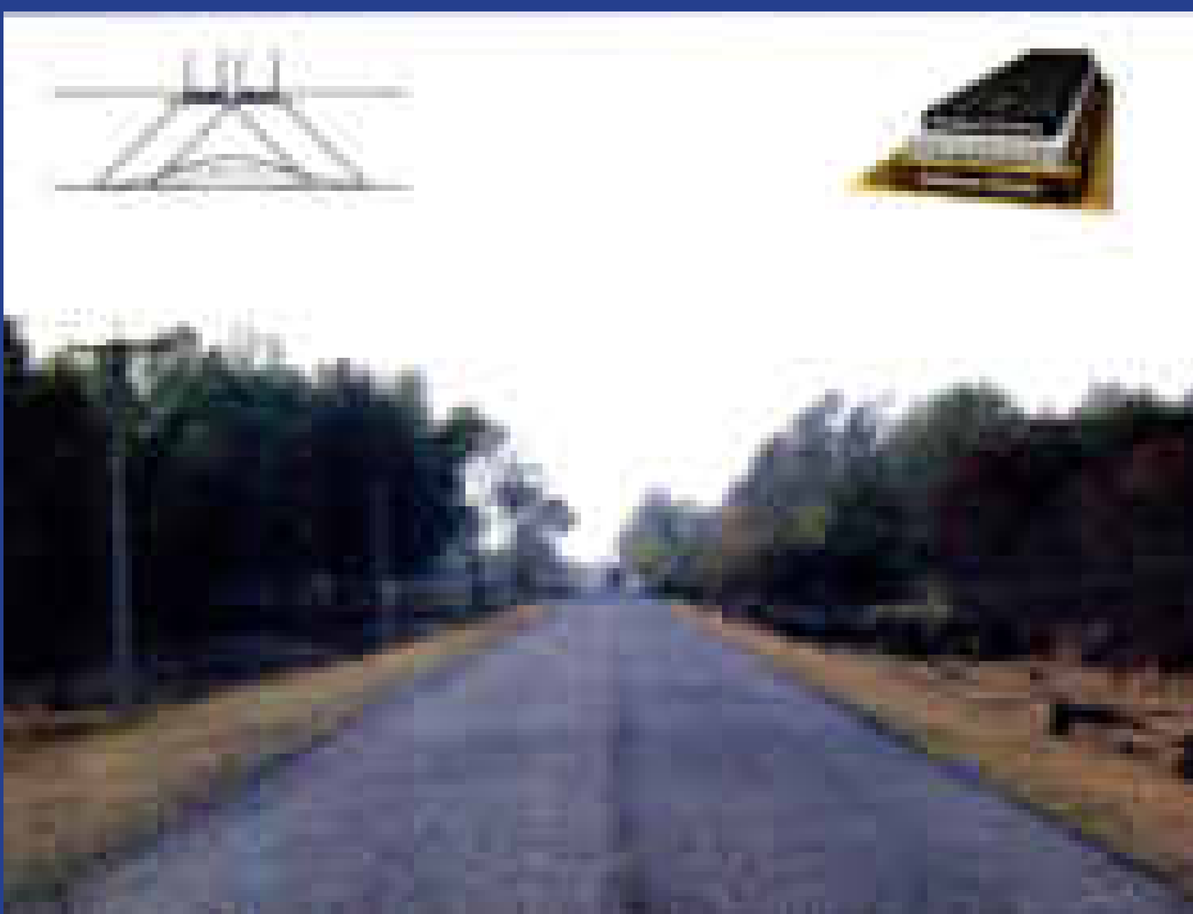
Government of Nepal
Ministry of Physical Infrastructure and Transport
Departments of Roads
Babarmahal, Kathmandu

# Pavement Design Guidelines

## (Flexible Pavement)



**2014, Kathmandu**

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# Contents

## Message from Director General

There has been a considerable increase of road network in Nepal. However, more than 65 percent of the road networks still remain in earthen and gravel stage, demanding a immediate need of improving such roads to blacktop standard. A very low traffic density with very high variation is dominant in most of the road network. However, the road linking capital and Indian border is different with high traffic density and heavier axle load.

IRC 37-2001 Guidelines for the design of flexible pavements and Overseas Road Note 31 of Transport Research Laboratory of UK have been widely used till date for the pavement design. However, the practice of thumb rule and personal judgement still remains prevalent in many of the small assignments. Further to this, different donors have been using different standards in many donor funded projects.

In this context, the Department of Roads felt a need of a unified flexible pavement design approach. The Planning and Design Branch, Department of Roads has taken a laudable initiative to bring experts from Universities, Consultants and practicing engineers towards the development of this guideline.

Considering the present day need towards durable, efficient and cost effective pavement design and construction, development of this guideline is a small step towards strengthening the capacity of the Department. I would like to thank all involved in this process and finally believe that this guideline will helpful to all practicing engineers in pavement design, construction and maintenance.

**Devendra Karki**
Director General
Department of Roads

# Abbreviation

| | |
|---|---|
| AADT | Annual Average Daily Traffic |
| AASHTO | American Association of State Highway and Transportation Officials |
| ADT | Average Daily Traffic |
| BC | Bituminous Concrete |
| BM | Bituminous Macadam |
| CBR | California Bearing Ratio |
| DBM | Dense Bituminous Macadam |
| DoR | Department of Roads |
| E | Elastic Modulus |
| EF | Equivalence Factor |
| ESA | Equivalent Standard Axles |
| FHWA | Federal Highway Administration |
| GB | Granular Base |
| GSB | Granular Sub Base |
| IRC | Indian Road Congress |
| MPa | Mega Pascal |
| msa | Million Standard Axles |
| ORN | Overseas Road Notes |
| PC | Premix Carpet |
| SDBC | Semi Dense Bituminous Concrete |
| SSRBW | Standard Specifications for Road and Bridge Works |
| TRB | Transportation Research Board |
| TRL | Transportation Research Laboratory |
| VDF | Vehicle Damage Factor |
| WBM | Water Bound Macadam |

## 1. Introduction

Pavement is most important component of highway section. The overall functioning of highway system greatly depends on the performance of its pavement. Furthermore, vehicle operating cost, and entire highway investment and life cycle are interrelated to the pavement design practice. The design procedure of flexible pavement involves the interplay of several variables, such as the wheel loads, traffic, climate, terrain and sub-grade soil conditions. Depending upon specific regional or nationwide characteristics, most of the countries are practicing some empirical and experience base methods for the design of flexible pavement.

This manual is written with the view to have a unified approach for working out the design of flexible pavement in Nepal. The objective of this manual is to guide to assist the highway engineer with sufficient information on pavement design so that one could prepare a suitable pavement structure for any specific cases of sub-grade soil, traffic scenario and materials available on the site.

## 2. Scope and Applicability

Guidelines in this booklet are prepared for the design of flexible pavements for National Highways and Feeder Roads. Furthermore, it could be followed for the design of Arterial and Sub-arterial roads of the urban road categories.

For the purpose of guidelines, flexible pavements are considered to include the pavements which have bituminous surfacing and granular base and sub-base courses conforming to Standard Specifications for Road and Bridge Works published by the Department of Roads in 2001.

The manual may require revision from time to time in the light of future experience and development in the field. The principal users of this manual are the Highway Engineers from government or their agents (i.e. Consultants).

## 3. References

The design procedures incorporated in this document are based on the IRC 37:2001 guidelines, American Association of State Highway and Transportation Officials (AASHTO) Guide for Design of Pavement Structures, Transportation Research Board (TRB), Federal Highway Administration (FHWA) publications, Pavement Structural Design of the Austroads Guide to Pavement Technology (Austroads, 2008) and Road Note 31 (TRL, 1993).

## 4. Design Approach and Criteria

The design of flexible road pavement is generally thought to be a specialist activity that can only be undertaken by consultants experienced in this type of design. Part of the reason for this may be that foreign consultants engaged on the design of road pavements in Nepal have tended to use design standards from their respective

## 5. Traffic

### 5.1 General

Road pavement failure is mainly due to the traffic movement from both the magnitude of the individual wheel loads and the number of times these loads are applied. The total number of vehicles as well as wheel loads (axle load) should be considered for pavement design. The load imposed by passenger cars does not contribute significantly to the structural damage of the pavement. Therefore, cars and similar sized vehicles can be ignored for the structural design of pavement. Only the total number and the axle loading of the commercial vehicles (heavy vehicles) that will use the road during its design life need to be considered. In this context, heavy vehicles are defined as those having an unladen weight of 3000 kg or more. In some circumstances, particularly for low volume roads, construction traffic can be a significant component of overall traffic loading and the designer should take this into account. The total number of anticipated commercial vehicles during the design life is converted in to the cumulative equivalent standard axle of 8160 kg.

### 5.2 Design Life

In the context of pavement, design life does not mean that at the end of the period the pavement will be completely worn out and in need of reconstruction. It means that towards the end of the period the pavement will need to be strengthened so that it can continue to carry traffic satisfactorily for a further period. Condition surveys of bituminous pavements are used to determine not only the maintenance requirements but also the nature and rate of change of condition to help to identify if and when the pavement is likely to need strengthening.

The design life for the pavement is considered as cumulative number of standard axles that can be carried before strengthening of pavement is necessary. It is recommended that National highways should be designed for a life of 15 years. Expressways and urban roads may be designed longer life of 20 yrs. For other categories of roads, a design life of 10 to 15 years may be taken.

### 5.3 Traffic Estimation

#### 5.3.1 Base year traffic flow

For the determination of the total traffic over the design life of the road, the first step is to estimate base year traffic flows. The estimate should be the Average Daily Traffic (ADT) currently using the route, classified into the vehicle categories of cars, light goods vehicles, trucks (heavy goods vehicles) and buses. The ADT is defined as the average number of traffic counted for both directions. Further ADT is multiplied by the seasonal factors to convert it into Average Annual Daily Traffic (AADT). Here mix traffic flow can be expressed by using a single number i.e. Passenger Car Unit. It is recommended that traffic count for the purpose of pavement design is conducted for twenty four hours and for seven days.

### [illegible] Traffic forecasting

The estimation of future traffic depends on the many factors such as economic, land use and demographic factors. Therefore, traffic forecasting is an uncertain process. In a developing economy the problem becomes more difficult because such economies are often very sensitive to the world prices of just one or two commodities. In order to forecast traffic growth it is necessary to separate traffic into the following three categories:

a) Normal traffic. Traffic which would pass along the existing road or track even if no new pavement were provided. The conventional method of forecasting normal traffic is to extrapolate from count data on traffic levels and assume that growth will either remain constant in absolute terms i.e. a fixed number of vehicles per year (a linear extrapolation), or constant in relative terms i.e. a fixed percentage increase.

b) Diverted traffic. Traffic that changes from another route (or mode of transport) to the project road because of the improved pavement, but still travels between the same origin and destination. Where parallel routes exist, traffic will usually travel on the quickest route although this may not necessarily be the shortest. Thus, surfacing an existing road may divert traffic from a parallel and shorter route because higher speeds are possible on the surfaced road. Origin and destination surveys should be carried out to provide data on the traffic diversions likely to arise.

Diverted traffic is normally assumed to grow at the same rate as traffic on the road from which it is diverted.

c) Generated traffic. Additional traffic which occurs in response to the provision or improvement of the road. Generated traffic arises either because a journey becomes more attractive by virtue of a cost or time reduction or because of the increased development that is brought about by the road investment. Generated traffic is difficult to forecast accurately and can be easily overestimated. It is only likely to be significant in those cases where the road investment brings about large reductions in transport costs. For example, in the case of a small improvement within an already developed highway system, generated traffic will be small and can normally be ignored. However, in the case of a new road allowing access to a undeveloped area, there could be large reductions in transport costs as a result of changing mode from, for example, animal-based transport to motor vehicle transport. In such a case, generated traffic could be the main component of future traffic flow.

## 3.4 Axle Loading

An accurate estimate of the various traffic loading is essential for an appropriate pavement design. Traffic volumes can be determined by traffic counts, but for current vehicle loads can be found by an axle load survey. It is not rational to design pavement layers on the basis of legal axle load limits because of the widespread problem of overloading. In addition to this, the proportion of vehicles with partially loaded is unknown. In these circumstances of axle loading, pavement design across the world is accepted to design on the basis of Standard Axle i.e. 8.16 tonnes (80 kN). In Nepal, the legal axle load limit is 10.2 tonnes.

### 3.4.1 Equivalence Factor

The damage that vehicles do to a road pavement depends very strongly on the axle loads of the vehicles. For pavement design purposes the damaging power of axles is related to a 'standard' axle of 8.16 tonnes (80 kN) using equivalence factors which have been derived from empirical studies. In order to determine the cumulative axle load damage that a pavement will sustain during its design life, it is necessary to express the total number of heavy vehicles that will use the road over this period in terms of the cumulative number of equivalent standard axles (esa). Axle load surveys must be carried out to determine the axle load distribution of a sample of the heavy vehicles using the road. Data collected from these surveys are used to calculate the mean number of equivalent standard axles for a typical vehicle in each class. These values are then used in conjunction with traffic forecasts to determine the predicted cumulative equivalent standard axles that the road will carry over its design life. Equivalence factor is calculated by using the following relationships:

- Front steering wheel (single wheel) axle $EF = \left[\frac{\text{Axle load (kg)}}{6440\ \text{kg} (\approx 65\ \text{kN})}\right]^4$
- Single axle dual wheel $EF = \left(\frac{\text{Axle load (kg)}}{8160\ \text{kg} (80\ \text{kN})}\right)^4$
- Tandem axle dual wheel $EF = \left(\frac{\text{Axle load (kg)}}{15000\ \text{kg} (148\ \text{kN})}\right)^4$

### 5.4.2 Vehicle Damage Factor (VDF)

Where sufficient information on axle load is not available and project size does not warrant conducting an axle load survey, the indicative values of Vehicle damage factor (VDF) may be used as given in the table below.

