GUIDELINES FOR THE DESIGN OF FLEXIBLE PAVEMENTS

(Second Revision)

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ABBREVIATIONS

1.	AASHTO	-	American Association of State Highway and Transportation Officials
2.	BC	-	Bituminous Concrete
3.	BUSG	-	Built up Spray Grout
4.	BM	-	Bituminous Macadam
5.	CBR	-	California Bearing Ratio
6.	DBM	-	Dense Bituminous Macadam
7.	GB	-	Granular Base
8.	GSB	-	Granular Sub-Base
9.	IRC	-	Indian Roads Congress
10.	MORT&H	-	Ministry of Road Transport & Highways
11.	msa	-	Million Standard Axles
12.	SDBC	-	Semi-Dense Bituminous Concrete

GUIDELINES FOR THE DESIGN OF FLEXIBLE PAVEMENTS

1. INTRODUCTION

The design of flexible pavement involves the interplay of several variables, such as, the wheel loads, traffic, climate, terrain and sub-grade conditions. With a view to have a unified approach for working out the design of flexible pavement in the country, the IRC first brought out guidelines in 1970. These were based on California Bearing Ratio method. To handle large spectrum of axle load, these guidelines were revised in 1984 following the equivalent axle load concept. In this approach, the pavement thickness was related to the cumulative number of standard axles to be carried out for different sub-grade strengths. These guidelines were based on semi-empirical approach based on a large extent on past experience and judgement of highway agencies. Design curves were developed to cater upto 30 million standard axles.

With the rapid growth of traffic now, the pavements are required to be designed for heavy volume of traffic of the order of 150 million standard axles. In the meanwhile, an in-house software package was developed under MORT&H's Research Scheme R-56. This enabled mathematical modelling of the pavement structure using multiple layer elastic theory. With this background and the feed back on the performance of the existing designs, the Flexible Pavement Committee in 1997 set up a Sub-group consisting of the following personnel to review the existing "Guidelines for Design of Flexible Pavements". This Sub-group developed the design charts and catalogue of pavement designs for conditions prevailing in the country.

Dr. M.P. Dhir	...	*(Convenor)*
S.C. Sharma		
R.K. Pandey		
Dr. L.R. Kadiyali		
Dr. S.S. Jain		
D.P. Gupta		
V.K. Sood		
Dr. Sunil Bose		

The Sub-group discussed revision of IRC:37 in a number of meetings and finally on 10.8.98 submitted the revised draft to Flexible Pavement Committee (H-4). The draft was approved by H-4 Committee (Personnel given below) in its meeting held on 26.2.99 and the Convenor was authorised to incorporate the comments/suggestions made by the members and other experts appropriately and send the final draft to Highways Specifications & Standards Committee for consideration and approval.

Dr. A.K. Gupta	...	*Convenor* (upto 6.11.97)
S.C. Sharma	...	*Convenor* (w.e.f. 7.11.97)
Spl. Secy. & Chief Engineer R&B Deptt., Gandhinagar, (S.S. Rathore)	...	*Co-Convenor*
Dr. S.S. Jain	...	*Member-Secretary*

Members

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Prof. C.E.G. Justo	Chief Engineer(R) S&R,
R.K. Jain	MORT&H
B.K. Dam	(Indu Prakash)
B.R. Tyagi	Head, Flexible Pavement
I.C. Goel	Division, CRRI (I.R. Arya)
Dr. L.R. Kadiyali	Rep. of DGBR (A.R. Aiyengar)
Prof. B.B. Pandey	Engineer-in-Chief, UP PWD
Dr. M.P. Dhir	(Ravinder Kumar)
D.P. Gupta	

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Secretary, IRC (S.C. Sharma)	

Corresponding Members

Hari Om Prakash Sharma	I.K. Bhavsar
R.S. Shukla	Dr. P.D. Marathe
Prof. S.P. Jog	

The draft was further vetted by an Expert Group comprising of Shri S.C. Sharma, Prof. B.B. Pandey and Dr. S.S. Jain and forwarded to newly constituted Flexible Pavement Committee.

The newly constituted Flexible Pavement Committee (Personnel given below) in its meeting held on 23.9.2000 discussed and approved the revised draft of IRC:37 for placing before the Highways Specifications & Standards (HSS) Committee for approval.

S.C. Sharma	...	*Convenor*
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Dr. S.S. Jain	...	Member-Secretary

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Dr. A.K. Bhatnagar	D. Sreerama Murthy
Dr. M.P. Dhir	Prof. C.G. Swaminathan
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Secretary, IRC (G. Sharan)

Corresponding Members

Sukomal Chakraborty | Smt. A.P. Joshi | R.S. Shukla

The HSS Committee in its meeting held on 30.9.2000 after detailed discussion approved the revised draft IRC:37 and authorised the Convenor, Flexible Pavement Committee to modify the same in light of the comments of members and submit to Convenor, HSS Committee for its approval. The draft of revised guidelines as modified by the Convenor, HSS Committee was approved by the Executive Committee in its meeting held at New Delhi on 5.10.2000 and by the Council in its meeting held at Kolkata on 4.11.2000. The draft as modified in light of comments of members of the Council was approved by the Convenor, HSS Committee on 12.2.2001 for printing.

2. SCOPE

2.1. These guidelines will apply to design of flexible pavements for Expressways, National Highways, State Highways, Major District Roads and other categories of roads predominantly carrying motorised vehicles.

2.2. For the purpose of the guidelines, flexible pavements are considered to include the pavements which have bituminous surfacing and granular base and sub-base courses conforming to IRC Standards or to Sections 500 and 400 of the Specifications

for Road and Bridge Works, Ministry of Road Transport and Highways.

2.3. These guidelines apply to new pavements.

2.4. For design of strengthening measures or overlays for existing pavements, the design procedure described in IRC:81 "Tentative Guidelines for Strengthening of Flexible Road Pavements Using Benkelman Beam Deflection Technique" shall apply.

2.5. The guidelines may require revision from time to time in the light of future experience and developments in the field. Towards this end, it is suggested that all the organisations intending to use the guidelines, should keep a detailed record of year of construction, subgrade CBR, soil characteristics, pavement composition and specifications, traffic, pavement performance, overlay history, climatic conditions, etc. and provide feedback to the Indian Roads Congress.

3. RECOMMENDED METHOD OF DESIGN

3.1. General

The pavement designs given in the previous edition IRC:37-1984 were applicable to design traffic upto 30 million standard axles (msa). With the increasing traffic and incidence of overloading, arterial roads need to be designed for traffic far greater than 30 msa. As empirical methods have limitations regarding their applicability and extrapolation, the analytical method of design has been used to reanalyse the existing designs and develop a new set of designs for design traffic upto 150 msa making use of the results of pavement research work done in the country and experience gained over the years on the performance of the existing designs.

3.2. Design Approach and Criteria

3.2.1. The flexible pavement has been modelled as a three layer structure and stresses and strains at critical locations *(Annexure-1)* have been computed using the linear elastic model FPAVE developed under the MORT&H Research Scheme R-56 "Analytical Design of Flexible Pavements"[1].

3.2.2. To give proper consideration to the aspect of performance, the following three types of pavement distress resulting from repeated application of traffic loads are considered:

(i) Vertical compressive strain at the top of the subgrade. If the strain is excessive, the subgrade will deform resulting in permanent deformation at the pavement surface during the design life.

(ii) Horizontal tensile strain at the bottom of the bituminous layer. Large tensile strains cause fracture of the bituminous layer during the design life.

(iii) Pavement deformation within the bituminous layer.

While the permanent deformation within the bituminous layer can be controlled by meeting the mix design requirements as per the MORT&H Specification[2], thicknesses of granular and bituminous layers are selected using the analytical design approach so that strains at the critical points are within the allowable limits.

For calculating tensile strains at the bottom of the bituminous layer, the Elastic Modulus of Dense Bituminous

Macadam (DBM) layer with 60/70 bitumen has been used in the analysis. The relationships used for (i) allowable vertical subgrade strain; and (ii) allowable tensile strain at the bottom of the DBM layer along with elastic moduli of different pavement materials and the relationships for assessing the elastic moduli of subgrade, granular sub-base and base layers are given in *Annexure-1*.

3.2.3. Based on the performance of existing designs and using analytical approach, simple design charts (Figs. 1 and 2) and a catalogue of pavement designs (Plates 1 and 2) have been added for use of field Engineers. The pavement designs are given for subgrade CBR values ranging from 2 per cent to 10 per cent and design traffic ranging from 1 msa to 150 msa for an average annual pavement temperature of 35°C. The layer thicknesses obtained from the analysis have been slightly modified to adapt the designs to stage construction. Using the following simple input parameters, appropriate designs could be chosen for the given traffic and soil strength :

(i) Design traffic in terms of cumulative number of standard axles; and

(ii) CBR value of subgrade

The procedure for estimating design traffic and assessing the CBR value of the subgrade soil is described in paragraphs 3.3 and 3.4 respectively.

