. The ranges of bitumen contents that satisfy each of the properties are computed, and subsequently the range of bitumen contents that satisfy all the requirements is computed. The mid-range of this bitumen content is the optimum bitumen content for the mix. However, it is important to note that this optimum bitumen content should be less than or equal to the bitumen content at maximum density.

6.3.12 In case there is no bitumen content that satisfy all the requirements, adjustments to the aggregates gradations, mineral filler content should be considered.

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