The Vehicle Damage factor (VDF) is the 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 axle per commercial vehicle. The VDF varies with the vehicle axle configuration, axle loading, and terrain type and from region to region. The VDF is arrived at axle load surveys on typical sections so as to cover various influencing factors, such as traffic mix, mode of transportation, commodities carried, time of the year, terrain, road condition and degree of enforcement.

**Table 1 Values of VDF**

| Vehicle type | VDF | Remarks |
|---|---|---|
| Heavy truck (three axle or more) | 6.81 | |
| Heavy two axle | 4.75 | fully loaded 3.5 |
| Mini truck/tractor | 1.0 | |
| Large bus | 0.50 | |
| Bus | 0.25 | |

### 5.5 Distribution of Commercial Traffic over the Carriageway

Total traffic AADT (both ways) is distributed over the whole carriageway for design of pavement. During the calculation of design traffic (total equivalent standard axle) realistic study should be done for the directional distribution of total traffic. In the absence of adequate and conclusive data for particular project, it is recommended that following distribution may be assumed for design.

a) **Single lane roads:** traffic tends to be more channelized 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 direction.

b) **Two-lane single carriage way roads/ Intermediate lane roads:** the design should be based on 75 percent of the total number of commercial vehicles in both directions.

c) **Four-lane single carriageway roads:** the design should be based on 40 percent of the total number of commercial vehicles in both directions.

d) **Dual carriageway roads:** The design of dual two lane carriageway roads should be based on 75 percent 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 percent and 45 percent respectively.

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 carriageway 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.

**3.6 Computation of Design Traffic**

The design traffic is considered in terms of cumulative number of standard axles (in the particular lane carrying maximum traffic) to be carried during the design life of the pavement. This can be computed as:

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

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 number of commercial vehicles per day
- F = Lane distribution factor
- D = Vehicle damage factor
- n = Design life in year
- r = annual growth rate of commercial vehicle (in the absence of detail traffic study r can be taken as 7% i.e 0.07)

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

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

Where, P is the number of commercial vehicles as per the last traffic count, x is the number of years between the last traffic count and the year of completion of construction.

## 6. Sub-grade

The sub-grade in cut and fill should be well compacted to utilize its full strength and to economize on the overall thickness of the pavement required. Heavy compaction is recommended for the construction of express ways, National highways and feeder roads as well as urban roads. Current Standard Specification for Road and Bridge Works (SSRBW) describes the provision of Capping layer (Clause 1004), mechanical stabilization (Clause 1005) and Lime stabilization (Clause 1006) for the preparation of sub-grade in different soil conditions. The general requirements for the construction detail of sub-grade should be referred to the Section 1000 of Standard Specifications for Road and Bridge Works.

## 7. Pavement Thickness and Composition

Total pavement thickness is recommended to adopt from the Chart given in the **Annex II** of this document. Total thickness of the pavement (in mm) is interpolated based on the given values of the CBR of sub-grade and cumulative number of standard axles (msa). The composition of pavement layer and their thickness is found by using the Pavement Design Catalogue given in the **Annex III**. Charts provided in the Annex II are based on the IRC 37:2001. Pavement Design Catalogue has been developed for particular CBR value and cumulative number of standard axles. The total thickness is reduced to granular sub-base, granular base and bituminous wearing course.

### 7.1 Pavement Composition

#### 7.1.1 Sub-base

Sub-base construction material requirements and construction procedure shall be followed the standard Specification for Road and Bridge Works (Clause 1201). Gravel, Sands, Silty and Clayey sands could be used for the construction of sub-base course. The CBR values of the materials, after 4 days soaking, shall not be less than 30 % at 95 % heavy compaction (Clause 1201 (6)). These requirements and the specified grain size distribution of the sub-base material should be strictly adhered in order to meet stability and drainage requirements of the granular sub-base layer.

From drainage consideration the granular sub-base should be extended over the entire formation width. The minimum thickness of the sub-base layer shall be 100 mm. Where stage construction is adopted for pavements, the thickness of sub-base shall be provided for ultimate pavement section for the full design life. In the areas affected by frost, care should be taken to avoid using frost susceptible materials in the sub-base.

### 7.1.2. Base course

Unbound granular bases which comprise conventional Graded Crushed Stone and Water Bound Macadam (WBM) base shall be provided as per the Standard Specification (Clause 1202 and 1203). Materials used in the base must satisfy the grading and physical requirements in the Standard Specification. The recommended minimum thickness of granular base is 150 mm.

### 7.1.3 Bituminous surfacing

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 wearing course used are surface dressing, open graded premix carpet, mix seal surfacing, semi dense bituminous macadam and dense bituminous macadam. For surfacing as well as binder courses the Standard Specification prescribes surface dressing, penetration macadam, asphalt concrete, sand asphalt and cold asphalt (Section 1300).

Specifications for Dense Bituminous Macadam (DBM) and Premix Carpet (PC) have been included herewith in **Annex IV**. These specifications have been developed on the basis of the IRC SPECIFICATIONS FOR ROAD AND BRIDGE WORKS (Ministry of Road Transport and Highways, India) and DoR publication SSRBW, Nepal.

The recommended pavement composition and thickness in terms of the cumulative standard axles to be carried during the design life are given in the design catalogue in the **Annex III**. The thickness of surface treatments such as Premix Carpet (PC) or Surface Dressing 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.

The choice of appropriate type of bituminous surfacing will depend upon 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 thickness of wearing courses for traffic from 10 msa to 150 msa are given in the design catalogue, which may be modified if the environmental conditions and experience so justify.

The grade of the bitumen will be selected keeping in view traffic, rainfall and other environmental conditions. The selection criteria for the grade of the bitumen to be used is given in the Annex I. Special consideration shall be given to the areas with high altitude with snow precipitation.

### 7.2 Pavement Design Catalogue

Based on the results of analysis of the pavement structure, practical requirements and specifications the recommended designs for the traffic range from [illegible] to [illegible] msa and for [illegible] to [illegible] msa are given in the Annex [illegible] (Pavement Design Catalogue). In some cases, the total pavement thickness are 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) Adopt the design to stage construction which necessitated some adjustment and increase in sub-base thickness.

## 8. Typical Section of Pavement Layer

Typical section of the pavement layers is given in figure 1 as per the design approach in this design manual. Functions of each layer are described in the table below.

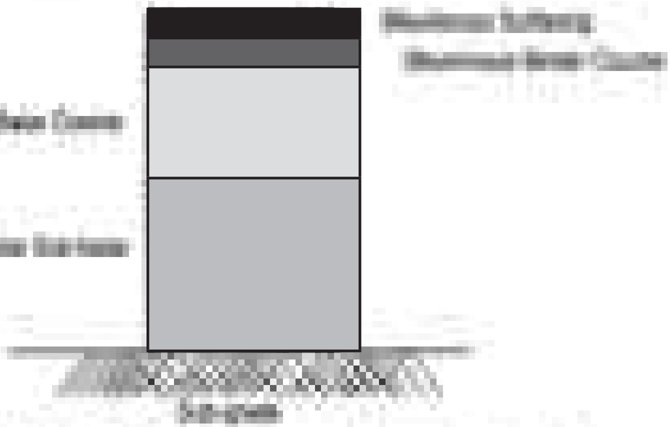


**Figure 1: Typical pavement cross section**

## 9. Worked out Example

Design the flexible pavement for construction of a new road with the following data:

- Two lane single carriage way is to be designed in plain area
- Initial traffic in the year of completion of construction = [illegible] (CVPD) (sum of both directions) as mentioned below:
  - heavy truck three axle: [illegible]
  - heavy truck two axle: [illegible]
  - mini truck: [illegible]

- large bus: 60
- bus: 30

- Traffic growth rate = 7.0 %
- Design life = 15 years
- Vehicle damage factor based on axle load survey
- Vehicle
- Design CBR of sub grade soil = 5%

Solution:

a) Lane distribution factor = 0.75
b) Cumulative number of standard axle for design life of 15 years

| Vehicle type | Numbers | VDF | Equivalent standard axle, per day |
|---|---|---|---|
| heavy truck three axle | 30 | 5.50 | 165 |
| heavy truck two axle | 70 | 4.75 | 333 |
| mini truck | 120 | 1.0 | 120 |
| large bus | 60 | 0.55 | 33 |
| bus | 30 | 0.35 | 11 |

Total: 669 standard axles per day

Initial standard number of axles = A*F = 669 esa

Cumulative Number of standard axles for design period:

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

$$N = \frac{365 * [(1 + 0.07)^{15} - 1]}{0.07} * 0.75 * 669$$

N = 4.[illegible] msa

c) Total thickness of the pavement with CBR 5% and 4.[illegible] msa (Figure 4) = 575 mm
d) Pavement composition from (Figure 20)

i. Bituminous wearing course: Asphalt Concrete 50 mm
ii. Bituminous Binder course: DBM 50 mm
iii. Base course: Water Bound Macadam 150 mm
iv. Sub base: Granular sub base 325 mm CBR not less than 30%
v. Pavement cross section

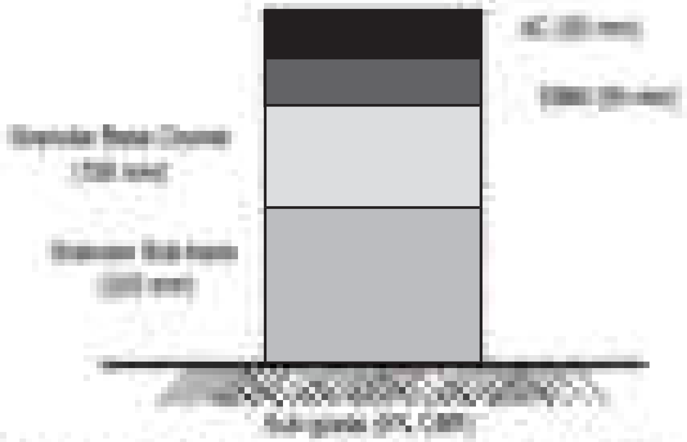

Figure 2: Cross section of the designed pavement

## 10. Glossary of Pavement Terms

**Asphalt concrete** Bituminous concrete/ Asphalt Concrete is a dense graded premixed bituminous mix which is well compacted to form a high quality pavement surface. The AC consists of carefully proportioned mixture of coarse aggregates, fine aggregates, mineral filler and bitumen and the mix is designed by an appropriate method such as Marshall Stability method to fulfill the requirements of stability, density, flexibility and voids.

**Base course** Main structural layer below wearing course.

**Binder course** An asphalt layer that is placed between an asphalt base layer and an asphalt surface layer. The binder layer is included for to better workability or reduce permeability and improve roughness levels.

**Bituminous Macadam** BM or Bituminous Bound Macadam is premixed type of construction consisting one or more courses of compacted crushed aggregates premixed with bituminous binder, laid immediately after mixing. BM is base course or binder course and should be covered by surfacing course before exposing to traffic.

**Bituminous surface** Dressing: BSD is provided over an existing pavement to serve as thin wearing coat. It can be done in two layers. Function of surface dressing: to provide a dust free road free surface over a base course; to provide a waterproof layer to prevent infiltration of surface water; to protect the base course.

**Capping layer** Where shown on the Drawing or where in-situ material in the subgrade in cutting does not meet the requirements, in-situ materials shall be replaced with selected material from cuttings or borrow pits.

**Design period** The time span considered appropriate for the major structural elements of the road pavement to function without rehabilitation and/or reconstruction. Treatments, such as replacement of surfacing layers and single construction treatments, that maintain the integrity of the other components of the pavement are included within the design period. The time span considered appropriate for the road pavement to function without major rehabilitation and/or reconstruction. It is defined in terms of cumulative number of standard axles that can be carried before strengthening of pavement is necessary.

| | |
|---|---|
| **Diverted traffic** | Traffic that changes from another route (or mode of transport) to the project road because of the improved pavement, but still travels between the same origin and destination |
| **Flexible pavement** | Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of material. Each layer receives the loads from the above layer, spreads them out, and then passes on these loads to the next layer below. Thus, the further down in the pavement structure a particular layer is, the less load (in terms of force per area) it must carry. |
| **Formation level** | The level of the top surface of the sub-grade upon which pavement structure is built up |
| **Generated traffic** | Additional traffic which occurs in response to the provision or improvement of the road |
| **Normal traffic** | Traffic which would pass along the existing road or track even if no new pavement were provided |
| **Penetration Macadam** | Penetration Macadam or grouted Macadam is used as a base or binder course. The coarse aggregates are first spread and compacted well in dry state and after that hot bitumen of relatively high viscosity is sprayed in fairly large quantity at the top. The bitumen penetrates into the voids and binding stone aggregates together. After the penetration of bitumen, key aggregates are spread over the previous layer and it is compacted. |
| **Premix carpet** | PC consists of coarse aggregates of 12.5 mm and 10 mm, also premixed with bitumen or tar binder are compacted to a thickness of 20 mm to serve as a surface course of the pavement. Being open graded construction, the PC is to be covered by a suitable seal coat such as premixed sand bitumen seal coat before opening to traffic. |
| **Prime coat** | Prime coat is applied over an existing porous or absorbent pavement surface (for example on WBM) with low viscosity. Main function of prime coat is to seal the pores and waterproof the underlying layer and to develop interface conditions for bonding. Usually MC or SC cutback bitumen with suitable grade are used. |
| **Rigid pavement** | Rigid pavements are the pavement structure deflects very little under loading due to the high modulus of elasticity of their surface course. A rigid pavement structure is typically composed of a PCC |

surface course built on top of either (1) the subgrade or (2) an underlying base course. Because of its relative rigidity, the pavement structure distributes loads over a wide area with only one, or at most two, structural layers.

**Seal coat** — Seal Coat is usually recommended as a top coat over certain bituminous pavements which are not impervious, such as open graded bituminous construction like premixed carpet and grouted Macadam. Seal coat is also provided over an existing bituminous pavement which is worn out. The seal coat is a very thin surface treatment or a single coat surface dressing which is usually applied over an existing black top surface. A premixed sand bitumen (fine mix) seal coat is also commonly used over the premixed carpet.