3.3. Traffic

3.3.1. General

3.3.1.1. The recommended method considers traffic in terms of the cumulative number of standard axles (8160 kg) to

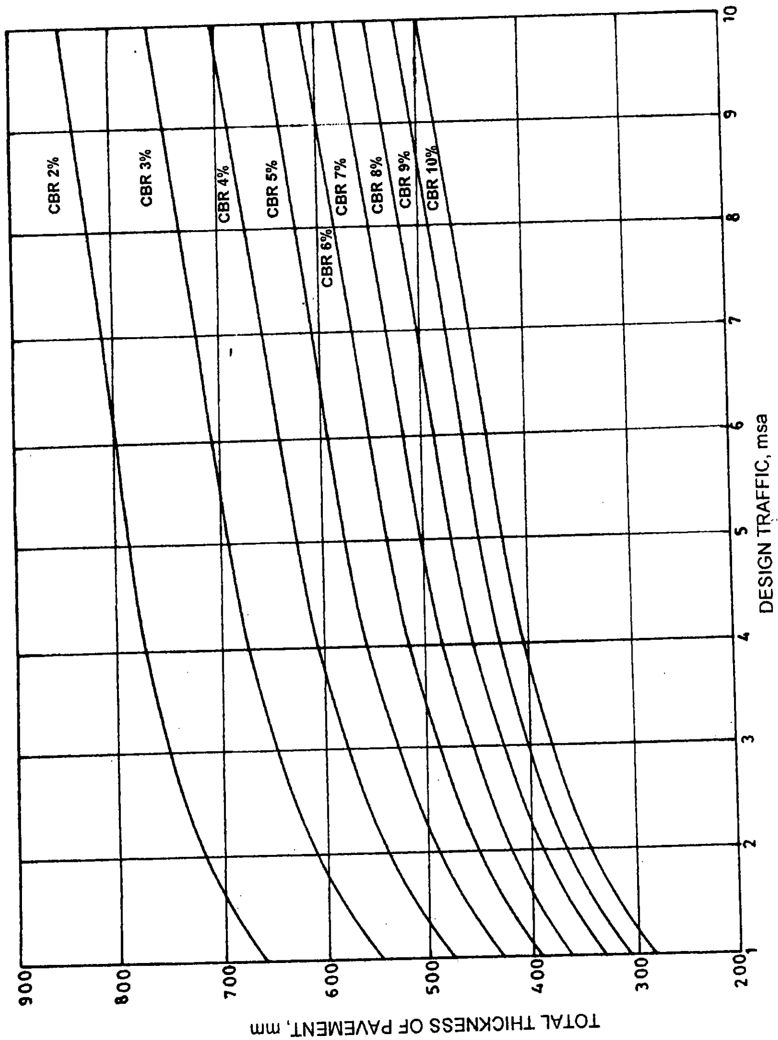


Fig. 1. Pavement Thickness Design Chart for Traffic 1-10 msa

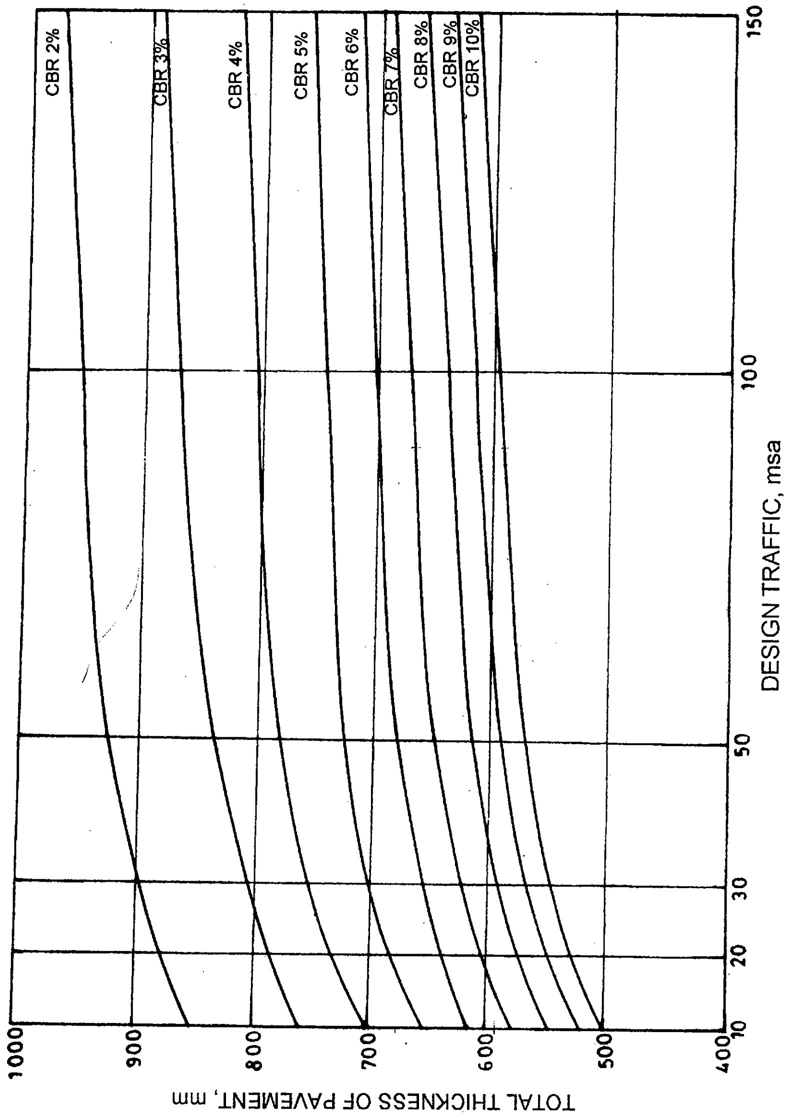


Fig. 2. Pavement Thickness Design Chart for Traffic 10-150 msa

be carried by the pavement during the design life. For estimating design traffic, the following information is needed :

(i) Initial traffic after construction in terms of number of commercial vehicles per day (CVPD)

(ii) Traffic growth rate during the design life in percentage

(iii) Design life in number of years

(iv) Vehicle damage factor (VDF)

(v) Distribution of commercial traffic over the carriageway.

3.3.1.2. For the purpose of structural design, only the number of commercial vehicles of gross vehicle weight of three tonnes or more and their axle-loading is considered.

3.3.1.3. To obtain a realistic estimate of design traffic, due consideration should be given to the existing traffic or that anticipated based on possible changes in the road network and land use of the area served, the probable growth of traffic and design life.

Estimate of the initial daily average traffic flow for any road should normally be based on atleast 7 days, 24 hour classified traffic counts. In cases of new roads, traffic estimates can be made on the basis of potential land use and traffic on existing routes in the area.

3.3.2. **Traffic growth rate**

3.3.2.1. Traffic growth rates should be estimated :

(i) by studying the past trends of traffic growth, and

(ii) by establishing econometric models, as per the procedure outlined in IRC:108 "Guidelines for Traffic Prediction on Rural Highways".

3.3.2.2. If adequate data is not available, it is recommended that an average annual growth rate of 7.5 per cent may be adopted.

3.3.3. **Design life**

3.3.3.1. For the design of pavement, the design life is defined in terms of the cumulative number of standard axles that can be carried before strengthening of the pavement is necessary.

3.3.3.2. It is recommended that pavements for National Highways and State Highways should be designed for a life of 15 years. Expressways and urban roads may be designed for a longer life of 20 years. For other categories of roads, a design life of 10 to 15 years may be adopted.

3.3.3.3. Very often it is not possible to provide the full thickness of pavement right at the time of initial construction. Stage construction techniques should be resorted to in such cases.

3.3.4. **Vehicle damage factor**

3.3.4.1. The vehicle damage factor (VDF) is a multiplier to convert the number of commercial vehicles of different axle loads and axle configuration to the number of standard axle load repetitions. It is defined as equivalent number of standard axles per commercial vehicle. The VDF varies with the vehicle axle configuration, axle loading, terrain, type of road and from region to region. The VDF is arrived at from axle load surveys on typical road sections so as to cover various influencing factors, such as traffic mix, mode of transportation, commodities carried, time of the year, terrain, road conditions and degree of enforcement.

3.3.4.2. The axle load equivalency factors recommended in the AASHTO guide are given in *Annexure-2*. They are used for converting different axle load repetitions into equivalent standard axle load repetitions.

3.3.4.3. For designing a new pavement, the VDF should be arrived at carefully by carrying out specific axle load surveys on the existing roads. Some surveys have been carried out in the country on National Highways, State Highways and Major District Roads which reveal excessive overloading of commercial vehicles. Therefore, it is recommended that the designer should take the realistic values of VDF after conducting the axle load survey, particularly in the case of major projects. On some sections, there may be significant difference in axle loading in two directions of traffic. In such situations, the VDF should be evaluated direction wise to determine the lanes which are heavily loaded for the purpose of design.

3.3.4.4. Where sufficient information on axle loads is not available and the project size does not warrant conducting an axle load survey, the indicative values of vehicle damage factor as given in Table 1 may be used.

TABLE 1. INDICATIVE VDF VALUES

Initial traffic volume in terms of number of commercial vehicles per day	Terrain Rolling/Plain	Terrain Hilly
0-150	1.5	0.5
150-1500	3.5	1.5
More than 1500	4.5	2.5

3.3.5. Distribution of commercial traffic over the carriageway

3.3.5.1. A realistic assessment of distribution of commercial traffic by direction and by lane is necessary as it directly affects the total equivalent standard axle load applications used in the design. In the absence of adequate and conclusive data for Indian conditions, it is recommended that for the time being the following distribution may be assumed for design until more reliable data on placement of commercial vehicles on the carriageway lanes are available :

(i) **Single-lane roads**

Traffic tends to be more channelised on single-lane roads than two-lane roads and to allow for this concentration of wheel load repetitions, the design should be based on total number of commercial vehicles in both directions.

(ii) **Two-lane single carriageway roads**

The design should be based on 75 per cent of the total number of commercial vehicles in both directions.

(iii) **Four-lane single carriageway roads**

The design should be based on 40 per cent of the total number of commercial vehicles in both directions.

(iv) **Dual carriageway roads**

The design of dual two-lane carriageway roads should be based on 75 per cent of the number of commercial vehicles in each direction. For dual three-lane carriageway and dual four-lane carriageway, the distribution factor will be 60 per cent and 45 per cent respectively.

3.3.5.2. The traffic in each direction may be assumed to be half of the sum in both directions when the latter only is known. Where significant difference between the two streams can occur, condition in the more heavily trafficked lane should be considered for design.

Where the distribution of traffic between the carriagway lanes and axle loads spectrum for the carriageway lanes are available, the design should be based on the traffic in the most heavily trafficked lane and the same design will normally be applied for the whole carriageway width.

3.3.6. **Computation of design traffic**

3.3.6.1. The design traffic is considered in terms of the cumulative number of standard axles (in the lane carrying maximum traffic) to be carried during the design life of the road. This can be computed using the following equation :

$$N = \frac{365x[(1+r)^n-1]}{r} x\ A\ x\ D\ x\ F$$

where,

N = The cumulative number of standard axles to be catered for in the design in terms of msa.

A = Initial traffic in the year of completion of construction in terms of the number of commercial vehicles per day.

D = Lane distribution factor (as explained in para 3.3.5)
F = Vehicle damage factor
n = Design life in years
r = Annual growth rate of commercial vehicles (for 7.5 per cent annual growth rate, r = 0.075)

The traffic in the year of completion is estimated using the following formula :

$$A = P(1 + r)^x$$

where,

P = Number of commercial vehicles as per last count.
x = Number of years between the last count and the year of completion of construction.

3.4. **Subgrade**

3.4.1. The subgrade whether in cut or fill should be well compacted to utilise its full strength and to economise thereby on the overall thickness of pavement required. For Expressways, National Highways, State Highways and Major District Roads, heavy compaction is recommended. Most of the specifications prescribe use of selected material and stiffer standards of compaction in the subgrade (top 500 mm portion of the roadway). The current MORT&H Specification for Road & Bridge Works (Third Revision 1995) recommend that the subgrade shall be compacted to 97 per cent of dry density achieved with heavy compaction (modified proctor density) as per IS:2720 (Part 8). This density requirement is recommended for subgrade compaction for Expressways, National Highways, State Highways, Major District Roads and other heavily trafficked roads. In other cases the subgrade should be compacted to atleast 97 per cent of the standard proctor density conforming to IS:2720 (Part 7). These requirements should be strictly enforced. IRC:36 "Recommended Practice for the Construction of Earth Embankments for Road Works" should be followed for guidance during planning and execution of work.

3.4.2. For high category roads, like, Expressways, National Highways and State Highways, the material used for subgrade construction should have the dry density of not less than 1.75 gm/cc.

3.4.3. For design, the subgrade strength is assessed in terms of the CBR of the subgrade soil in both fill and cut sections at the most critical moisture conditions likely to occur in-situ.

3.4.4. For determining the CBR value, the standard test procedure should be strictly adhered to. This is described in IS:2720 (Part 16) "Methods of Test for Soils; Laboratory Determination of CBR". The test must always be performed on remoulded samples of soils in the laboratory. Wherever possible the test specimens should be prepared by Static Compaction but if not so possible dynamic method may be used as an alternative. Both procedures are described in brief in *Annexure-3*. In-situ tests are not recommended for design purposes as it is not possible to satisfactorily simulate the critical conditions of dry density and moisture content in the field.

3.4.5. **Selection of dry density and moisture content for test specimen**

3.4.5.1. For a given soil, the CBR value and consequently the design, will depend largely on the density and moisture content of the test sample. Therefore, the test conditions should reproduce as closely as possible the weakest conditions likely to occur under the road after construction.

3.4.5.2. The samples of soil collected from selected borrow pits for fill sections or from subgrade level at cut sections

should be compacted to a dry density corresponding to the minimum state of compaction likely to be achieved in practice having regard to the compaction equipment used and the compaction limits specified.

3.4.5.3. The moisture condition of the subgrade which the test sample is expected to simulate is governed by local environmental factors, such as, the water table, precipitation, soil permeability, drainage conditions and the extent to which the pavement is waterproof. Thin surfacings do not always seal the pavement effectively against ingress of water. Further, the berms and verges are usually unsurfaced, and if not kept in well-maintained state to the requisite cross-fall, will enable surface water to percolate into the subgrade from near the edges of the pavement, leading to weak subgrade conditions.

Hence, it is recommended that as a general practice, the design for new construction should be based on the strength of the samples prepared at the values of prescribed dry density and moisture content obtained in accordance with IS:2720 (Part 8) or (Part 7) as the case may be and soaked in water for a period of four days prior to testing. Use of expansive clays is not allowed for subgrade construction particularly for heavily trafficked roads. As far as possible, a non-expansive soil should be used for the subgrade. Where use of expansive clays is unavoidable, the compaction requirements and additional measures as discussed in *Annexure-4* should be followed.

3.4.5.4. However, it should be realised that soaking for four days may be an unrealistically severe moisture condition in certain cases, where the climate is arid throughout the year, i.e., the annual rainfall is of the order of 500 mm or less and the water table is too deep to affect the subgrade adversely. It is anticipated that in this situation the most severe moisture condition in the field will be far below that of the sample at the end of four days soaking, resulting in unduly conservative designs if soaking procedure is adopted. In such cases, the specimens for finding the CBR value may be prepared at the natural moisture content of the soil at subgrade depth immediately after recession of the monsoon.