**Stabilizer** — The selected natural or crushed material, lime, cement and other similar materials to be mixed into the in-situ material of the subgrade is defined as the "stabilizer".

**Sub-grade** — Up to 500 mm below formation level is designated as "sub-grade".

**Sub-Base Course** — The sub-base course is between the base course and the sub-grade. It functions primarily as structural support but it can also: to minimize the intrusion of fines from the sub-grade into the pavement structure; to improve drainage; to minimize frost action damage; to provide a working platform for construction

**Tack coat** — Tack coat is applied on relatively impervious layer like example existing bituminous or cement concrete pavements or a previous layer like the WBM which has already been treated by prime coat.

**Vehicle Damage Factor (VDF)** — It is a multiplier to convert the number of commercial vehicles of different axle loads and configurations to the number of standard axle load repetitions. It is equivalent number of standard axles per commercial vehicle. The VDF varies with vehicle axle configuration, axle loading, terrain, type of road and from region to region.

**Water Bound Macadam** — The water bound macadam (WBM) is the construction known after the name of John Mac Adam. Present understanding is made of crushed or broken aggregates. Crushed or broken aggregates are bound together by the action of rolling. Binding is achieved by stone dust used as filler in presence of water. The thickness of each compacted layer ranges from 10cm to 7.5 cm depending on the size and gradation of the aggregate used.

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## Annex-3: Failure Criteria

Failure criteria, relationship between number of cumulative standard axles, strain values and elastic moduli of materials.

**a) Fatigue Criteria**

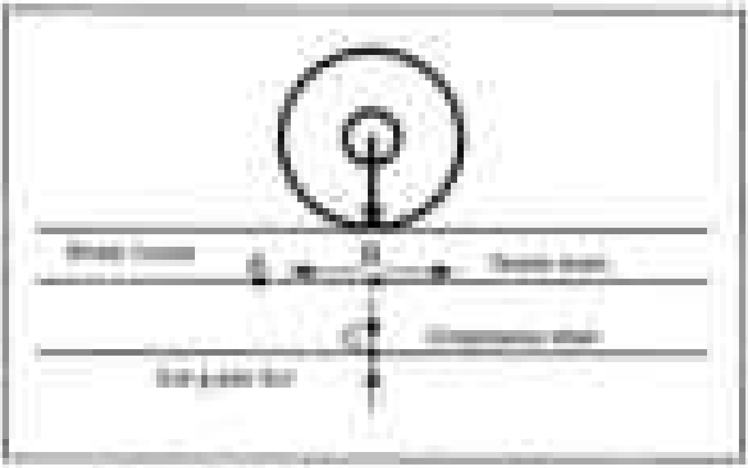


**Figure 3: Critical Locations in Pavement**

A and B are the critical locations for tensile strains ($\varepsilon_t$). Thus the maximum value of the tensile strain is adopted for design ie ($\varepsilon_t$). C is the critical location for the vertical sub-grade strain ($\varepsilon_z$) since the maximum value of the $\varepsilon_z$ occurs mostly at point C.

Bituminous surfacing of pavement displays flexural fatigue cracking if the tensile strain at the bottom of the bituminous layer is beyond certain limit. The relation between the fatigue life of the pavement and the tensile strain in the bottom of the bituminous layer can be obtained.

$$N_f = 2.21 * 10^{-4} * \left(\frac{1}{\varepsilon_t}\right)^{3.89} * \left(\frac{1}{E}\right)^{0.854}$$

Where, Nf is the number of cumulative standard axles to produce 20 percentage cracked surface area; ($\varepsilon_t$) is the tensile strain at the bottom of the bituminous concrete layer; E is the Elastic modulus of bituminous surfacing.

The values of the elastic moduli of Asphalt Concrete (AC), Dense Bituminous Macadam (DBM) and Bituminous Macadam (BM) meeting the requirements of the Standard specifications of DoR are given below.

Table 1: Elastic Modulus (MPa) of Bituminous materials

| Mix Type | Temperature, 0C | | | | |
|---|---|---|---|---|---|
| | 20 | 25 | 30 | 35 | 40 |
| AC and DBM 80/100 Bitumen | 2300 | 1966 | 1455 | 975 | 797 |
| AC and DBM 60/70 Bitumen | 3600 | 3126 | 2579 | 1695 | 1270 |
| AC and DBM 30/40 Bitumen (75 blows compaction and 4% air voids) | 6000 | 4928 | 3809 | 2944 | 2276 |
| BM 80/100 Bitumen | - | - | - | 500 | - |
| BM 60/70 Bitumen | - | - | - | 700 | - |

The above fatigue equation was calibrated at 35°C for bituminous concrete surfacing having 80/100 bitumen and the equation was generalised 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 Poisson's ratio of bituminous layer may be taken as 0.5 for pavement temperature of 35°C and 40°C. For temperature 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 pavement temperature. Catalogue of design has been worked for temperature of 35°C.

**b) Rutting criteria**

The rutting criteria as mentioned in IRC 37 2001 is the allowable rut depth as 20 mm, the rutting equation was obtained as:

$$N_R = 4.1656 \times 10^{-8} \times \left[\frac{1}{\varepsilon_z}\right]^{4.5337}$$

Where, Nr is the number of cumulative standard axles to produce rutting of 20 mm εz is the vertical sub-grade strain.

**c) Modulus of Elasticity of Sub-grade, Sub-Base and Base layers**

Sub-grade: $E = 10 \times CBR$ for CBR < 5
$E = 176 \times (CBR)^{0.64}$ for CBR > 5

Granular Sub-base: $E_2 = E_3 \times 0.2 h^{0.45}$

Where, $E_2$ is the composite Elastic Modulus of granular sub-base and Base (MPa); $E_3$ is Elastic Modulus of Sub-grade (MPa); h is the thickness of granular layers (mm); Poisson's ratio for both the granular layers as well as sub-grade layer may be taken as 0.4.

**d) Calculation of equivalent modulus of elasticity**

For two layered system of pavement system, equivalent modulus of elasticity can be found using empirical relationship:

$$E_{eq} = \text{[illegible]}$$

Where;

- E1 – Modulus of elasticity of upper layer
- E2 – Modulus of Elasticity of lower layer
- t – Thickness of upper layer
- D – Diameter of circular area of contact between transferring wheel loads to the pavement.

$h_{eq}$ = [illegible] – equivalent thickness of materials of lower layer with E2

**e) Substitution of Dense Bituminous Macadam (DBM):**

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

$$\frac{E_1 H_1^3}{12(1-\mu_1^2)} = \frac{E_2 H_2^3}{12(1-\mu_2^2)}$$

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 DBM and BM respectively. Based on the above equation, following equivalent thickness may be used:

Conversion factors for the thickness of pavement layers (i.e. different constituent materials) can be done in terms of modulus of Elasticity. Considering the equal value of the Poisson's ratios (µ) for both the layers, the equivalent thickness ($H_2$) of layer 2 is equal to:

$$h_1 = \left[\frac{E_2}{E_1}\right]^{\frac{1}{3}} h_2$$

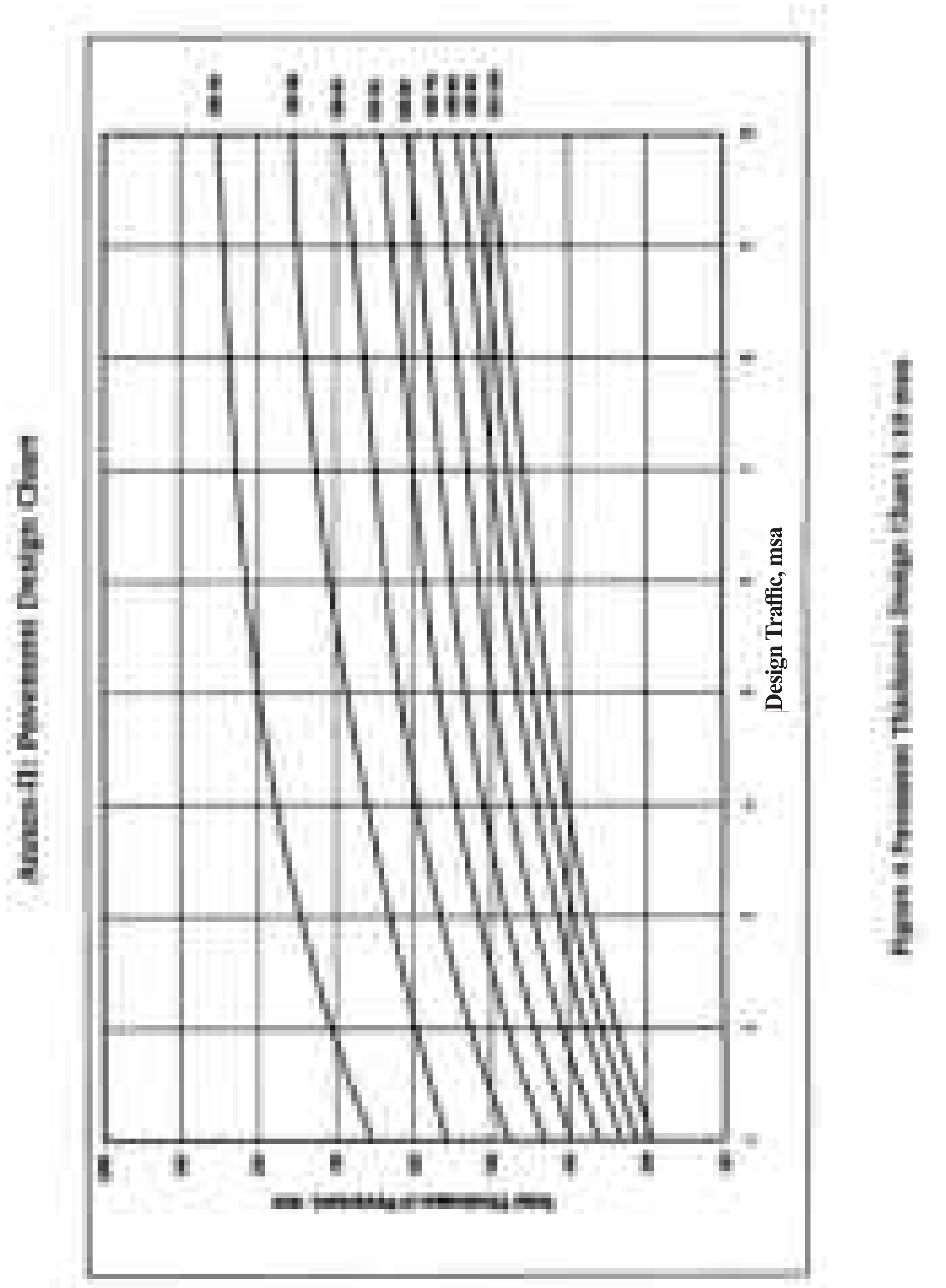
Where, $h_2$ is the thickness of layer 2 ; $E_1$ and $E_2$ are Modulus of elasticity of layers.

**Examples:**

The value of modulus of elasticity of Dense Bituminous Macadam (DBM) and Bituminous Macadam (BM) are 1500 and 700 MPa respectively.

The thickness of 180 mm DBM can be split into: 120 mm DBM + 75 mm BM.

The 60 mm thickness of DBM can be converted into 75 mm of BM using above relationship.


Design Traffic, msa

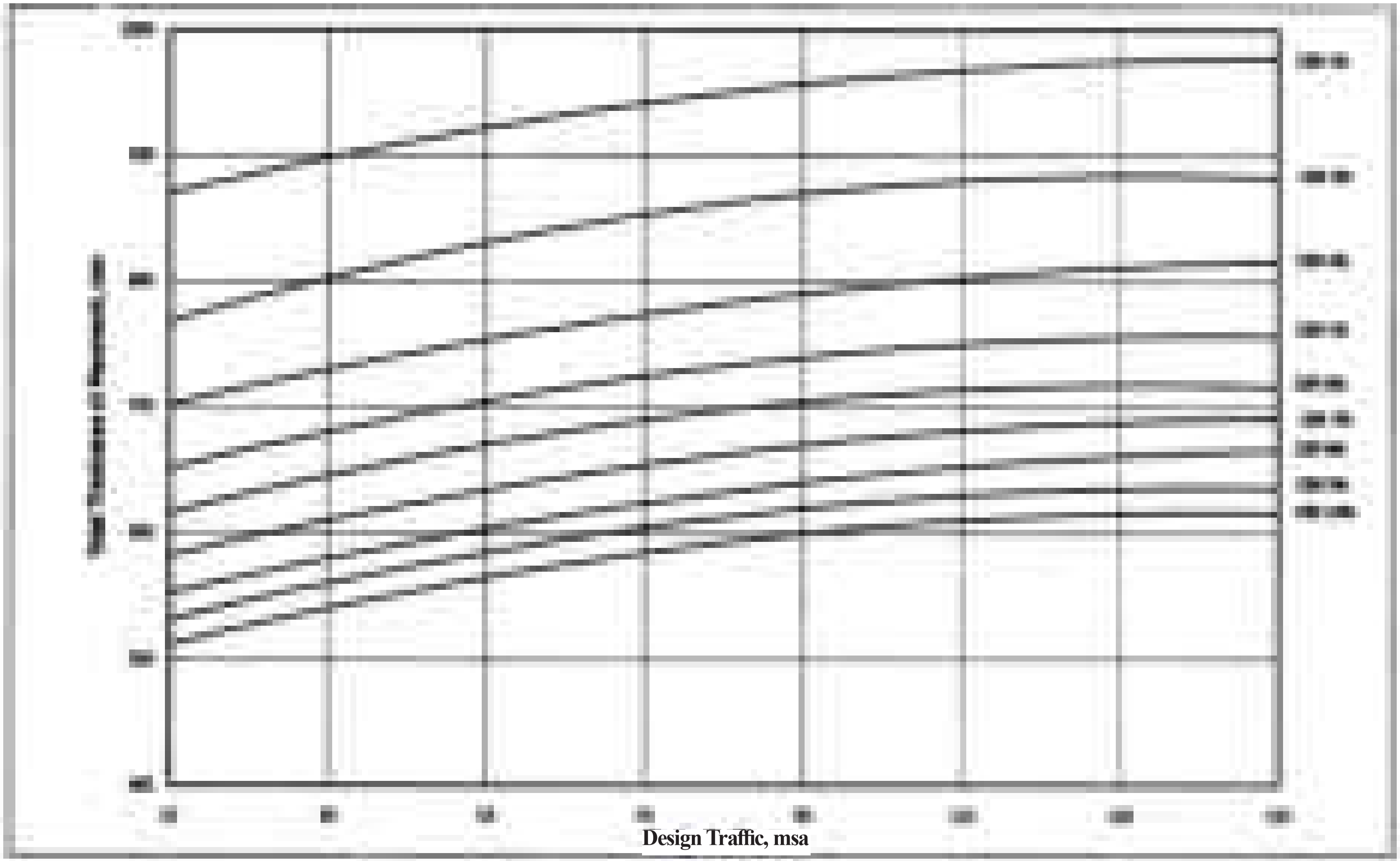


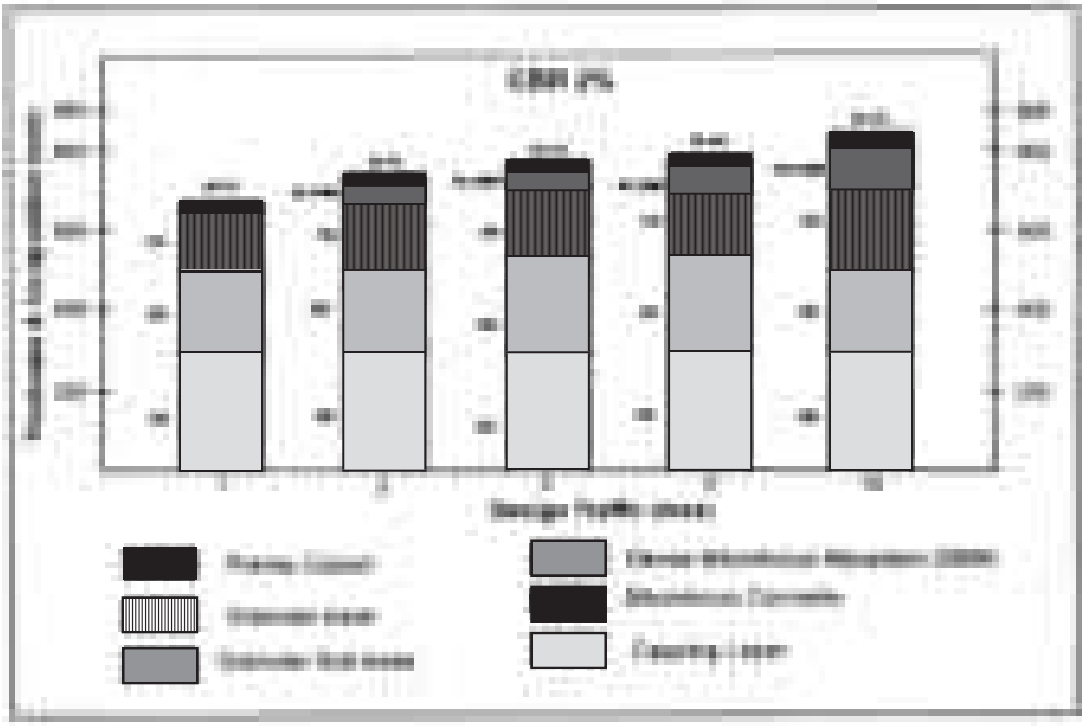

Figure 5 Pavement Design Chart, 10-150 msa

# Annex III: Pavement Design Catalogue

## Pavement Design Catalogue

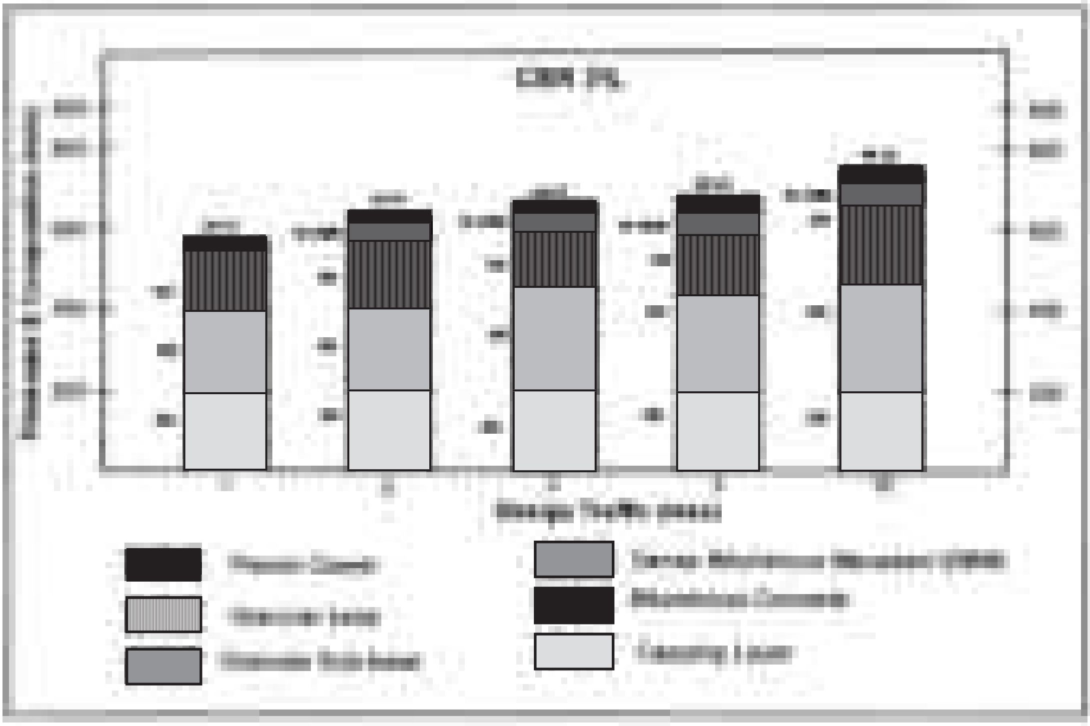
### Plate 1 - Recommended Design for Traffic Range 1 – 10 msa

| CBR 2% | | | | | | |
|---|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm | Capping, Layer, mm |
| | | Wearing Course, mm | Binder Course, mm | | | |
| 1 | 660 | 20 PC | | 150 | 200 | [illegible] |
| 2 | 710 | 20 PC | 50 DBM | [illegible] | 200 | [illegible] |
| 3 | 750 | 20 PC | 50 DBM | [illegible] | 240 | [illegible] |
| 5 | 790 | 50 AC | 50 DBM | 150 | 240 | [illegible] |
| 10 | 850 | 50 AC | 100 DBM | 200 | 200 | [illegible] |



## Pavement Design Catalogue
## Plate 1 - Recommended Design for Traffic Range 1 - 10 msa

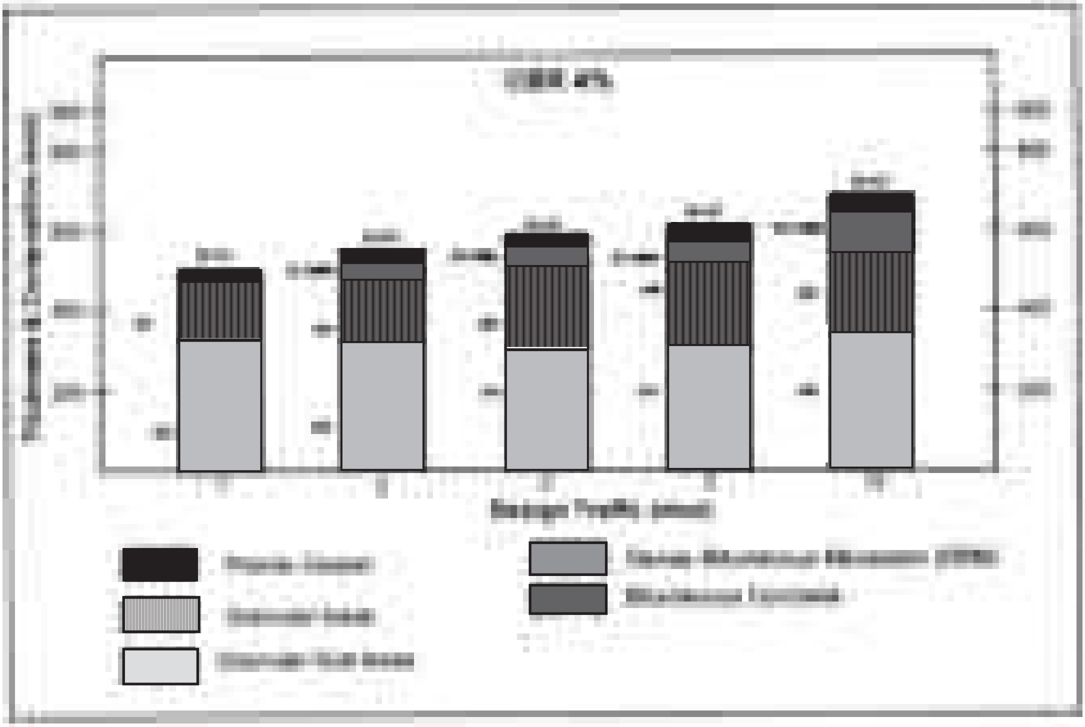
| CBR 3% | | | | | | |
|---|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm | Capping, Layer, mm |
| | | Wearing Course, mm | Binder Course, mm | | | |
| 1 | 550 | 20 PC | | [illegible] | [illegible] | 200 |
| 2 | 610 | 20 PC | 50 DBM | [illegible] | [illegible] | 200 |
| 3 | 645 | 20 PC | 50 DBM | [illegible] | [illegible] | 200 |
| 5 | 690 | 50 AC | 50 DBM | [illegible] | [illegible] | 200 |
| 10 | 750 | 50 AC | 50 DBM | [illegible] | [illegible] | 200 |



## Pavement Design Catalogue

## Plate 1 - Recommended Design for Traffic Range 1 - 10 msa

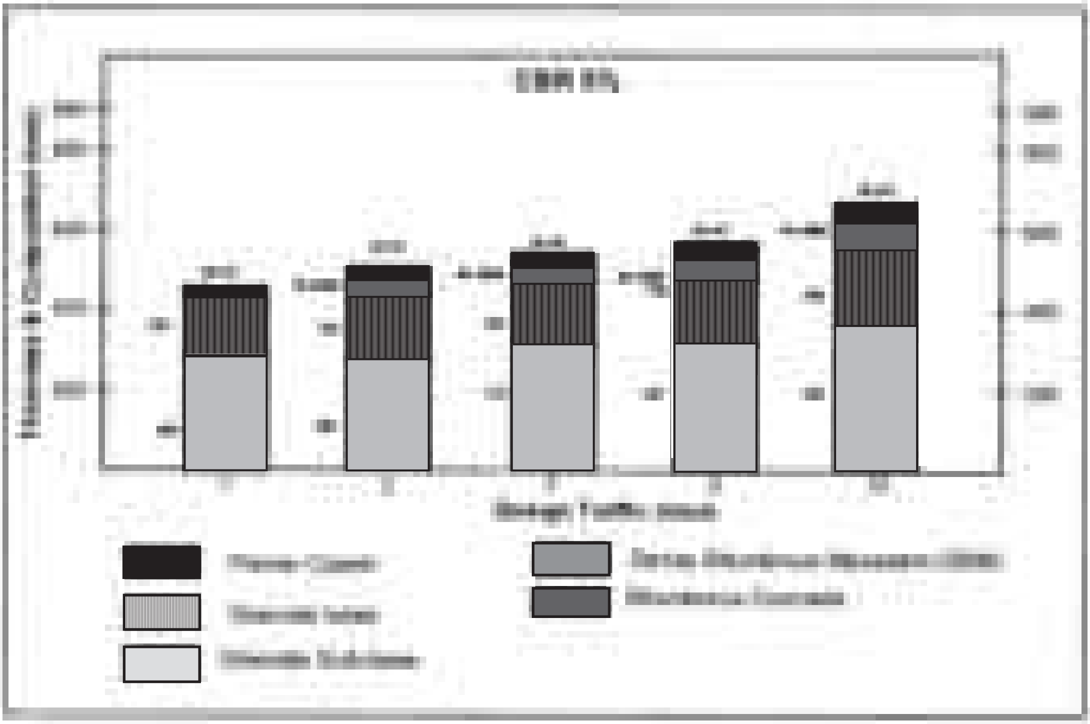
| CBR 4% | | | | | |
|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm |
| | | Wearing Course, mm | Binder Course, mm | | |
| 1 | [illegible] | 20 PC | | [illegible] | [illegible] |
| 2 | [illegible] | 20 PC | 50 DBM | [illegible] | [illegible] |
| 3 | [illegible] | 20 PC | 50 DBM | [illegible] | [illegible] |
| 5 | [illegible] | 50 AC | 50 DBM | [illegible] | [illegible] |
| 10 | [illegible] | 50 AC | 100 DBM | [illegible] | [illegible] |