3.4.6. Use of test results for design and the minimum number of tests required

3.4.6.1. The design should be based on the CBR value of the weakest soil type proposed to be used for subgrade construction or encountered extensively at subgrade level over a given section of the road, as revealed by the soil surveys. Pavement thickness on new roads may be modified at intervals as dictated by the soil changes but generally it will be found inexpedient to do so frequently from practical considerations.

3.4.6.2. It is possible that in certain soil types or under abnormal conditions the measured CBR values may appear doubtful and not truly representative of the strength of soil. A more complete study of the soil may be warranted in such cases to arrive at a more reliable design.

3.4.6.3. The design evolved should be revised during construction phase if found necessary on account of the field compaction being lower than that considered in the initial design. In addition, the alternative of retaining local areas of soft soil or soil not meeting prescribed compaction level should also be considered.

3.4.6.4. As the reproducibility of the CBR results is dependent on a number of factors, wide variations in values can be expected. Therefore, atleast three samples should be tested on each type of soil at the same density and moisture content. This will enable a reliable average value to be obtained in most cases. To weed out erratic results, permissible maximum variation within the CBR values from the three specimens is indicated in Table 2.

Table 2. Permissible Variation in CBR value

CBR (per cent)	Maximum variation in CBR value
5	±1
5-10	±2
11-30	±3
31 and above	±5

Where variation is more than the above, the design CBR value should be the average of test results from atleast six samples and not three.

4. PAVEMENT THICKNESS AND COMPOSITION

4.1. Pavement Thickness Design Charts

For the design of pavements to carry traffic in the range of 1 to 10 msa, the Pavement Thickness Chart is given in Fig. 1 and for traffic in the range of 10-150 msa, the Pavement Thickness Design Chart is given in Fig. 2. The design curves relate pavement thickness to the cumulative number of standard axles to be carried over the design life for CBR values of subgrade ranging from 2 per cent to 10 per cent. The thickness deduced from Fig. 1 or Fig. 2 for the given CBR value and design traffic is the total pavement thickness to be provided and consists of granular sub-base, granular base and bituminous surfacing. The requirements for the component layers are given in paragraph 4.2. Based on these, the recommended designs giving minimum thickness and compositions of pavement layers for new constructions are given in the Pavement Design Catalogue, Plates 1 and 2. The design procedure is illustrated with examples in paragraph 7.

4.2. Pavement Composition

4.2.1. Sub-base course

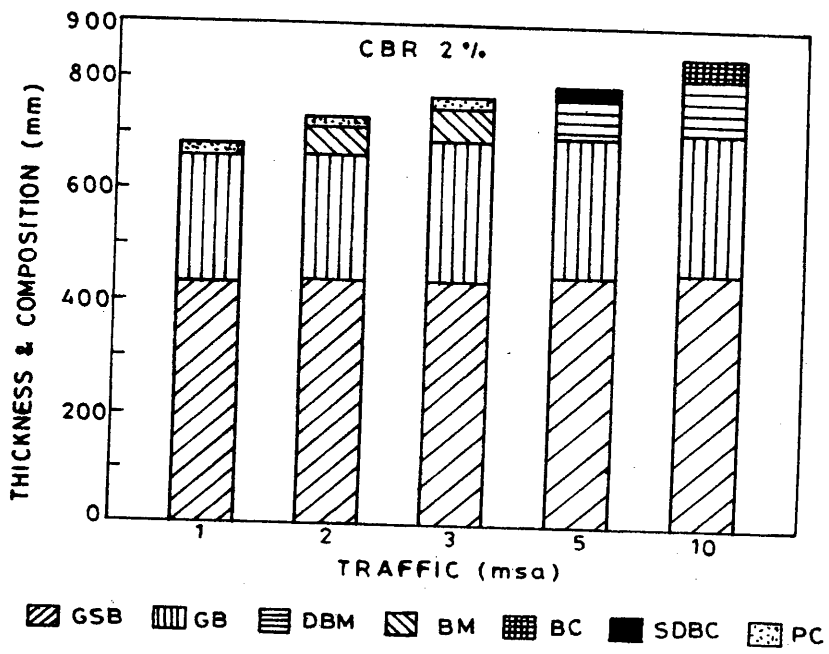
4.2.1.1. Sub-base materials comprise natural sand, moorum, gravel, laterite, kankar, brick metal, crushed stone, crushed slag, crushed concrete or combinations thereof meeting the prescribed grading and physical requirements. When the sub-base material consists of combination of materials, mixing shall be done mechanically either using a suitable mixer or adopting mix-in-place method.

Granular sub-base materials conforming to Clause 401 of MORT&H Specifications for Road and Bridge Works are recommended for use. These specifications suggest three gradings each for close and coarse graded granular sub-base materials and specify that the materials passing 425 micron sieve when tested in accordance with IS:2720 (Part 5) should have liquid limit and plasticity index of not more than 25 and 6 respectively. These requirements and the specified grain size distribution of the sub-base material should be strictly enforced in order to meet stability and drainage requirements of the granular sub-base layer.

PAVEMENT DESIGN CATALOGUE

PLATE 1 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 1-10 msa

CBR 2%						
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION				
		Bituminous Surfacing		Granular Base (mm)	Granular Sub-base (mm)
		Wearing Course (mm)	Binder Course (mm)		
1	660	20 PC		225	435
2	715	20 PC	50 BM	225	440
3	750	20 PC	60 BM	250	440
5	795	25 SDBC	70 DBM	250	450
10	850	40 BC	100 DBM	250	460



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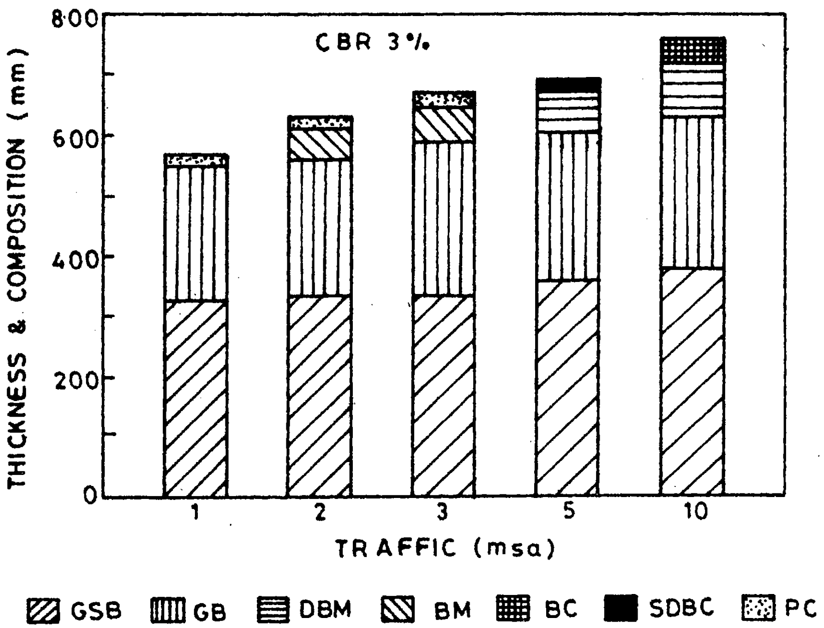
PAVEMENT DESIGN CATALOGUE

PLATE 1 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 1-10 msa

CBR 3%					
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION			
		Bituminous Surfacing		Granular Base (mm)	Granular Sub-base (mm)
		Wearing Course (mm)	Binder Course (mm)		
1	550	20 PC		225	435
2	610	20 PC	50 BM	225	335
3	645	20 PC	60 BM	250	335
5	690	25 SDBC	60 DBM	250	335
10	760	40 BC	90 DBM	250	380



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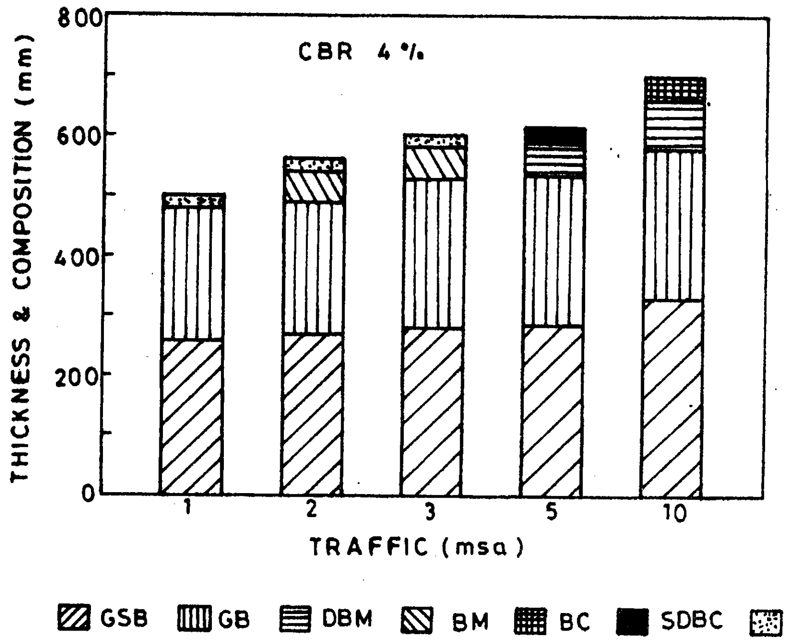
PAVEMENT DESIGN CATALOGUE

PLATE 1 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 1-10 msa

CBR 4%					
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION			
		Bituminous Surfacing		Granular Base (mm)	Granular Sub-base (mm)
		Wearing Course (mm)	Binder Course (mm)		
1	480	20 PC		225	255
2	540	20 PC	50 BM	225	265
3	580	20 PC	50 BM	250	280
5	620	25 SDBC	60 DBM	250	285
10	700	40 BC	80 DBM	250	330



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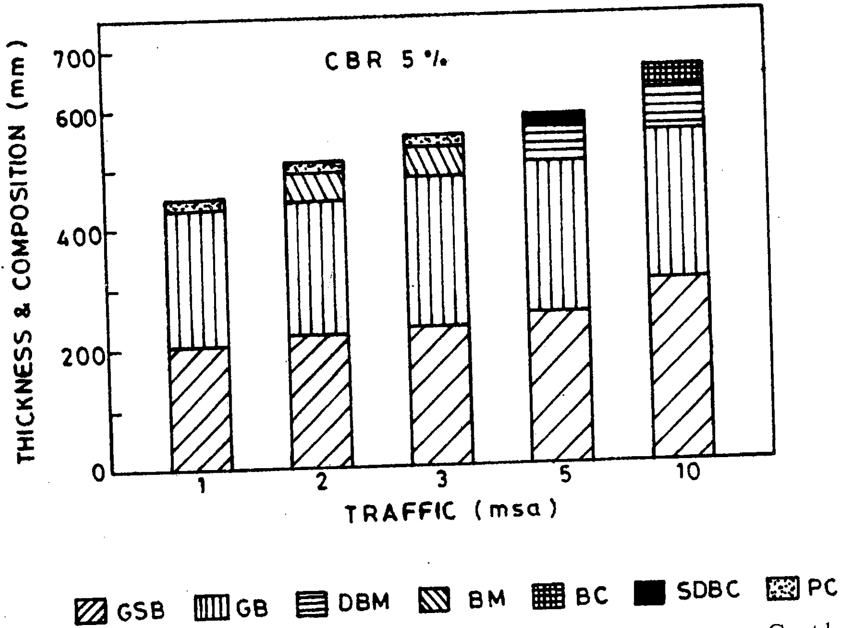
PAVEMENT DESIGN CATALOGUE

PLATE 1 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 1-10 msa

CBR 5%					
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION			
		Bituminous Surfacing		Granular Base (mm)	Granular Sub-base (mm)
		Wearing Course (mm)	Binder Course (mm)		
1	430	20 PC		225	205
2	490	20 PC	50 BM	225	215
3	530	20 PC	50 BM	250	230
5	580	25 SDBC	55 DBM	250	250
10	660	40 BC	70 DBM	250	300