## Pavement Design Catalogue

## Plate I - Recommended Design for Traffic Range 1 - 10 msa

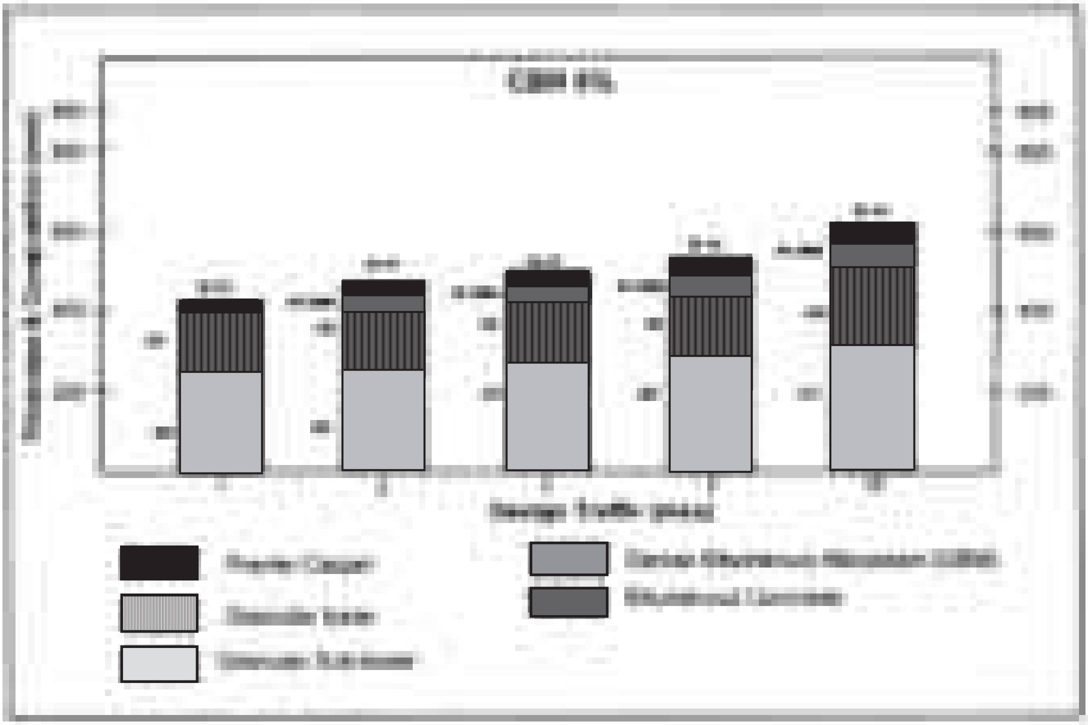
| CBR 5% | | | | | |
|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm |
| | | Wearing Course, mm | Binder Course, mm | | |
| 1 | [illegible] | 20 PC | | [illegible] | [illegible] |
| 2 | [illegible] | 20 PC | [illegible] | [illegible] | [illegible] |
| 3 | [illegible] | 20 PC | [illegible] | [illegible] | [illegible] |
| 5 | [illegible] | 40 AC | [illegible] | [illegible] | [illegible] |
| 10 | [illegible] | 40 AC | [illegible] | [illegible] | [illegible] |



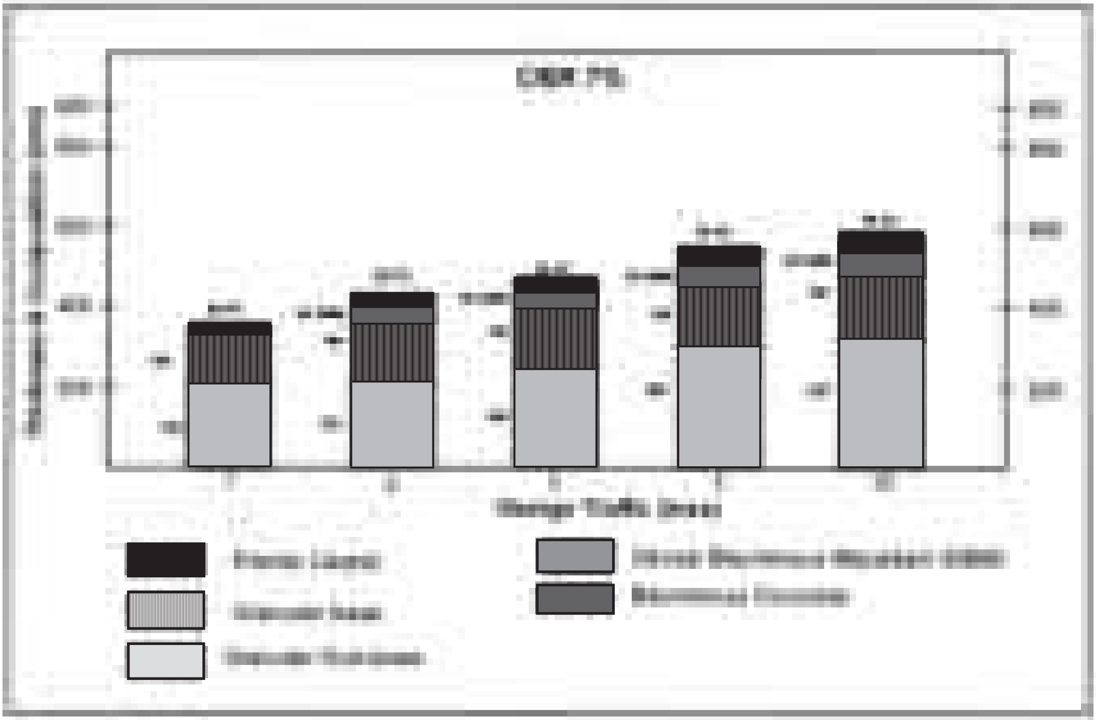
## Pavement Design Catalogue

## Plate 1 - Recommended Design 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 | 400 | 20 PC | | 150 | 250 |
| 2 | [illegible] | 20 PC | [illegible] | 150 | [illegible] |
| 3 | 475 | 20 PC | 50 DBM | 150 | 275 |
| 5 | [illegible] | [illegible] | 50 DBM | 150 | [illegible] |
| 10 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

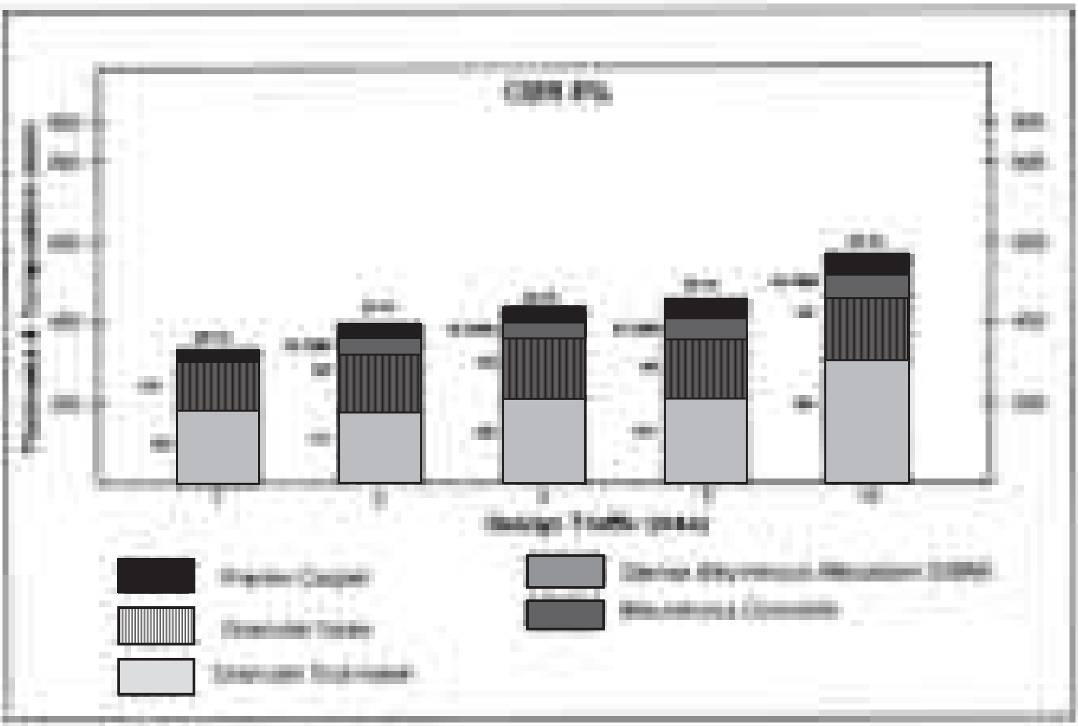


| CBR 7% | | | | | |
|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm |
| | | Wearing Course, mm | Binder Course, mm | | |
| [illegible] | [illegible] | [illegible] | | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |



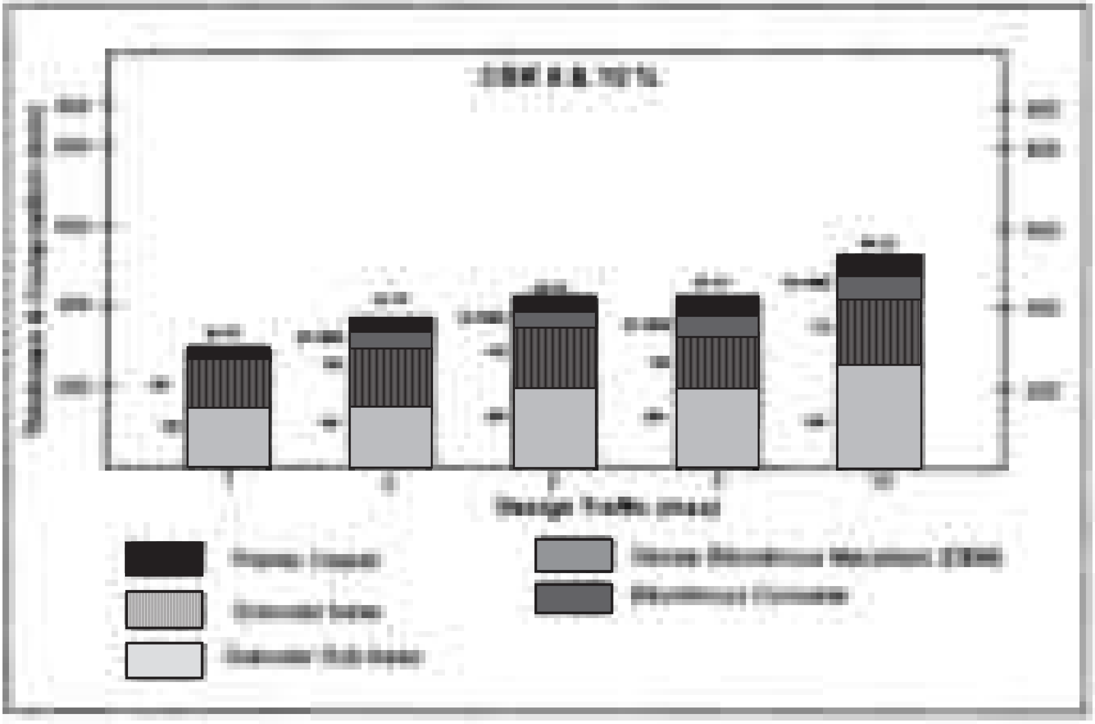
## Pavement Design Catalogue
## Plate 1 - Recommended Design for Traffic Range 1 – 10 msa

| 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 | 340 | 20 PC | | 150 | [illegible] |
| 2 | 375 | 20 PC | 50 DBM | 150 | 175 |
| 5 | 420 | 20 PC | 50 DBM | 150 | 200 |
| 8 | 460 | 40 BC | 50 DBM | 150 | 210 |
| 10 | 550 | 40 BC | 60 DBM | 150 | 300 |



## Pavement Design Catalogue
## Plate 1 - Recommended Design for Traffic Range 1 - 10 msa

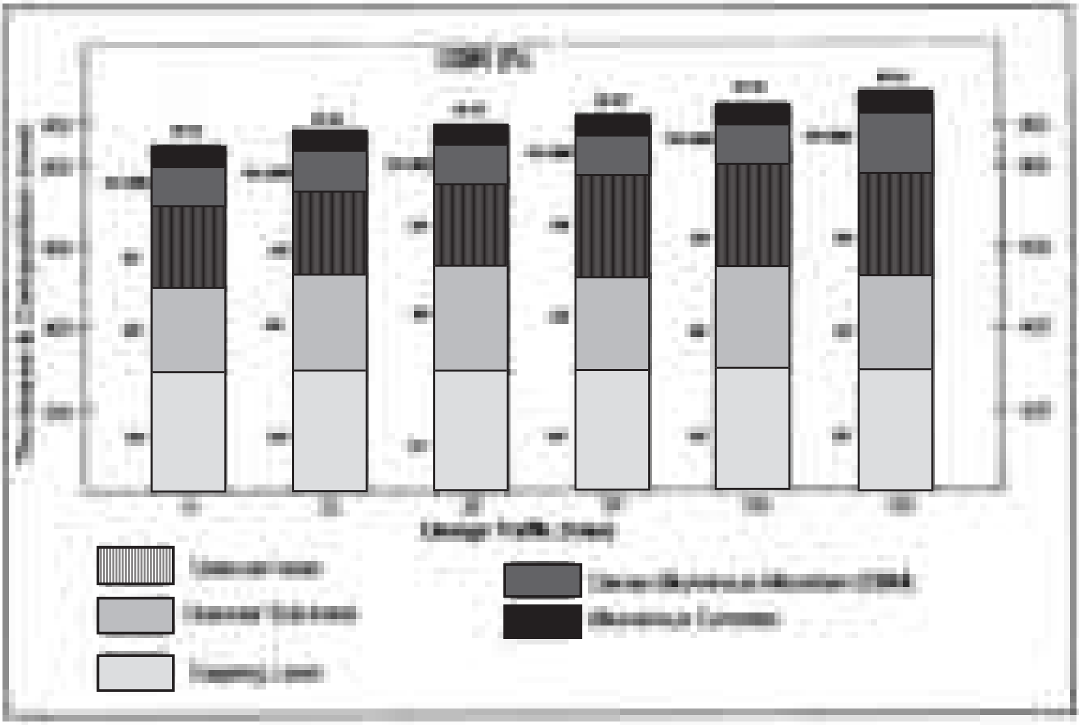
| CBR 9&10% | | | | | |
|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm |
| | | Wearing Course, mm | Binder Course, mm | | |
| 1 | [illegible] | 20 PC | | [illegible] | [illegible] |
| 2 | [illegible] | 20 PC | [illegible] DBM | [illegible] | [illegible] |
| 3 | [illegible] | 20 PC | [illegible] DBM | [illegible] | [illegible] |
| 5 | [illegible] | [illegible] AC | [illegible] DBM | [illegible] | [illegible] |
| 10 | [illegible] | [illegible] AC | [illegible] DBM | [illegible] | [illegible] |