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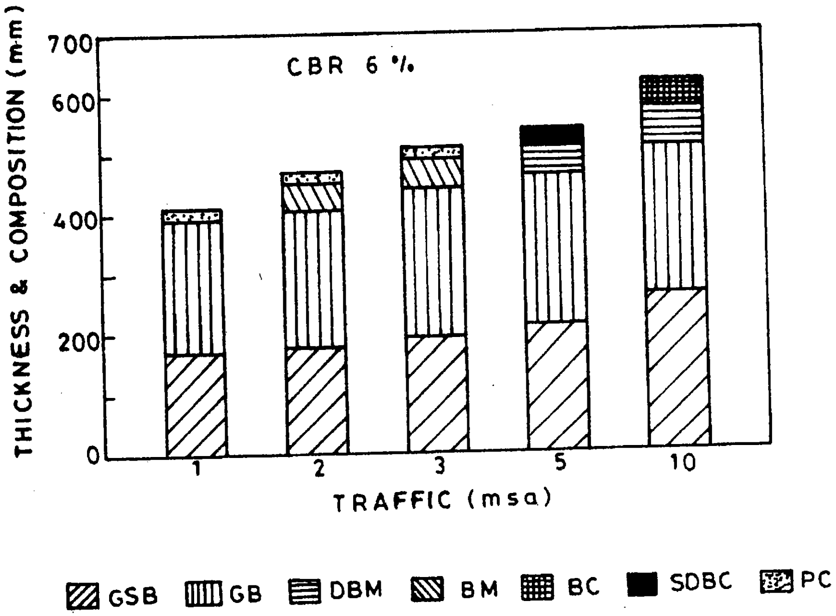
PAVEMENT DESIGN CATALOGUE

PLATE 1 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 1-10 msa

CBR 6%					
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION			
		Bituminous Surfacing		Granular Base (mm)	Granular Sub-base (mm)
		Wearing Course (mm)	Binder Course (mm)		
1	390	20 PC		225	165
2	450	20 PC	50 BM	225	175
3	490	20 PC	50 BM	250	190
5	535	25 SDBC	50 DBM	250	210
10	615	40 BC	65 DBM	250	260



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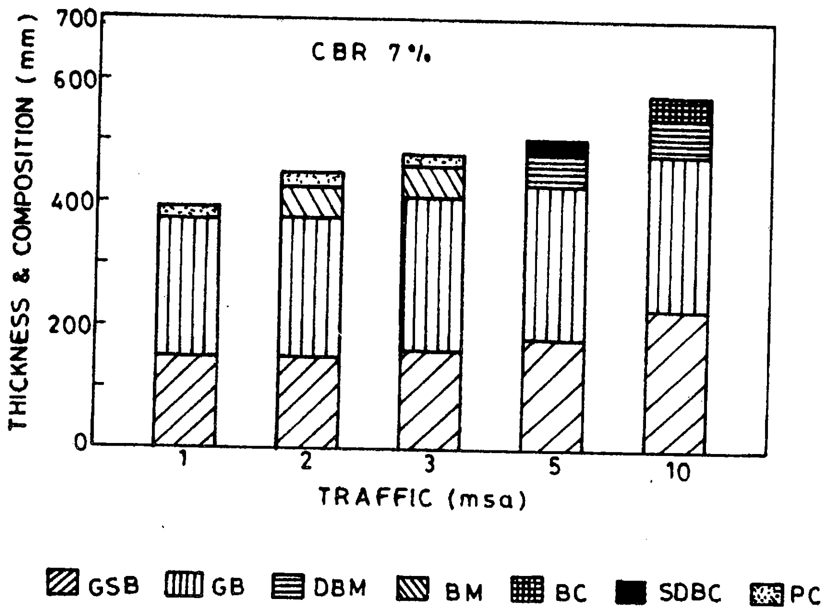
PAVEMENT DESIGN CATALOGUE

PLATE 1 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 1-10 msa

CBR 7%					
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION			
		Bituminous Surfacing		Granular Base (mm)	Granular Sub-base (mm)
		Wearing Course (mm)	Binder Course (mm)		
1	375	20 PC		225	150
2	425	20 PC	50 BM	225	150
3	460	20 PC	50 BM	250	160
5	505	25 SDBC	50 DBM	250	180
10	580	40 BC	60 DBM	250	230



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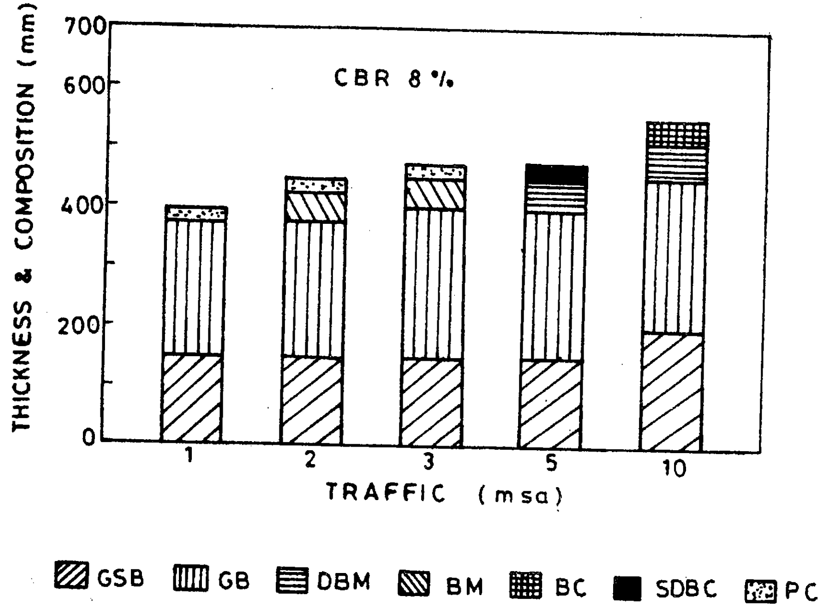
PAVEMENT DESIGN CATALOGUE

PLATE 1 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 1-10 msa

CBR 8%					
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION			
		Bituminous Surfacing		Granular Base (mm)	Granular Sub-base (mm)
		Wearing Course (mm)	Binder Course (mm)		
1	375	20 PC		225	150
2	425	20 PC	50 BM	225	150
3	450	20 PC	50 BM	250	150
5	475	25 SDBC	50 DBM	250	150
10	550	40 BC	60 DBM	250	200



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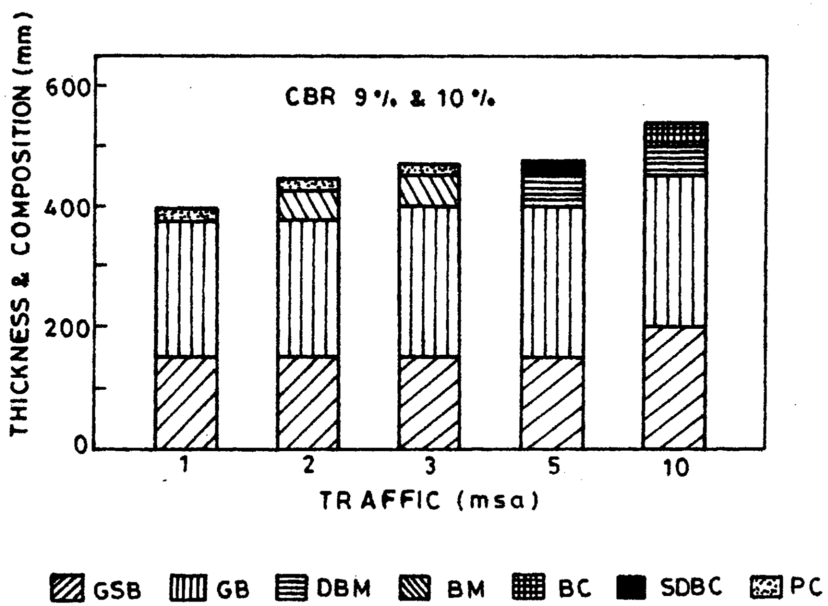
PAVEMENT DESIGN CATALOGUE

PLATE 1 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 1-10 msa

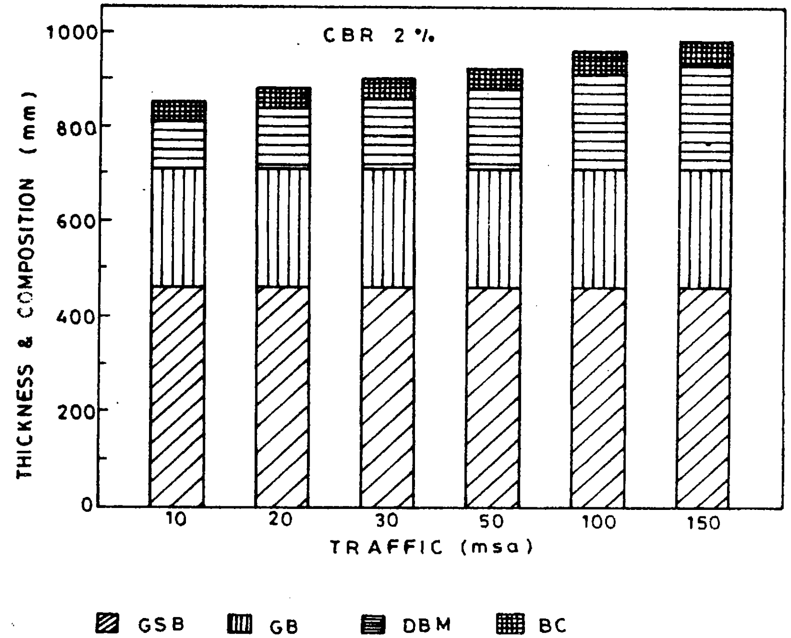
CBR 9% & 10%					
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION			
		Bituminous Surfacing		Granular Base (mm)	Granular Sub-base (mm)
		Wearing Course (mm)	Binder Course (mm)		
1	375	20 PC		225	150
2	425	20 PC	50 BM	225	150
3	450	20 PC	50 BM	250	150
5	475	25 SDBC	50 DBM	250	150
10	540	40 BC	50 DBM	250	200



PAVEMENT DESIGN CATALOGUE

PLATE 2 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 10-150 msa

CBR 2%				
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		Granular Base & Sub-base (mm)
		BC (mm)	DBM (mm)	
10	850	40	100	
20	880	40	130	
30	900	40	150	Base = 250
50	925	40	175	
100	955	50	195	Sub-base = 460
150	975	50	215	



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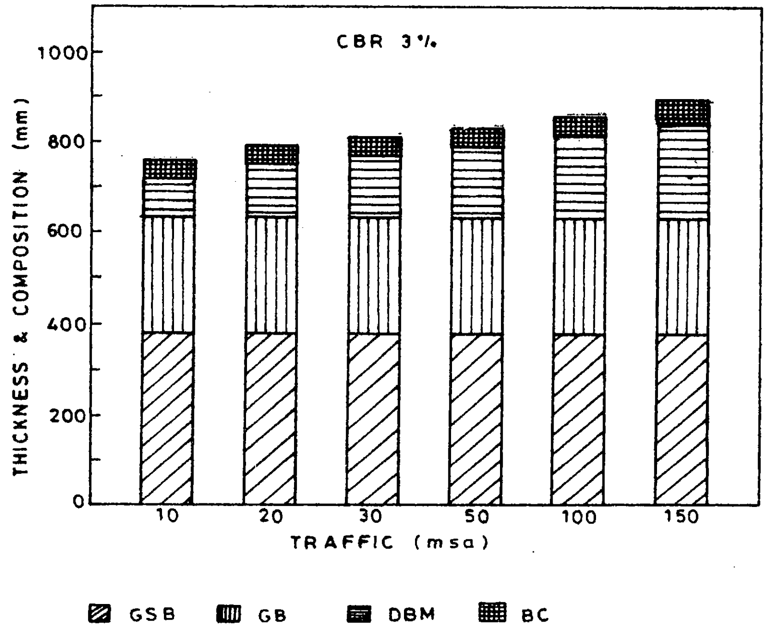
PAVEMENT DESIGN CATALOGUE

PLATE 2 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 10-150 msa

CBR 3%				
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		Granular Base & Sub-base (mm)
		BC (mm)	DBM (mm)	
10	760	40	90	
20	790	40	120	
30	810	40	140	Base = 250
50	830	40	160	
100	860	50	180	Sub-base = 380
150	890	50	210	



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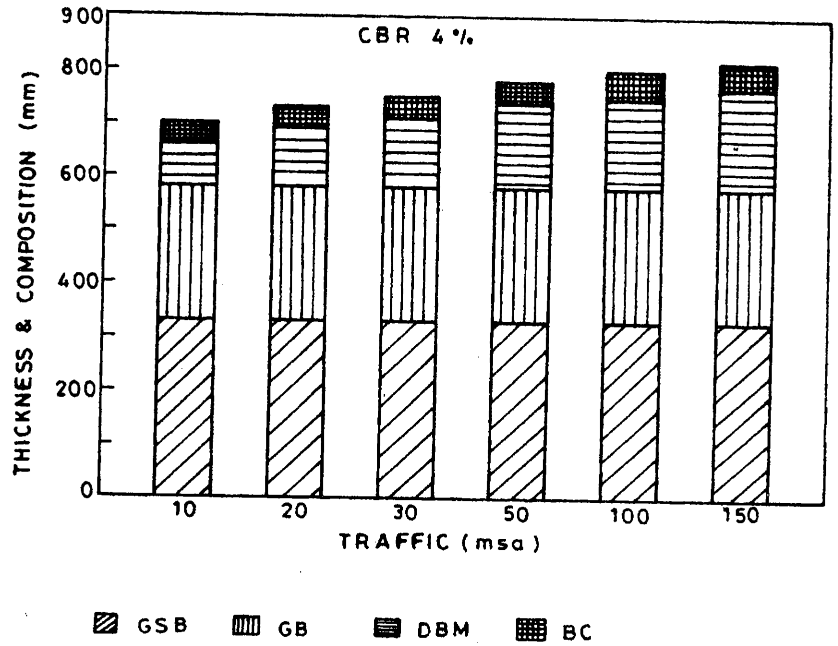
PAVEMENT DESIGN CATALOGUE

PLATE 2 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 10-150 msa

CBR 4%				
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		Granular Base & Sub-base (mm)
		BC (mm)	DBM (mm)	
10	700	40	80	
20	730	40	110	
30	750	40	130	Base = 250
50	780	40	160	
100	800	50	170	Sub-base = 330
150	820	50	190	



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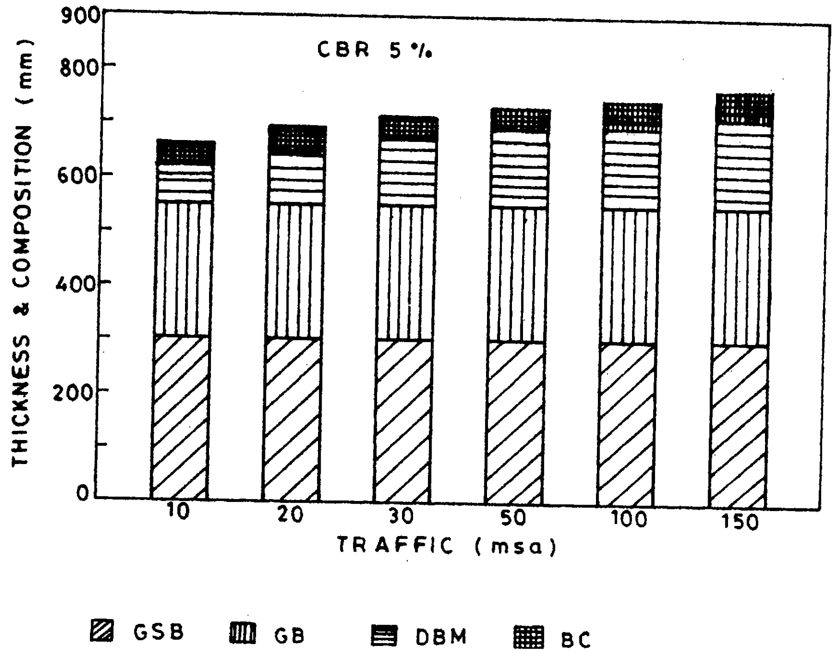
PAVEMENT DESIGN CATALOGUE

PLATE 2 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 10-150 msa

CBR 5%				
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		Granular Base & Sub-base (mm)
		BC (mm)	DBM (mm)	
10	660	40	70	Base = 250 Sub-base = 300
20	690	40	100	
30	710	40	120	
50	730	40	140	
100	750	50	150	
150	770	50	170	



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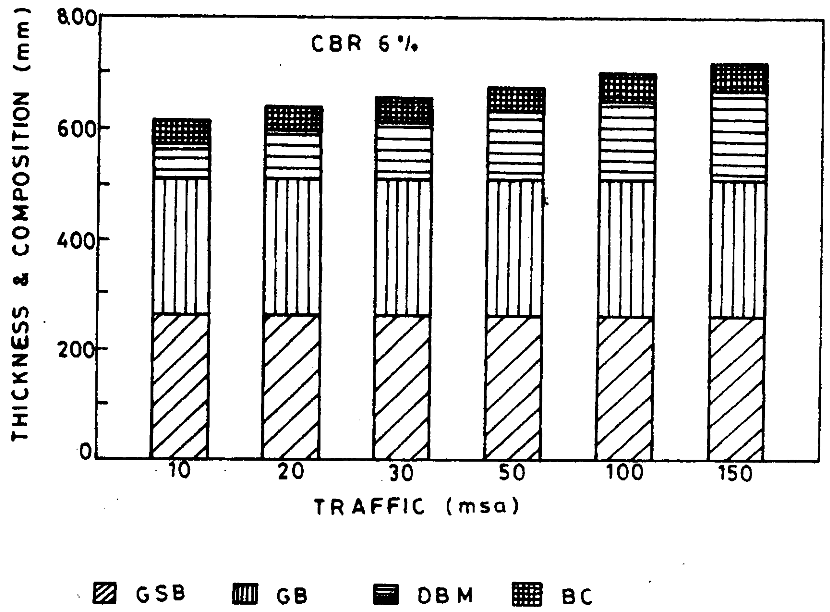
PAVEMENT DESIGN CATALOGUE

PLATE 2 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 10-150 msa

CBR 6%				
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		Granular Base & Sub-base (mm)
		BC (mm)	DBM (mm)	
10	615	40	65	Base = 250 Sub-base = 260
20	640	40	90	
30	655	40	105	
50	675	40	125	
100	700	50	140	
150	720	50	160	



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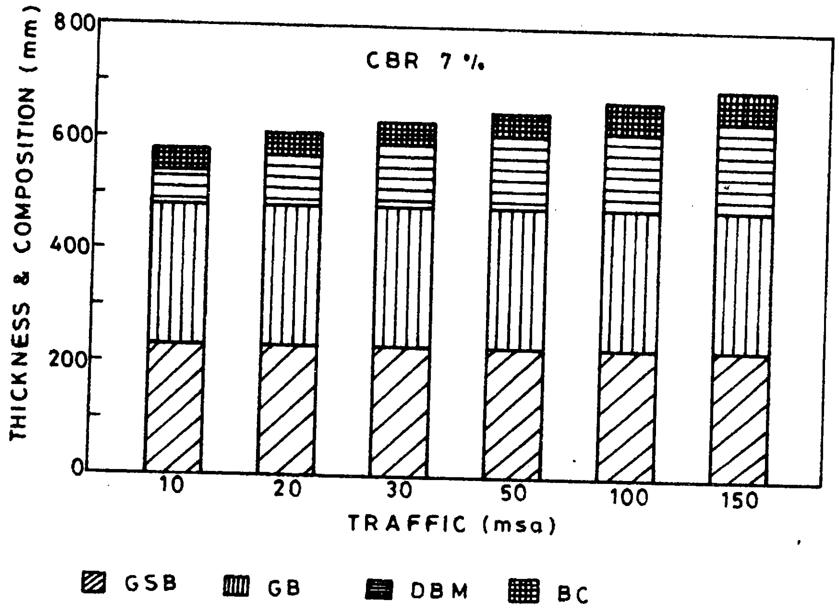
PAVEMENT DESIGN CATALOGUE

PLATE 2 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 10-150 msa

CBR 7%				
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		Granular Base & Sub-base (mm)
		BC (mm)	DBM (mm)	
10	580	40	60	Base = 250 Sub-base = 230
20	610	40	90	
30	630	40	110	
50	650	40	130	
100	675	50	145	
150	695	50	165	



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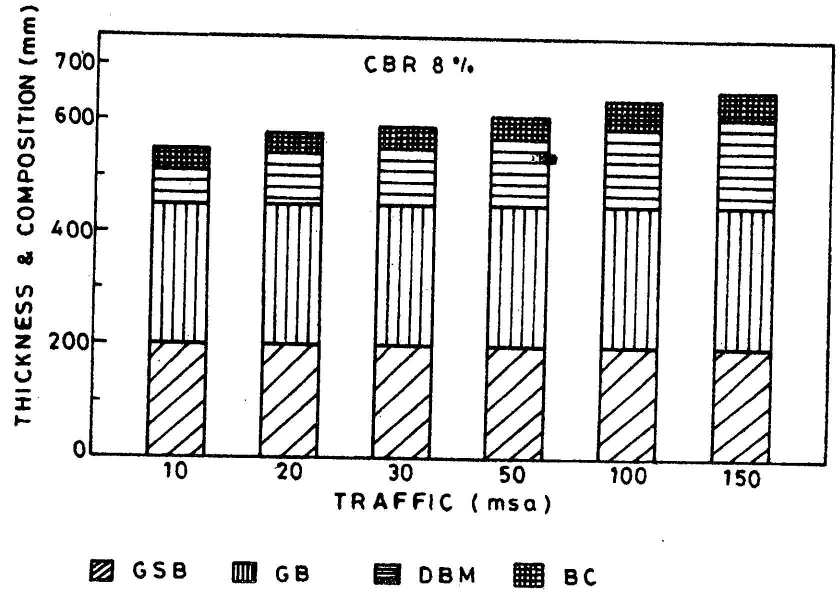
PAVEMENT DESIGN CATALOGUE

PLATE 2 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 10-150 msa

CBR 8%				
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		Granular Base & Sub-base (mm)
		BC (mm)	DBM (mm)	
10	550	40	60	Base = 250 Sub-base = 200
20	575	40	85	
30	590	40	100	
50	610	40	120	
100	640	50	140	
150	660	50	160	



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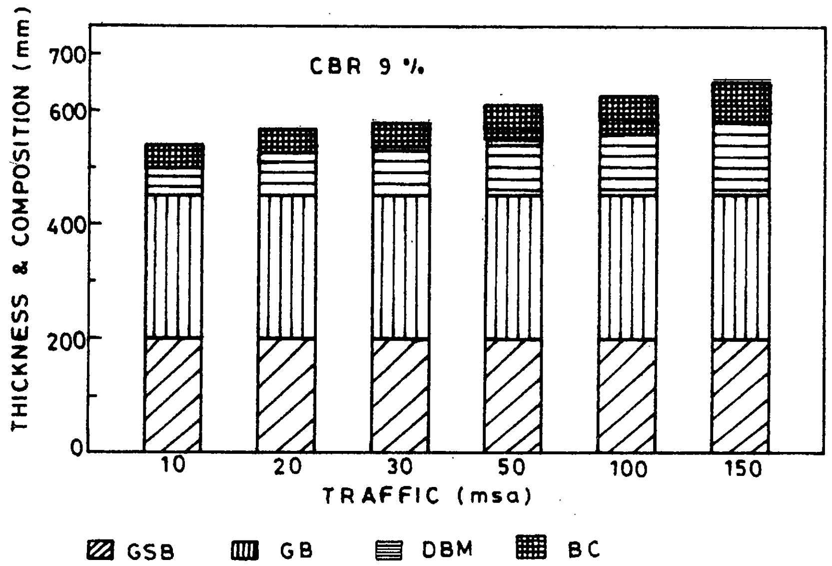
PAVEMENT DESIGN CATALOGUE