## Pavement Design Catalogue

## Plate II - Recommended Design for Traffic Range 10 - 150 msa

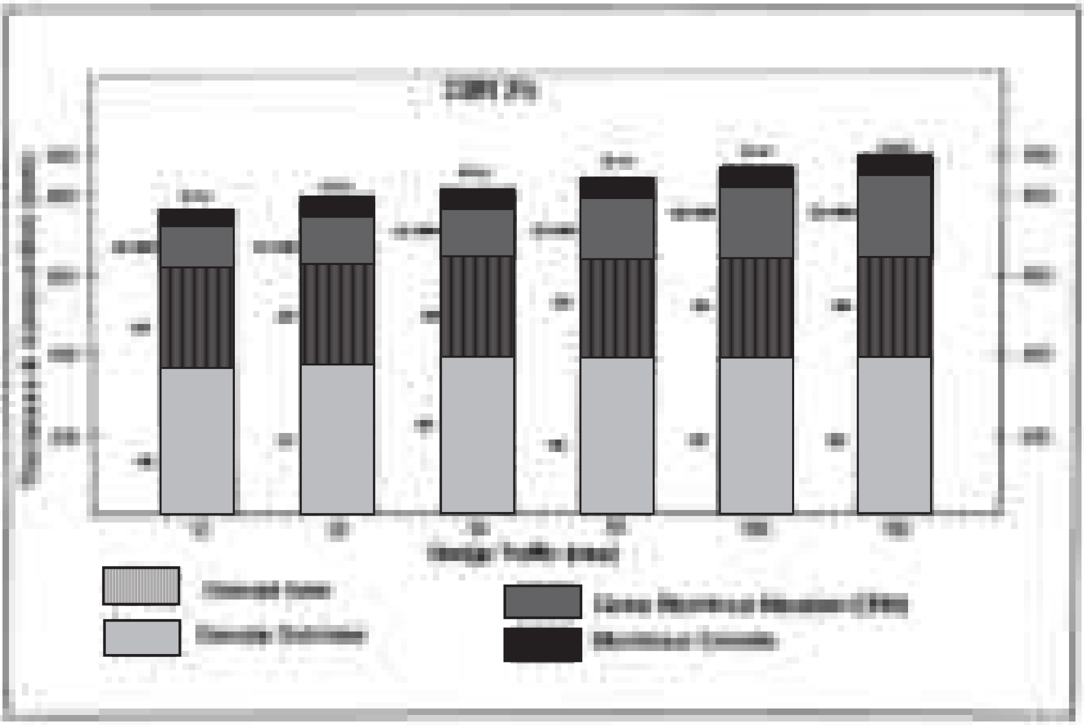
| CBR 2% | | | | | | |
|---|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm | Capping Layer, mm |
| | | Asphalt Concrete | D B M | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |



## Pavement Design Catalogue

### Plate II - Recommended Design for Traffic Range 10 - 150 msa

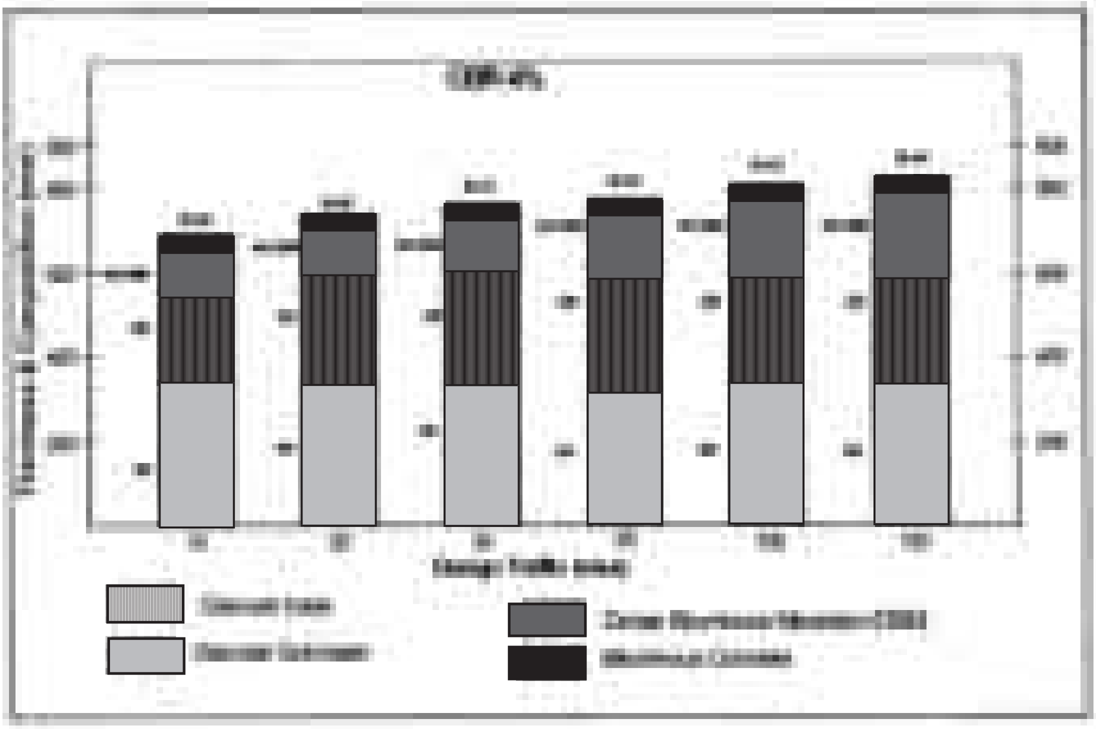
| CBR 3% | | | | | |
|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm |
| | | Asphalt Concrete | D B M | | |
| 10 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 20 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 30 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 50 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 100 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 150 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |



# Pavement Design Catalogues

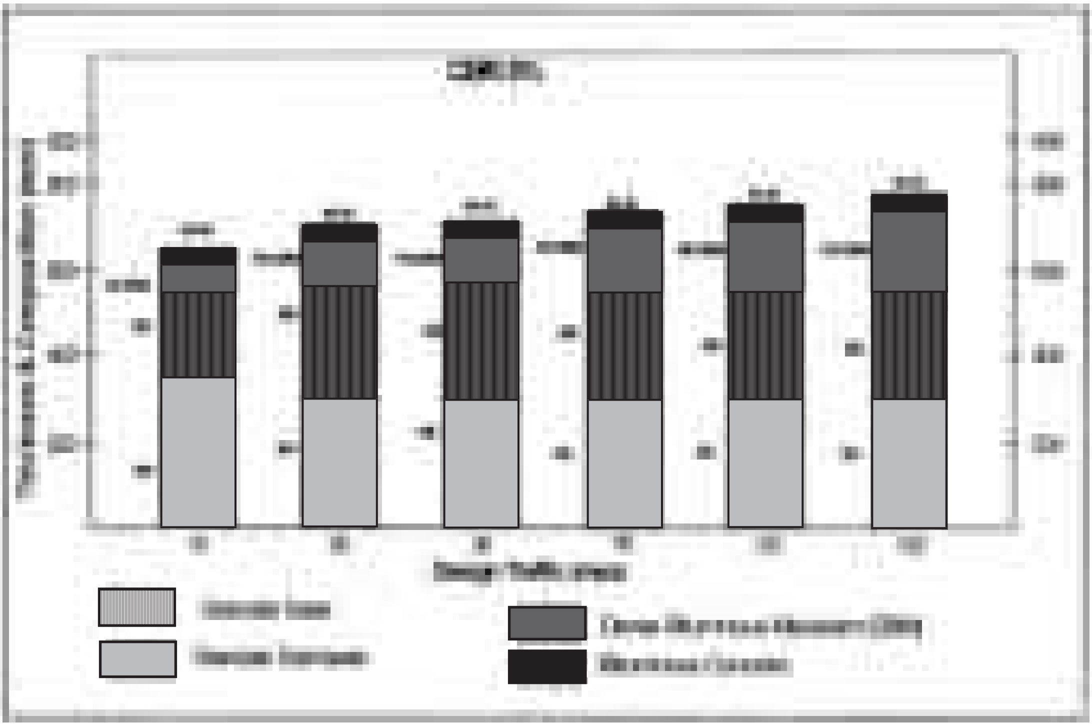
## Plate II - Recommended Design for Traffic Range 10 - 150 msa

| CBR 4% | | | | | |
|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm |
| | | Asphalt Concrete | D B M | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

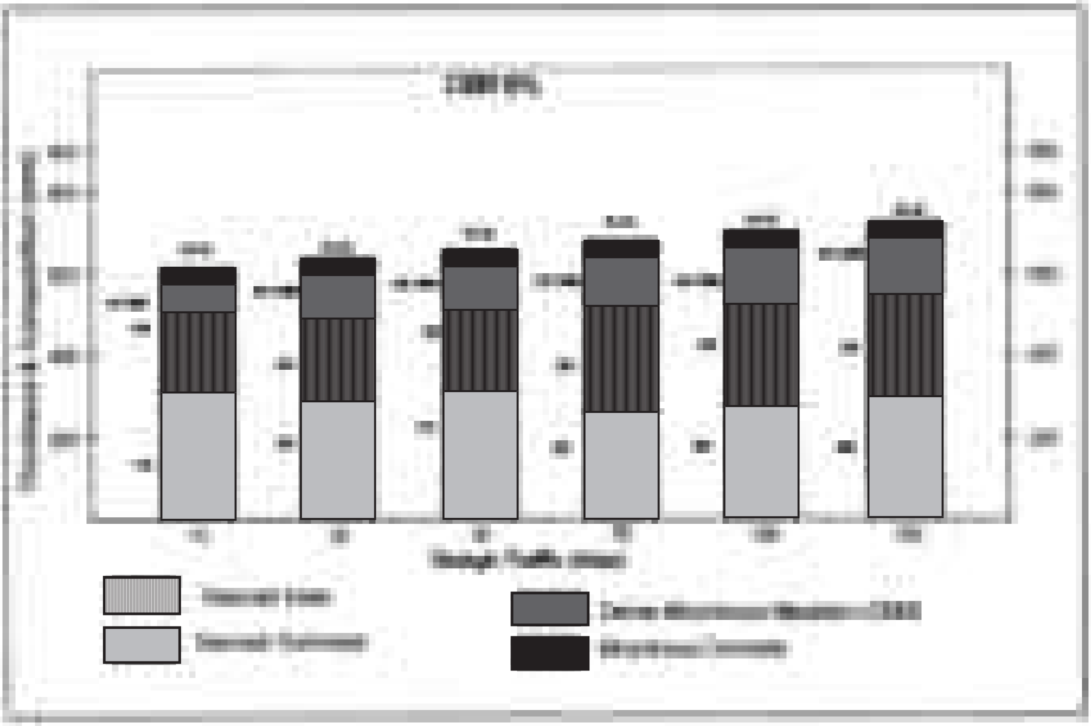


## Pavement Design Catalogue:
## Plate II - Recommended Design for Traffic Range 10 - 150 msa

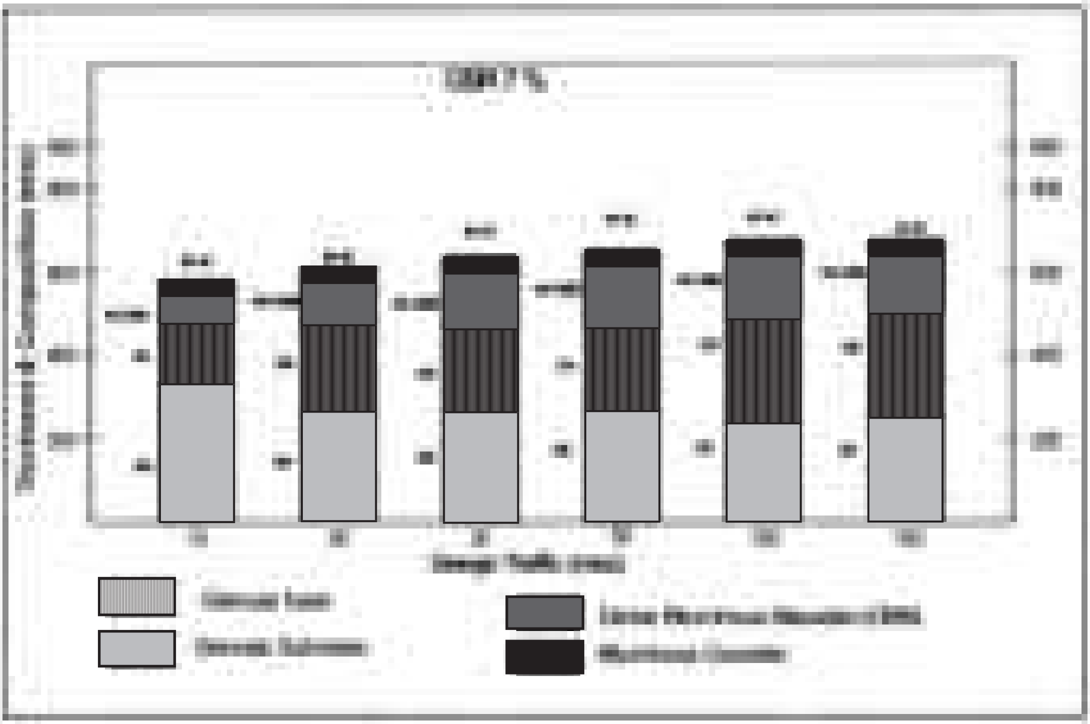
| CBR 5% | | | | | |
|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm |
| | | Asphalt Concrete | D B M | | |
| 10 | 660 | 50 | 90 | 200 | 300 |
| 20 | 700 | 50 | 100 | 250 | 300 |
| 30 | 715 | 50 | 115 | 250 | 300 |
| 50 | 730 | 50 | 130 | 250 | 300 |
| 100 | 750 | 50 | 150 | 250 | 300 |
| 150 | 770 | 50 | 170 | 250 | 300 |



| CBR 6% | | | | | |
|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm |
| | | Asphalt Concrete | D B M | | |
| 10 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 20 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 30 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 50 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 100 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 150 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