PLATE 2 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 10-150 msa

CBR 9%				
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		Granular Base & Sub-base (mm)
		BC (mm)	DBM (mm)	
10	540	40	50	Base = 250 Sub-base = 200
20	570	40	80	
30	585	40	95	
50	605	40	115	
100	635	50	135	
150	655	50	155	



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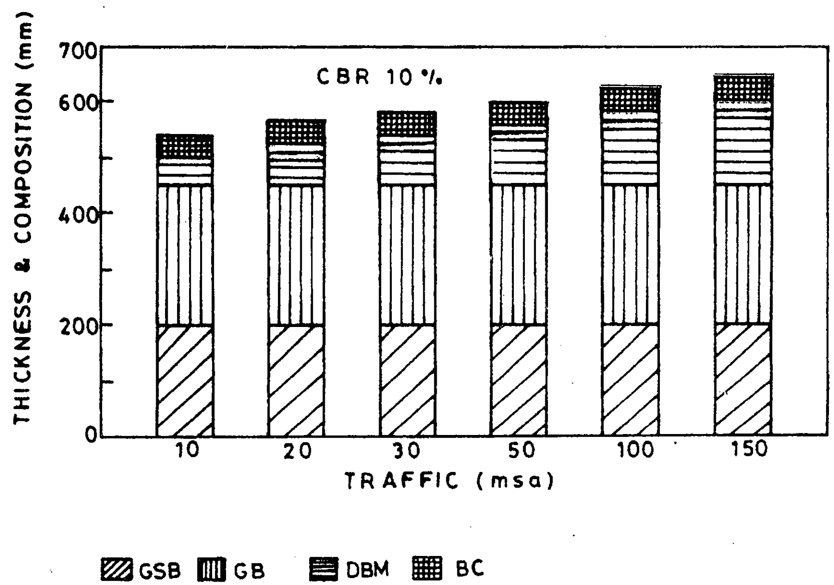
PAVEMENT DESIGN CATALOGUE

PLATE 2 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 10-150 msa

CBR 10%				
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		Granular Base & Sub-base (mm)
		BC (mm)	DBM (mm)	
10	540	40	50	Base = 250 Sub-base = 200
20	565	40	75	
30	580	40	90	
50	600	40	110	
100	630	50	130	
150	650	50	150	



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The sub-base material should have minimum CBR of 20 per cent for cumulative traffic upto 2 msa and 30 per cent for traffic exceeding 2 msa. It should be ensured prior to actual execution that the material to be used in sub-base satisfies the CBR and other prescribed physical requirements. The material should be tested for CBR at the dry density and moisture content expected in the field. Where soaking conditions apply for design, the minimum strength of the sub-base material should be determined after soaking the test specimen in water for four days.

4.2.1.2. Where the granular sub-base material conforming to the above specifications is not available economically, other granular sub-bases, like, Water Bound or Wet Mix Macadam conforming to MORT&H Specifications are recommended.

4.2.1.3. From drainage considerations the granular sub-base should be extended over the entire formation width in case the subgrade soil is of relatively low permeability. The thickness of sub-base in the extended portions should not be less than the prescribed minimum as given in para 4.2.1.4.

4.2.1.4. The thickness of sub-base should not be less than 150 mm for design traffic less than 10 msa and 200 mm for design traffic of 10 msa and above.

4.2.1.5. Preferably the subgrade soil should have a CBR of 2 per cent. Where the CBR value of the subgrade is less than 2 per cent, the design should be based on subgrade CBR value of 2 per cent and a capping layer of 150 mm thickness of material with a minimum CBR of 10 per cent shall be provided in addition to the sub-base.

4.2.1.6. Where stage construction is adopted for pavements, the thickness of sub-base shall be provided for ultimate pavement section for the full design life.

4.2.1.7. In the areas affected by frost, care should be taken to avoid using frost susceptible materials in the sub-base.

4.2.2. Base course

4.2.2.1. Unbound granular bases which comprise conventional Water Bound Macadam (WBM), Wet Mix Macadam (WMM) or other equivalent granular construction conforming to IRC/MORT&H Specifications shall be adopted.

4.2.2.2. Materials for use in the base course must satisfy the grading and physical requirements prescribed in the IRC/ MORT&H Specifications. The recommended minimum thickness of granular base is 225 mm for traffic upto 2 msa and 250 mm for traffic exceeding 2 msa.

4.2.2.3. For heavily trafficked roads, use of WMM base laid by paver finisher or motor grader is recommended.

4.2.2.4. Where WBM construction is adopted in the base course for roads carrying traffic more than 10 msa, the thickness of WBM base shall be increased from 250 mm to 300 mm (i.e., 4 layers of WBM grades II and III each of 75 mm compacted thickness) for ease of construction with corresponding reduction in the sub-base thickness keeping the overall pavement thickness unchanged as deduced from the design chart.

4.2.3. **Bituminous surfacing**

4.2.3.1. The bituminous surfacing shall consist of either a wearing course or a binder course with a wearing course depending upon the traffic to be carried. The most commonly used wearing courses are surface dressing, open-graded premix carpet, mix seal surfacing, semi-dense bituminous concrete and bituminous concrete. For binder courses, the MORT&H Specification prescribes Bituminous Macadam and Dense Bituminous Macadam. Bituminous Macadam has low binder content and high voids and is thus not impervious to water. Further the effect of high voids is reduced stiffness and increased stress concentrations. From fatigue considerations, the deterimental effect of voids is more apparent at low temperatures. On the other hand, during prolonged hot spells the average pavement temperatures are very high and consequently such a mix will operate over a very low stiffness range. Hence, the use of bituminous macadam binder course to IRC/MORT&H Specifications may desirably be restricted only to roads designed to carry traffic less than 5 msa. Dense Bituminous Macadam binder course is recommended for roads designed to carry more than 5 msa.

4.2.3.2. Recommended surfacing materials and thicknesses in terms of the cumulative standard axles to be carried during the design life are given in Plates 1 and 2. The suggested surfacings are a desirable minimum from functional and structural requirements.

4.2.3.3. However, in case the granular base is manually laid or if recommended by the Engineer, the Dense Bituminous Macadam (DBM) binder course may be preceeded by a 75 mm

thick Bituminous Macadam (BM) layer. Where this is done the thickness of the DBM layer will be suitably reduced. For practical purposes 10 mm BM can be taken as equivalent to 7 mm DBM for modifying the thickness of DBM layer.

4.2.3.4. Choice of the appropriate type of bituminous wearing course will depend on several factors, like, design traffic over the service life, the type of base/binder course provided, whether the pavement is to be built up in stages, rainfall and other related factors. The recommended types and thicknesses of wearing courses for traffic from 10 msa to 150 msa are given in Plate 2 and for traffic less than 10 msa in Plate 1, which may be read in conjunction with *Annexure-5* and may be modified if the environmental conditions and experience so justify.

4.2.3.5. The grade of bitumen will be selected keeping in view the traffic, rainfall and other environmental conditions. The selection criteria for the grade of bitumen to be used for bituminous courses are given in *Annexure-6.* Use of high performance mixes/modified binders are recommended in heavily trafficked situations.

4.2.3.6. For areas with heavy snow precipitation where mechanised snow clearance operations may be undertaken as well as at locations, like, bus stops and roundabouts, consideration ought to be given to the provision of bituminous concrete in single or multiple courses so as to render the surface more stable and waterproof. Mastic asphalt may be used at bus-stops and intersections.

4.2.3.7. Where the wearing surface adopted is open graded premix carpet of thickness upto 25 mm, the thickness of surfacing should not be counted towards the total thickness of the pavement as such surfacing will be purely for wearing and will not add to the structural capacity of the pavement.

4.3. **Pavement Design Catalogue**

4.3.1. Based on the results of analysis of pavement structures, practical requirements and specifications spelt out in paragraph 4.2, the recommended designs for traffic range 1 msa to 10 msa are given in Plate 1 and for traffic range 10 msa to 150 msa are given in Plate 2. In some cases, the total pavement thickness given in the recommended designs is slightly more than the thickness obtained from the design charts. This is in order to :

(a) provide the minimum prescribed thickness of sub-base

(b) adapt the design to stage construction which necessitated some adjustment and increase in sub-base thickness.

Dense Bituminous Macadam shall be constructed in two layers when the prescribed thickness is more than 100 mm.

4.3.2. The designs relate to CBR values ranging from 2 per cent to 10 per cent and ten levels of design traffic 1,2,3,5,10,20,30,50,100,150 msa. The pavement compositions given in the design catalogue are relevant to Indian conditions, materials and specifications. Where any change in layer thickness and specification is considered desirable from practical considerations, the composition can be suitably modified using analytical approach with in-service performance related information and appropriate design values.

4.3.3. For intermediate traffic ranges, the pavement layer thicknesses will be interpolated linearly.

4.3.4. For traffic exceeding 150 msa, the pavement design appropriate to 150 msa may be chosen and further strengthening carried out to extend the life at the appropriate time based on pavement deflection measurements as per IRC:81.

5. DRAINAGE MEASURES

5.1. The performance of a pavement can be seriously affected if adequate drainage measures to prevent accumulation of moisture in the pavement structure are not taken. Some of the measures to guard against poor drainage conditions are maintenance of transverse section in good shape to reasonable crossfall so as to facilitate quick run-off of surface water and provision of appropriate surface and sub-surface drains where necessary. Drainage measures are especially important when the road is in cutting or built on low permeability soils or situated in heavy rainfall/snow precipitation area.

5.2. On new roads, the aim should be to construct the pavement as far above the water table as economically practicable. The difference between the bottom of subgrade level and the level of water table/high flood level should, however, not be less than 0.6-1 m. In water logged areas, where the subgrade is within the zone of capillary saturation, consideration should be given to the installation of suitable capillary cut-off as per IRC:34 at appropriate level underneath the pavement.

5.3. When the traditional granular construction is provided on a relatively low permeability subgrade, the granular sub-base should be extended over the entire formation width

(Fig. 3) in order to drain the pavement structural section. Care should be exercised to ensure that its exposed ends do not get covered by the embankment soil. The trench type section should not be adopted in any case as it would lead to the entrapment of water in the pavement structure.

If the granular sub-base is of softer variety which may undergo crushing during rolling leading to denser gradation and low permeability, the top 100 to 150 mm thickness should be substituted by an open graded crushed stone layer to ensure proper drainage.

Drainage of the pavement structural section can be greatly improved by providing a high permeability drainage layer satisfying the following criteria :

$$\frac{D_{15} \text{ of drainage layer}}{D_{15} \text{ of subgrade}} \geq 5$$

To prevent entry of soil particles into the drainage layer

$$\frac{D_{15} \text{ of subgrade}}{D_{85} \text{ of subgrade}} \leq 5$$

$$\text{And } \frac{D_{50} \text{ of drainage layer}}{D_{50} \text{ of subgrade}} \leq 5$$

Aggregates meeting the following criteria are regarded as very good drainage materials :

$D_{85} < 4\ D_{15}$
$D_2 > 2.5$ mm

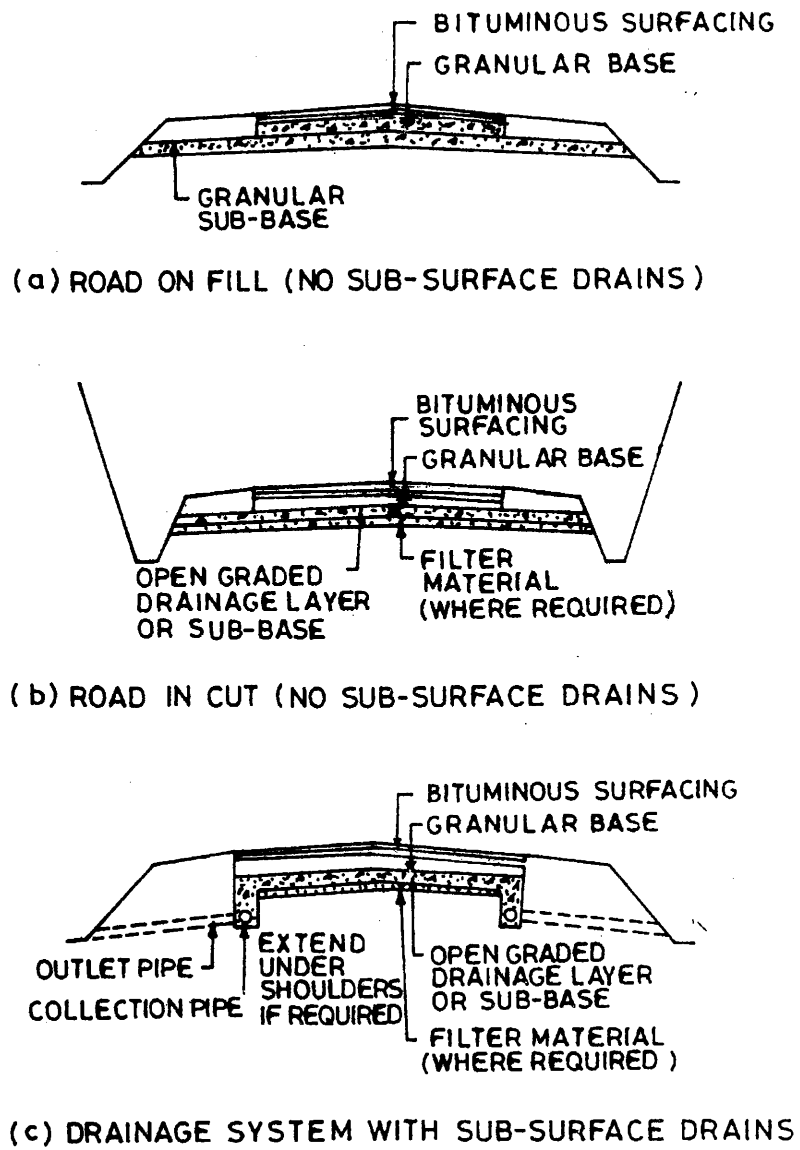


Fig. 3. Drainage of Pavements on Impermeable Subgrade

D_{85} means the size of sieve that allows 85 per cent by weight of the material to pass through it. Similar is the meaning of D_{50}, D_{15} and D_2 .

The permeable sub-base when placed on soft erodible soils should be underlain by a layer of filter material to prevent the intrusion of soil fines into the drainage layer (Fig. 3). Non-woven geosynthetic can be provided to act as filter.

5.4. Where large inflows are to be taken care of, an adequately designed sub-surface drainage system consisting of an open graded drainage layer with collection and outlet pipes should be provided. The system should be designed on a rational basis using seepage principles to estimate the inflow quantities and the outflow conductivity of the drainage system. It should be ensured that the outflow capabilities of the system are atleast equal to the total inflow so that no free water accumulates in the pavement structural section. Sub-surface drains using geosynthetics can also be used. Sub-surface drains should be constructed to the requirements prescribed in Clause 309.3 of the MORT&H Specification for Road and Bridge Works.

5.5. Drainage of existing pavement of 'Trench Type' section on low permeability subgrades can be improved by providing a continuous drainage layer of 100-150 mm thickness under the shoulders at the subgrade level or by providing a combination of longitudinal and lateral drains, the latter spaced at 5 to 6 m intervals. The drains are cut through the shoulders upto the subgrade level and backfilled with coarse drainage material.

5.6. Very often, water enters the base, sub-base or the

subgrade at the junction of the verges and the bituminous surfacing. To counteract the harmful effects of this water, it is recommended that the shoulders should be well-shaped and if possible, constructed of impermeable material. With the same intent, it is suggested that as far as practicable, and in any case on major through roads, the base should be constructed 300-450 mm wider than the required bituminous surfacing so that the run-off water disperses harmlessly well clear off the main carriageway.

5.7. Shoulders should be accorded special attention during subsequent maintenance operation too. They should be dressed periodically so that they always conform to the requisite cross-fall and are not higher than the level of carriageway at any time.

6. DESIGN IN FROST AFFECTED AREAS

6.1. In areas susceptible to frost action, the design will have to be related to actual depth of penetration and severity of the frost. At the subgrade level, fine grained clayey and silty soils are more susceptible to ice formation, but freezing conditions could also develop within the pavement structure if water has a chance of ingress from above.

6.2. One remedy against frost attack is to increase the depth of construction to correspond to the depth of frost penetration, but this may not always be economically practicable. As a general rule, it would be inadvisable to provide total thickness less than 450 mm even when the CBR value of the subgrade warrants a smaller thickness. In addition, the materials used for building up the crust should be frost resistant.

6.3. Another precaution against frost attack is that water should not be allowed to collect at the subgrade level which may happen on account of infiltration through the pavement surface or verges or due to capillary rise from a high water table. Whereas capillary rise can be prevented by subsoil drainage measures and cut-offs, infiltrating water can be checked only by providing a suitable wearing surface.

7. WORKED EXAMPLES ILLUSTRATING THE DESIGN METHOD

Example - 1 : Design the pavement for construction of a new bypass with the following data :

DATA

(i)	Two-lane single carriageway	
(ii)	Initial traffic in the year of completion of construction	= 400 CV/day (sum of both directions)
(iii)	Traffic growth rate per annum	= 7.5 per cent
(iv)	Design life	= 15 years
(v)	Vehicle damage factor (based on axle load survey)	= 2.5 (standard axles per commercial vehicle)
(vi)	Design CBR of subgrade soil	= 4 per cent

DESIGN CALCULATIONS

(i) Distribution factor (para 3.3.5) = 0.75

(ii) Cumulative number of standard axles to be catered for in the design (Equation given in para 3.3.6.1)

$$N = \frac{365 \times [(1+0.075)^{15}-1]}{0.075} \times 400 \times 0.75 \times 2.5 = 7200000 = 7.2 \text{ msa}$$

(iii)	Total pavement thickness for CBR 4% and Traffic 7.2 msa (from Fig. 1)	= 660 mm
(iv)	Pavement Composition interpolated from Plate 1, CBR 4%	
	(a) Bituminous surfacing	= 25 mm SDBC + 70 mm DBM
	(b) Road base	= 250 mm WBM
	(c) Sub-base	= 315 mm granular material of CBR not less than 30 per cent

Example - 2 : It is proposed to widen an existing 2-lane National Highway section to 4-lane divided road. Design the pavement for new carriageway with the following data :

DATA

(i)	4-lane divided carriagway	
(ii)	Initial traffic in each directions in the year of completion of construction	= 5600 CV/day
(iii)	Design life	= 10 years/15 years
(iv)	Design CBR of subgrade soil	= 5 per cent
(v)	Traffic growth rate	= 8 per cent
(vi)	Vehicle damage factor (Found out from axle load survey on existing road)	= 4.5 (Standard axles per CV)

DESIGN CALCULATIONS

(i) Distribution factor (para 3.3.5) = 0.75

(ii) Vehicle damage factor = 4.5

(iii) Cumulative number of standard axles to be carried during

(a) Design life of 10 years

$$N = \frac{365 \times [(1+0.08)^{10}-1]}{0.08} \times 5600 \times 0.75 \times 4.5 = 99.2 \text{ msa or say } 100 \text{ msa}$$

(b) Design life of 15 years

$$N = \frac{365 \times [(1+0.08)^{15}-1]}{0.08} \times 5600 \times 0.75 \times 4.5 = 185.6 \text{ msa or say } 186 \text{ msa}$$

(iv) Pavement thickness and composition (from Fig. 2 and Plate 2) for CBR = 5 per cent and traffic = 100 msa/186 msa.

(a) For 10 years life

Total Pavement thickness for traffic 100 msa (from Fig. 2) CBR 5%	= 745 mm
Composition (from Plate 2, CBR 5%)	
Bituminous surfacing	= 50 mm BC + 150 mm DBM
Base	= 250 mm Wet Mix Macadam
Sub-base	= 300 mm Granular Sub-base of CBR not less than 30 per cent
Provide Total Pavement Thickness	= 750 mm

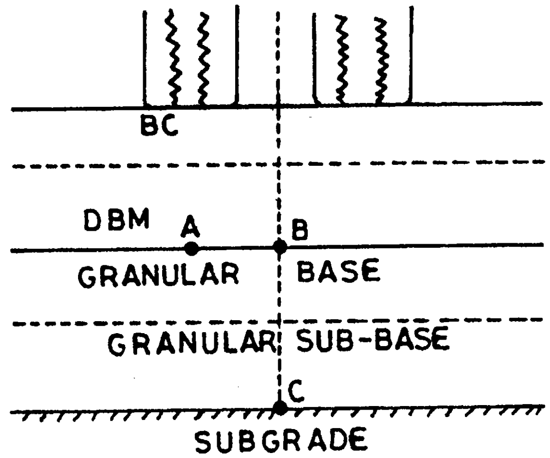
(b) For 15 years life (para 4.3.4) Accordingly provide pavement thickness and composition for 150 msa

Total pavement thickness (from Fig. 2)	= 760 mm
Composition, (from Plate 2, CBR 5%)	
Bituminous surfacing	= 50 mm BC + 170 mm DBM
Base	= 250 mm Wet Mix Macadam
Sub-base	= 300 mm GSB of CBR not less than 30 per cent
Provide Total Pavement Thickness	= 770 mm

Annexure-1

CRITICAL LOCATIONS, RELATIONSHIP BETWEEN NUMBER OF CUMULATIVE STANDARD AXLES, STRAIN VALUES AND ELASTIC MODULUS OF MATERIALS

Critical Locations in Pavement



A and B are the critical locations for tensile strains (ε_t). Maximum value of the strain is adopted for design.

C is the critical location for the vertical subgrade strain (ε_z) since the maximum value of the ε_z occurs mostly at C.

Fatigue Criteria :

Bituminous surfacings of pavements display flexural fatigue cracking if the tensile strain at the bottom of the bituminous layer is beyond certain limit. Based on large amount of field performance data of pavements of south, north, east and west zones in India collected under the Research Schemes R-6[4] and R-19[5] of Ministry of Surface Transport, Govt. of India, the relation between the fatigue life of the pavement and the tensile strain in the bottom of the bituminous layer was obtained[1] as

$$N_F = 2.21 * 10^{-4} [1/\varepsilon_t]^{3.89} [1/E]^{0.854}$$

Where,

N_F = Number of cumulative standard axles to produce 20 per cent cracked surface area

ε_t = Tensile strain at the bottom of BC layer (micro strain)

E = Elastic modulus of bituminous surfacing (MPa)

The above fatigue equation was calibrated at 35°C for Bituminous Concrete surfacing having 80/100 bitumen and the equation was generalised[1] by introducing the term containing the elastic modulus (E) of the bituminous layer so that pavement can be designed for temperatures from 20°C to 40°C using any grade of bitumen.

The values of the elastic moduli of Bituminous Concrete/ Dense Bituminous Macadam and Bituminous Macadam meeting the specifications of the MOST[2] are given below[1].

Elastic Modulus (MPa) Values of Bituminous Materials

Mix Type	Temperature °C				
	20	25	30	35	40
BC and DBM 80/100 bitumen	2300	1966	1455	975	797
BC and DBM 60/70 bitumen	3600	3126	2579	1695	1270
BC and DBM 30/40 bitumen (75 blow compaction and 4 per cent air void)	6000	4928	3809	2944	2276
BM 80/100 bitumen	-	-	-	500	-
BM 60/70 bitumen				700	

The Poisson's ratio of bituminous layer may be taken as 0.50 for pavement temperatures of 35°C and 40°C. For temperatures from 20°C to 30°C, a value of 0.35 may be adopted.

Fatigue equation at any pavement temperature from 20°C to 40°C can be evaluated by substituting the elastic modulus of the pavement temperature. Catalogue of designs has been worked out for temperature of 35°C.

Rutting Criteria :

As large number of data for rutting failure of pavements were obtained from the Research Scheme R-6[4] of the Ministry of Road Transport and Highways and other research investigations. Setting the allowable rut depth as 20 mm, the rutting equation was obtained[1] as

$$N_R = 4.1656*10^{-8} [1/\varepsilon_z]^{4.5337}$$

N_R = Number of cumulative standard axles to produce rutting of 20 mm

ε_z = Vertical subgrade strain (micro strain))

Modulus of Elasticity of Subgrade, Sub-base and Base Layers

Subgrade[8]

$E(MPa) = 10*CBR$ for $CBR \leq 5$ and

$= 176*(CBR)^{0.64}$ for $CBR > 5$

Granular Sub-base and Base[7]

$$E_2 = E_3*0.2 * h^{0.45}$$

E_2= Composite Elastic Modulus of granular Sub-base and Base (MPa)
E_3= Elastic Modulus of Subgrade (MPa)
h = Thickness of granular layers (mm)

Poisson's ratio for both the granular layer as well as subgrade layer may be taken as 0.4.