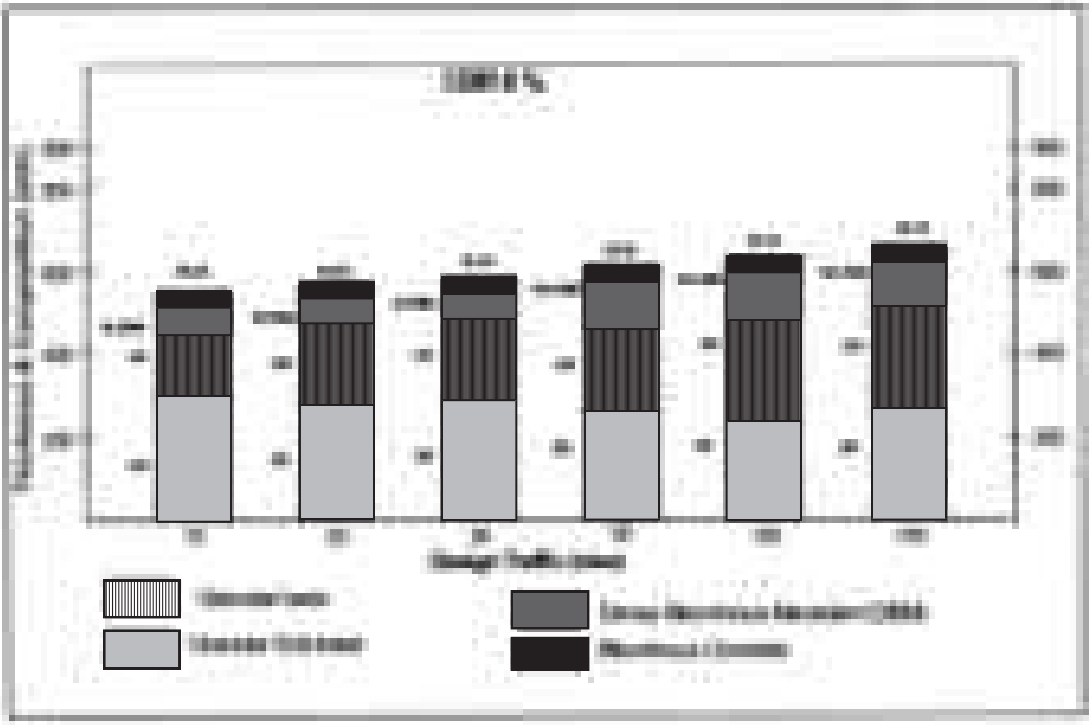


| CBR 7% | | | | | |
|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm |
| | | Asphalt Concrete | D B M | | |
| 10 | 575 | [illegible] | [illegible] | [illegible] | [illegible] |
| 20 | 610 | [illegible] | [illegible] | [illegible] | [illegible] |
| 30 | 630 | [illegible] | [illegible] | [illegible] | [illegible] |
| 50 | 650 | [illegible] | [illegible] | [illegible] | [illegible] |
| 100 | 675 | [illegible] | [illegible] | [illegible] | [illegible] |
| 150 | 690 | [illegible] | [illegible] | [illegible] | [illegible] |



## Pavement Design Catalogue
## Plate II - Recommended Design for Traffic Range [illegible]

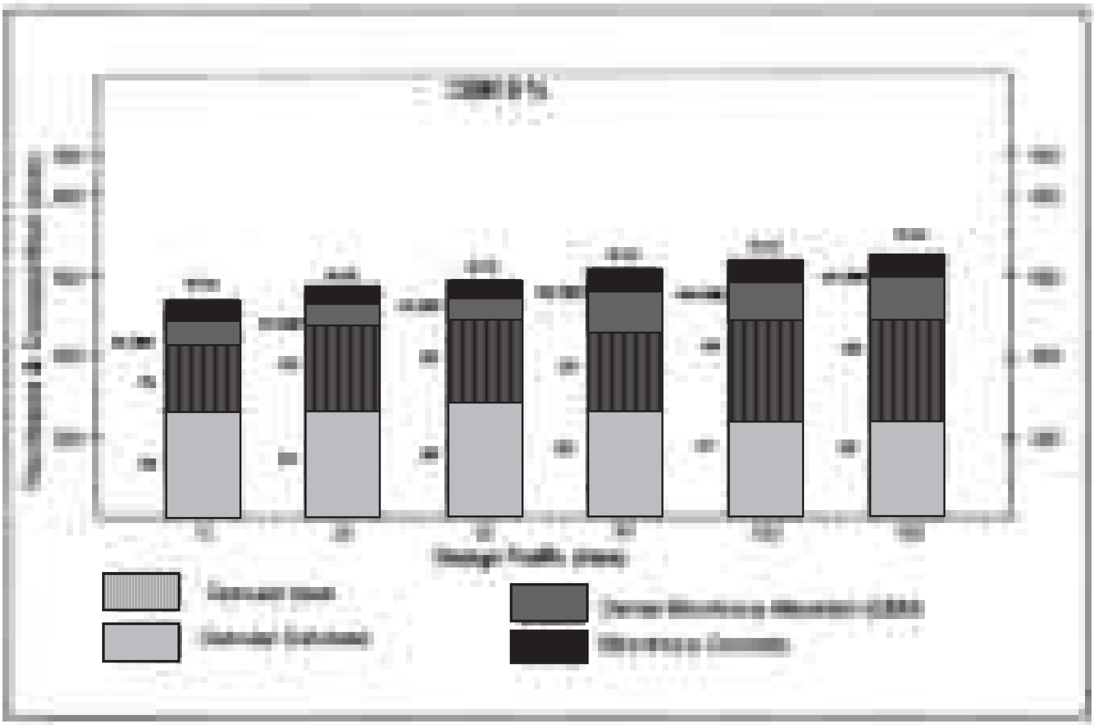
| CBR 8 % | | | | | |
|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm |
| | | Asphalt Concrete | D B M | | |
| 10 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 20 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 30 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 50 | 615 | [illegible] | [illegible] | [illegible] | [illegible] |
| 100 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 150 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |



## Pavement Design Catalogue

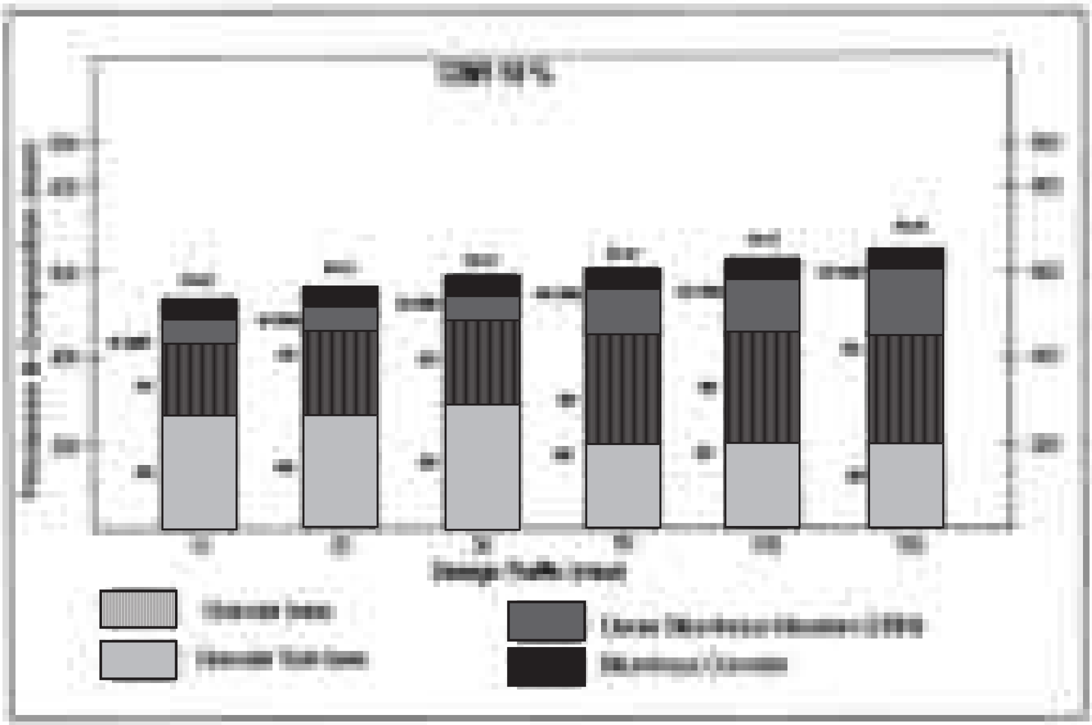
## Plate II - Recommended Design for Traffic Range 10 - 150 msa

| CBR 9% | | | | | |
|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm |
| | | Asphalt Concrete | D B M | | |
| 10 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 20 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 30 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 50 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 100 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 150 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |



## Pavement Design Catalogue
## Plate II : Recommended Design for Traffic Range 10 - 150 msa

| CBR 10% | | | | | |
|---|---|---|---|---|---|
| Cumulative Traffic, msa | Total Pavement Thickness, mm | Pavement Composition | | | |
| | | Bituminous Surfacing | | Granular Base, mm | Granular Sub-base, mm |
| | | Asphalt Concrete | D B M | | |
| 10 | 540 | [illegible] | [illegible] | [illegible] | [illegible] |
| 20 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 30 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 50 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 100 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 150 | 650 | [illegible] | [illegible] | [illegible] | [illegible] |



# Annex IV: Standard Specification for Bituminous Layers

## 1. Requirements for Sub-grade Layer

(This specification is taken from Standard Specifications for Road and Bridge Works, Section 1000)

1001 Scope: This section deals with the treatment of the upper layers of earthworks including preparation and surface treatment of the formation, the addition of layers of selected material, the improvement of in-situ materials by addition and mixing of selected materials or by addition and mixing of lime.

## 2. Capping Layers

## 3. Base Course

## 4. Dense Graded Bituminous Macadam

### 4.1 Scope

This clause specifies the construction of Dense Graded Bituminous Macadam, (DBM), for use mainly, in base/binder courses. DBM is also intended for use as road base material. This work shall consist of construction in a single or multiple layers of DBM on a previously prepared base or sub-base. The thickness of a single layer shall be 50mm to 100mm.

### 4.2. Materials

#### 4.2.1 Bitumen

Bitumen shall be 80/100 or [illegible] penetration grade as specified in Section [illegible].

#### 4.2.2 Coarse aggregates

The coarse aggregates shall consist of crushed rock, crushed gravel or other hard material retained on the 2.36 mm sieve. They shall be clean, hard, and durable, of cubical shape, free from dust and soft or friable matter, organic or other deleterious substances. The aggregates shall satisfy the physical requirements specified in Table 1, for dense bituminous macadam. Where crushed gravel is proposed for use as aggregate, not less than 90% by weight of the crushed material retained on the 4.75 mm sieve shall have at least two fractured faces.

#### 4.2.3 Fine aggregates

Fine aggregates shall consist of crushed or naturally occurring mineral material, or a combination of the two, passing the 2.36 mm sieve and retained on the 75 micron sieve. They shall be clean, hard, durable, dry and free from dust, and soft or friable matter, organic or other deleterious matter.

**Table 1. Physical Requirements for coarse aggregates for Dense Graded Bituminous Macadam (DBM)**

| Propert | Test | Specification |
|---|---|---|
| Cleanliness (dust) | Grain size analysis | Max 5% passing 0.075mm sieve |
| Particle shape | Flakiness and elongation Index (combined) | Max 30% |
| Strength | Los Angeles Abrasion value<br>Aggregate impact value | max 35%<br>max 27% |
| Polishing | Polished stone value | min 55 |
| Durability | Soundness<br>Sodium Sulphate<br>Magnesium Sulphate | <br>Max 12%<br>Max 18% |
| Water Absorption | Water absorption | Max 2% |
| Stripping | Coating and stripping of Bitumen<br>Aggregate mixtures | Minimum Retained<br>Coating 95% |
| Water Sensitivity | retained tensile strength | Min 80% |

**4.2.4 Filler**

Filler shall consist of finely divided mineral matter such as rock dust, hydrated lime or cement approved by the Engineer. The filler shall be graded within the limits indicated in Table 2.

**Table 2. Grading requirements for mineral filler**

| IS Sieve | Cumulative percent passing by weight of total aggregate |
|---|---|
| 0.6 | 100 |
| 0.3 | 95 - 100 |
| 0.075 | 85 - 100 |

The filler shall be free from organic impurities and have a Plasticity Index not greater than 4. The Plasticity Index requirement shall not apply if filler is cement or lime. When the coarse aggregate is gravel, 2 per cent by weight of total aggregate, shall be Portland cement or hydrated lime and the percentage of fine aggregate reduced accordingly. Cement or hydrated lime is not required when the limestone aggregate is used.

### 4.2.5 Aggregate grading and binder content

The combined grading of the coarse and fine aggregates and added filler for the particular mixture shall fall within the limits shown in Table 3, for dense bituminous macadam grading 1 or 2. The type and quantity of bitumen, and appropriate thickness, are also indicated for each mixture type.

**Table: 3. Composition of Dense Graded Bituminous Macadam Pavement Layers**

| Grading | Type 1 | Type 2 |
|---|---|---|
| Nominal aggregate size | 40 mm | 25 mm |
| Layer Thickness | 80 – 100 mm | 50 – 75 mm |
| IS Sieve (mm) | Cumulative % by weight of total aggregate passing | |
| 45 | 100 | |
| 37.5 | 95 – 100 | 100 |
| 26.5 | 63 – 93 | 90 – 100 |
| 19 | - | 71 – 95 |
| 13.2 | 55 – 75 | 56 – 80 |
| 9.5 | - | - |
| 4.75 | 38 – 54 | 38 – 54 |
| 2.36 | 28 – 42 | 28 – 42 |
| 1.18 | - | - |
| 0.6 | - | - |
| 0.3 | 7 – 21 | 7 – 21 |
| 0.15 | - | - |
| 0.075 | 2 – 8 | 2 – 8 |
| Bitumen content % by mass of total mix | min 4.5 | min 4.5 |
| Bitumen grade (pen) | 65 or 90 | 65 or 90 |

### 4.3 Mixture Design

#### 4.3.1 Requirement for the mixture

Apart from the conformity with the grading and quality requirements for individual ingredients, the mixture shall meet the requirements set out in Table 4.