Substitution of Dense Bituminous Macadam (DBM) :

Part of the DBM can be substituted for BM on the basis of equal flexural stiffness given as

$$E_1H_1^3/12(1- \mu_1^2) = E_2H_2^3/12(1- \mu_2^2)$$

where,

$E_1 H_1 \mu_1$ *and* $E_2 H_2 \mu_2$ are the parameters (Elastic Modulus, Thickness and Poisson's Ratio) of the DBM and BM respectively. Based on the above equation, following equivalent thicknesses may be used :

Example

180 mm DBM = 125 mm DBM + 75 mm BM

240 mm DBM = 185 mm DBM + 75 mm BM
75 mm of BM = 75* $(700/1695)^{1/3}$ = 55.85 mm of DBM

Annexure-2

EQUIVALENCE FACTORS AND DAMAGING POWER OF DIFFERENT AXLE LOADS

Gross Axle Weight Kg.	Load Equivalency Factors Single Axle	Tandem Axle
900	0.0002	0.0000
1810	0.002	0.0002
2720	0.009	0.001
3630	0.031	0.003
4540	0.08	0.006
5440	0.176	0.013
6350	0.35	0.024
7260	0.61	0.043
8160	1.00	0.070
9070	1.55	0.110
9980	2.30	0.166
10890	3.27	0.242
11790	4.48	0.342
12700	5.98	0.470
13610	7.8	0.633
14520	10.0	0.834
15420	12.5	1.08
16320	15.5	1.38
17230	19.0	1.73
18140	23.0	2.14
19051	27.7	2.61
19958	33.0	3.16
20865	39.3	3.79
21772	46.5	4.49
22680	55.0	5.28
23587	-	6.17
24494	-	7.15

Gross Axle Weight Kg.	Load Equivalency Factors	
	Single Axle	Tandem Axle
25401	-	8.20
26308	-	9.4
27216	-	10.7
28123	-	12.1
29030	-	13.7
29937	-	15.4
30844	-	17.2
31752	-	19.2
32660	-	21.3
33566	-	23.6
34473	-	26.1
35380	-	28.8
36288	-	31.7

In case the class mark of the axle load survey does not match with the above axle loads, 4th power law may be used for converting axle loads into equivalent standard axle loads using the following formulae :

Single axle load
Equivalency factor = $(\text{axle load in kg}/8160)^4$

Tandem axle load
Equivalency factor = $(\text{axle load in kg}/14968)^4$

The above equations also give reasonably correct results for practical values of axle loads.

Annexure-3

PREPARATION OF LABORATORY TEST SPECIMENS

GENERAL

1. Wherever possible, the test specimens should be prepared by static compaction, but if not possible, dynamic method may be used as an alternative.

STATIC COMPACTION

2. The weight of wet soil at the required moisture content to give the intended density when occupying the standard test mould is calculated as follows :

Volume of mould = 2209 cc

Weight of dry soil = 2209 d gm

$$\text{Weight of wet soil} = \frac{100 + m}{100} \times 2209 \text{ d gm}$$

where,

d = Required dry density in gm/cc
m = Required moisture content in per cent

3. The soil lumps are broken down and stones larger than 20 mm are removed. Sufficient quantity of the soil is mixed with water to give the required moisture content. The correct weight of wet soil is placed in the mould. After initial tamping with a steel rod, a filter paper is placed on top of the soil, followed by the 5 cm displacer disc, and the specimen compressed in the compression machine until the top of the displacer is flush with

the top of the collar. The load is held for about 30 seconds and then released. In some soil types where a certain amount of rebound occurs, it may be necessary to reapply load to force the displacer disc slightly below the top of the mould so that on rebound the right volume is obtained.

DYNAMIC COMPACTION

4. The soil is mixed with water to give the required moisture content, and then compacted into the mould in three layers using a standard soil rammer. After compaction, the soil is trimmed flush with the top of the mould with the help of a metal straight edge. The mould is weighed full and empty to enable determination of wet bulk density, and from it, knowing the moisture content, the dry density is calculated.

5. Further specimens, at the same moisture content, are then prepared to different dry densities by varying the number of blows applied to each layer of soil so that the amount of compaction that will fill the mould uniformly with calculated weight of wet soil (vide para 2 above) is known.

Annexure-4

SPECIAL POINTS RELATING TO DESIGN OF PAVEMENT ON EXPANSIVE SOILS

Potentially expansive soils, such as, black cotton soils are montmorillonite clays and are characterised by their extreme hardness and deep cracks when dry and with tendency for heaving during the process of wetting. Roadbeds made up of such soils when subjected to changes in moisture content due to seasonal wetting and drying or due to any other reason undergo volumetric changes leading to pavement distortion, cracking and general unevenness. In semi-arid climatic conditions, pronounced short wet and long dry conditions occur, which aggravate the problem of swelling and shrinkage. Due recognition of these problems at the design stage itself is required so that counter measures could be devised and incorporated in the pavement structure. A proper design incorporating the following measures may considerably minimise the problems associated with expansive soils.

SUBGRADE MOISTURE, DENSITY AND DESIGN CBR

The amount of volume change that occurs when an expansive soil road bed is exposed to additional moisture depends on the following :

(a) the dry density of the compacted soil
(b) the moisture content
(c) structure of soil and method of compaction

Expansive soils swell very little when compacted at low densities and high moisture but swell greatly when compacted at high densities and low moisture. Hence, where the probability of moisture variation in the subgrade is high, it is expedient to compact the soil slightly wet of the field optimum moisture content determined on the basis of a field trial. Experience shows that generally, it is not practicable to compact expansive soils at OMC determined by Laboratory Proctor Test. It is, therefore, necessary to study its field moisture density relationship through compacting the soil at different moisture contents and under the same number of roller passes. A minimum density corresponding to 95 per cent of the standard proctor density should be attained in the field and recommended moisture content should be 1-2 per cent wet of optimum moisture content.

1. Design CBR

The pavement thickness should be based on a 4-day soaked CBR value of the soil, remoulded at placement density and moisture content ascertained from the field compaction curve.

2. Buffer Layer

There is a definite gain in placing the pavement on a non-expansive cohesive soil cushion of 0.6-1.0 m thickness. It prevents ingress of water in the underlying expansive soil layer, counteracts swelling and secondly even if the underlying expansive soil heaves, the movement will be more uniform and consequently more tolerable. However, where provision of non-expansive buffer layer is not economically feasible, a blanket course of suitable material and thickness as discussed in para 3 below must be provided.

3. Blanket Course

A blanket course of atleast 225 mm thickness and composed of coarse/medium sand or non-plastic moorum having PI less than five should be provided on the expansive soil subgrade as a sub-base to serve as an effective intrusion barrier. The blanket course should extend over the entire formation width.

Alternatively, lime-stabilised black cotton sub-base extending over the entire formation width may be provided together with measures for efficient drainage of the pavement section.

4. Drainage

Improvement of drainage can significantly reduce the magnitude of seasonal heaves. Special attention should, therefore, be given to provision of good drainage measures as also discussed under Section 5 (Drainage Measures). The desirable requirements are :

(a) Provision must be made for the lateral drainage of the pavement structural section. The granular sub-base/base should accordingly be extended across the shoulders, refer to para 5.3 of section 5 (Drainage Measures).

(b) Normal camber of 1:40 for the black top surface and a cross slope of 1:20 for the berms should be provided to shed-off surface run-off quickly.

(c) No standing water should be allowed on either side of the road embankment.

(d) A minimum height of 1 m between the subgrade level and the highest water level should be ensured.

5. Bituminous Surfacing

Desirably 40 mm thick bituminous surfacing should be provided to prevent ingress of water through surface.

6. Shoulders

Shoulders should be made up of impervious material so as not to allow water to permeate into the body of the pavement. Lime stabilised black cotton soil shoulder of 150-200 mm thickness may serve the purpose economically.

Annexure-5

RECOMMENDED TYPE AND THICKNESS OF BITUMINOUS WEARING COURSES FOR FLEXIBLE PAVEMENTS UNDER DIFFERENT SITUATIONS

Sl. No.	Type of Base/ Binder Course	Type of Bituminous Wearing Course	Annual Rainfall Low (L) less than 1500 mm; Medium (M) 1500-3000 mm; High (H) more than 3000 mm	Design Traffic (msa)
1.	Water Bound Macadam, Wet Mix Macadam, Crusher-run-Macadam, Built-up Spray Grout	(i) 20 mm Premix Carpet (PC) with sand seal coat	L and M	< 10.0
		(ii) 20 mm PC with liquid seal coat	L,M and H	<10.0
		(iii) Mix Seal Surfacing (MSS) (20 mm) Type 'A' or 'B'	L,M and H	<10.0
2.	Bituminous Macadam base/binder course	(i) Semi-Dense Bituminous Concrete (25 mm)	L,M and H	<10.0
		(ii) 20 mm PC with liquid seal coat		
		(iii) MSS (20 mm) Type 'A' or 'B'		
3.	Dense Bituminous Macadam	Bituminous Concrete		
		(i) 25 mm	L,M and H	>5<10
		(ii) 40 mm	L,M and H	≥10
		(iii) 50 mm	L,M and H	≥100

In applying the above recommendations, the following points should be kept in view :

(i) In case where a pavement is decided to be developed in stages, the surfacing should correspond to that for the design stage.

(ii) As far as possible, wearing course amenable to laying with paver-finisher should be adopted over paver-finished base/ binder course.

(iii) Expensive surfacings, like, Bituminous Concrete (BC) should not be provided directly over manually laid granular bases.

Annexure-6

CRITERIA FOR THE SELECTION OF GRADE OF BITUMEN FOR BITUMINOUS COURSES

Climate	Traffic (CVD)	Bituminous Course	Grade of Bitumen to be used
Hot	Any	BM, BPM, BUSG	60/70
Moderate/Cold	Any	BM, BPM, BUSG	80/100
Any	Heavy Loads, Expressways, Urban Roads	DBM, SDBC, BC	60/70
Hot/Moderate	Any	Premix Carpet	50/60 or 60/70
Cold	Any	Premix Carpet	80/100
Hot/Moderate	Any	Mastic Asphalt	15±5
Cold	Any	Mastic Asphalt	30/40

REFERENCES

1. Research Scheme R-56 'Analytical Design of Flexible Pavements' Final Report submitted to the Ministry of Surface Transport (Roads Wing), March 1999, Civil Engineering Department, Indian Institute of Technology, Kharagpur, West Bengal.

2. Specifications for Road and Bridge Works (Third Revision), 1995, Ministry of Surface Transport (Roads Wing), Published by Indian Roads Congress, New Delhi.

3. AASHTO Guide for Design of Pavement Structures, 1993, American Association of State Highway and Transportation Officials, Washington DC.

4. Development of Methods, such as, Benkelman Beam Method for Evaluation of Structural Capacity of Existing Flexible Pavements and also for Estimation and Design of Overlays for Strengthening of Weak Pavements, Research Scheme R-6 of Ministry of Surface Transport (Roads Wing), Final Report submitted by Central Road Research Institute, New Delhi 1995.

5. Pavement Performance Study of Existing Pavement Sections, Final Report, Volume-2, submitted to the Ministry of Surface Transport (Roads Wing), Central Road Research Institute, New Delhi 1994.

6. IRC:81-1997 "Guidelines for Strengthening of Flexible Pavements Using Benkelman Beam Deflection Technique", Indian Roads Congress, New Delhi.

7. Shell Pavement Design Manual - Asphalt Pavement and Overlays for Road Traffic, Shell International Petroleum Company Ltd., 1978, London.

8. N.W. Lister and W.D. Powell, 'Design Practice for Bitumen Pavements in the United Kingdom', Proceedings of 6th International Conference on Structural Design of Asphalt Pavements, Volume 1, 1987.