**Table 4. Requirements for Dense Graded Bituminous Macadam**

| | |
|---|---|
| Minimum stability (kN at 60 °C) | 9 |
| Minimum flow (mm) | 2 – 4 |
| Compaction level (Number of blows) | 75 blows |
| Percent air voids | 3 - 6 |
| Percent voids filled with bitumen | 65 - 75 |

**4.3.2 Binder content:**

The binder content shall be optimised to achieve the requirements of the mixture set out in Table 4. The Marshall method for determining the optimum binder content shall be adopted as described in the Asphalt Institute Manual MS-2, replacing the aggregates retained on the 26.5 mm sieve and retained on the 22.4 mm sieve, where approved by the Engineer.

**4.4 Construction Operation:**

**4.4.1 Weather and seasonal limitations:**

Laying shall be suspended while free standing water is present on the surface to be covered, or during rain, fog and dust storms. After rain, the bituminous surface, primer or tack coat, shall be blown off with a high pressure air jet to remove excess moisture, or the surface left to dry before laying shall start. Laying of bituminous mixtures shall not be carried out when the air temperature at the surface on which it is to be laid is below 10°C or when the wind speed at any temperature exceeds 40 km/h at 2m height unless specifically approved by the Engineer.

**4.4.2 Cleaning of surface:**

The surface on which the bituminous work is to be laid shall be cleaned of all loose and extraneous matter by means of a mechanical broom or any other approved equipment / method as specified in the contract. The use of a high pressure air jet from a compressor to remove dust or loose matter shall be available full time on the site, unless otherwise specified in the Contract.

**4.4.3 Preparation of base:**

The base on which Dense Graded Bituminous Macadam is to be laid shall be thoroughly swept clean by a mechanical broom, and the dust removed by compressed air. In locations where mechanical broom cannot access, other approved methods shall be used as directed by the Engineer.

### 4.4.4 Prime coat

Where the material on which the dense bituminous macadam is to be laid is other than a bitumen bound layer, a prime coat shall be applied, as specified, in accordance with the provisions of Clause 1301 and Clause 1302 [4], Standard Specifications for Road and Bridge Works, or as directed by the Engineer.

### 4.4.5 Tack coat

Where the material on which the dense bituminous macadam is to be placed is a bitumen bound surface, a tack coat shall be applied as specified, in accordance with the provisions of 1301 and Clause 1302 [4] Standard Specifications for Road and Bridge Works, or as directed by the Engineer.

### 4.4.6 Mixing and transportation of the mixture:

Pre-mixed bituminous materials, including dense bituminous macadam, and bituminous concrete, shall be prepared in a hot mix plant of adequate capacity and capable of yielding a mix of proper and uniform quality with thoroughly coated aggregates.

The bitumen shall be heated so that it can be distributed uniformly. Care shall be taken not to overheat it. The temperature shall never exceed 170o C for 80/100 or 60/70 bitumen.

The aggregate shall be dried and heated so that they are heated at the following temperatures unless otherwise specified in Clause 1306 in [31].

- $125^0$ - $160^0$ C when 80/100 bitumen is used.
- $120^0$ - $170^0$ C when 60/70 bitumen is used.

In order to ensure uniform quality of the mix and better coating of aggregates, the hot mix plant shall be calibrated from time to time.

Bituminous materials shall be transported in clean insulated vehicles, and unless otherwise agreed by the Engineer, shall be covered while in transit or waiting tipping. The bituminous mix shall be kept free of contamination and segregation during transportation. Each load shall be covered with canvas or similar covering to protect it from dust and adverse effect of the weather.

### 4.4.7 Spreading

Except in areas where a mechanical paver cannot access, bituminous materials shall be spread, levelled and tamped by an approved self-propelled paving machine. As soon as possible after arrival at site, the materials shall be supplied continuously to the paver and laid without delay.

The rate of delivery of material to the paver shall be regulated to enable the paver to operate continuously. The travel rate of the paver, and its method of operations, shall be adjusted to ensure an even and uniform flow of bituminous material across the screed, free from dragging, tearing and segregation of the material. In areas with restricted space where a mechanical paver cannot be used, the material shall be spread, raked and leveled with suitable hand tools by experienced staff, and compacted to the satisfaction of the Engineer.

The minimum thickness of material laid in each paver pass shall be in accordance with the minimum values given in the relevant parts of these Specifications. When laying binder course or wearing course approaching an expansion joint of a structure, machine laying shall stop 300 mm short of the joint. The remainder of the pavement up to the joint, and the corresponding area beyond it, shall be laid by hand, and the joint or joint cavity shall be kept clear of surfacing material.

Hand placing of pre-mixed bituminous materials shall only be permitted in the following circumstances:

i. For laying regulating courses of irregular shape and varying thickness.
ii. In confined spaces where it is impracticable for a paver to operate.
iii. For footways.
iv. At the approaches to expansion joints at bridges, viaducts or other structures.
v. For laying mastic asphalt.
vi. For filling of potholes.
vii. Where directed by the Engineer.

Manual spreading of pre-mixed wearing course material or the addition of such material by hand spreading to the paved area, for adjustment of level, shall only be permitted in the following circumstances:

i. At the edges of the layers of material and at gullies and manholes.
ii. At the approaches to expansion joints at bridges, viaducts or other structures.
iii. As directed by the Engineer.

**4.4.6 Rolling:**

Bituminous materials shall be laid and compacted in layers which enable the specified thickness, surface level, regularity requirements and compaction to be achieved.

Compaction of bituminous materials shall commence as soon as possible after laying. Compaction shall be substantially completed before the temperature falls below the minimum rolling temperatures stated in the relevant part of these Specifications. Rolling of the longitudinal joints shall be done immediately behind the paving operation. After this, rolling shall commence at the edges and progress towards the extent longitudinally except that on super elevated and unidirectional cambered portions, it shall progress from the lower to the upper edge parallel to the centre line of the pavement. Rolling shall continue until all roller marks have been removed from the surface. All deficiencies in the surface after laying shall be made good by the attendants behind the paver, before initial rolling is commenced. The initial or breakdown rolling shall be done with 8-10 tonnes dead weight smooth wheeled rollers. The intermediate rolling shall be done with 8-10 tonnes dead weight or vibratory roller or with a pneumatic tyred roller of 12 to 15 tonnes weight having nine wheels, with a tyre pressure of at least 5.6 kg/sqcm. The finish rolling shall be done with 6 to 8 tonnes smooth wheeled tandem rollers.

Bituminous materials shall be rolled in a longitudinal direction, with the driven rolls nearest the paver. The roller shall first compact material adjacent to joints and then work from the lower to the upper side of the layer, overlapping on successive passes by at least one-third of the width of the rear roll or, in the case of a pneumatic-tyred roller, at least the nominal width of 300 mm. In portions with super-elevated and uni-directional camber, after the edge has been rolled, the roller shall progress from the lower to the upper edge.

Rollers should move at a speed of not more than 5 km per hour. The roller shall not be permitted to stand on pavement which has not been fully compacted, and necessary precautions shall be taken to prevent dropping of oil, grease, petrol or other foreign matter on the pavement either when the rollers are operating or standing. The wheels of rollers shall be kept moist with water, and the spray system provided with the machine shall be in good working order, to prevent the mixture from adhering to the wheels. Only sufficient moisture to prevent adhesion between the wheels of rollers and the mixture should be used. Surplus water shall not be allowed to stand on the partially compacted pavement.

**4.4.9 Finishing, Joints and Edges**

Any mixture that becomes loose and broken, mixed with dirt or foreign matter or is in any way defective, shall be replaced with fresh hot mixture, which shall be compacted to conform with the surrounding area. Spreading of the mixture shall be as continuous as possible. Transverse joints shall be formed by cutting neatly in a straight line across the previous run to expose the full depth of the course. The vertical face so formed shall be painted lightly with hot 80/100 penetration grade bitumen just before the additional mixture is placed against it.

Longitudinal joint shall be rolled directly behind the paving operation. The first lane shall be placed true to line and level on approximately vertical face. The mixture placed in the abutting lane shall then be tightly crowded against the face of the previously placed lane. The paver shall be positioned to spread material overlapping the joint face by 20 - 30 mm. Before rolling, the excess material shall be raked off and discarded. When the abutting lane is not placed in the same day or the joint is destroyed by traffic, the edge of the lane shall be cut back as necessary, trimmed to line and painted lightly with hot 80/100 penetration grade bitumen just before the abutting lane is placed.

Any fresh mixture spread accidentally on the existing work at a joint shall be carefully removed by brooming it back on to uncompacted work, so as to avoid formation of irregularities at the joint. The finish at joints shall comply with the surface requirements and shall present the same uniformity of finish, texture and density as other sections of the work. The edges of the course shall be rolled concurrently with or immediately after the longitudinal joint. In rolling the edges, roller wheels shall extend 50 to 100 mm beyond the edge.

**4.5 Opening to Traffic**

The newly laid surface shall not be open to traffic for at least 24 hrs after laying and completion of compaction, without the express approval of the Engineer in writing.

**4.6 Surface Finish and Quality Control of Work**

The surface finished of the completed construction shall conform to the requirements of Clause 1507 (12), (13), (15).

**4.7 Arrangements for Traffic**

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 102 Standard Specifications for Road and Bridge Works.

**4.8 Measurement for Payment**

Dense Graded Bituminous Materials shall be measured as finished work either in cubic metres, tons or by the square metre at a specified thickness as detailed on the Contract drawings, or documents, or as directed by the Engineer.

**5. Open-Graded Premix Surfacing (Premix Carpet)**

(Open-graded Premix Surfacing using Penetration Bitumen or Cutback.)

**5.1 Scope**

This work shall consist of the preparation, laying and compaction of an open-graded premix surfacing material of 20 mm thickness composed of small-sized aggregates premixed with a bituminous binder on a previously prepared base, in accordance with the requirements of these Specifications, to serve as a wearing course.

## 5.2 Materials

### 5.2.1 Binder

The binder shall be a penetration bitumen of a suitable grade as specified in the Contract, or as directed by the Engineer, and satisfying the requirements as per the Clause 6.01 Standard Specifications of Road and Bridge Works.

### 5.2.2 Aggregate

The coarse aggregates shall consist of crushed rock, crushed gravel or other hard material retained on the 2.36 mm sieve. They shall be clean, hard, and durable, of cubical shape, free from dust and soft or friable matter, organic or other deleterious matter. Where the Contractor's selected source of aggregates have poor affinity for bitumen, as a condition for the approval of that source, the bitumen shall be treated with approved anti-stripping agents, as per the manufacturer's recommendations, without additional payment. Before approval of the source, the aggregates shall be tested for stripping.

Physical requirements on aggregates are given in the table 5.

**Table 5. Physical Requirements for coarse aggregates for open graded premix surfaces**

| Propert | Test | Specification |
|---|---|---|
| Cleanliness | Grain size analysis | Max 5% passing 0.075mm sieve |
| Particle shape | Flakiness and elongation index (combined) | Max 30% |
| Strength | Los Angeles Abrasion value<br>Aggregate impact value | Max 40%<br>Max 30% |
| Durability | Soundness<br>Sodium Sulphate<br>Magnesium Sulphate | <br>Max 12%<br>Max 18% |
| Water Absorption | Water absorption | Max 2% |
| Stripping | Coating and stripping of bitumen aggregate mixtures | Minimum Retained Coating 95% |
| Water sensitivity | Retained tensile strength | Min 80% |

### 5.2.3 Proportioning of materials:

The materials shall be proportioned in accordance with Table 6.

## 5.3 Construction Operations:

### 5.3.1 Weather and seasonal limitations:

Laying shall be suspended while free standing water is present on the surface to be covered, or during rain, fog and dust storms. After rain, the bituminous surface, primer or tack coat, shall be blown off with a high pressure air jet to remove excess moisture, or the surface left to dry before laying shall start. Laying of bituminous mixtures shall not be carried out when the air temperature at the surface on which it is to be laid is below 10°C or when the wind speed at any temperature exceeds 40 km/h at 2m height unless specifically approved by the Engineer.

**Table 6. Quantities of materials required for 10 sq. m of road surface for 20 mm thick open graded premix carpet using penetration bitumen or cutback**

| | | | |
|---|---|---|---|
| Aggregates: | | | 0.18 cub. m |
| | (a) | Nominal stone size 13.2 mm passing 22.4 mm sieve and retained on 11.2 mm sieve | |
| | (b) | Nominal stone size 11.2 mm passing 13.2 mm sieve and retained on 5.6 mm sieve | 0.09 cub. m |
| | | Total | 0.27 cub. m |
| Binder: | | (Quantities in terms of straight run bitumen) | |
| | (a) | For 0.18 cub m of 13.2 mm nominal size stone at 52 kg bitumen per cub. m | 9.5 kg |
| | (b) | For 0.09 cub m of 11.2 mm nominal size stone at 56 kg bitumen per cub. m | 5.1 kg |
| | | Total | |

### 5.3.2 Preparation of surface:

The underlying surface on which the bituminous surfacing is to be laid shall be prepared, shaped and conditioned to the specified lines, grade and cross-section. The surface on which the bituminous work is to be laid shall be cleaned of all loose and extraneous matter by means of a mechanical broom or any other approved equipment/method as specified in the contract. The use of a high pressure air jet from a compressor to remove dust or loose matter shall be available full time on the site, unless otherwise specified in the Contract.

A prime coat where needed shall be applied in as per the Clause 1301 and 1302 Standard Specification of Road and Bridge Works.

**5.2.3 Tack coat**

A tack coat complying with Clause 1301 and 1302 Standard Specification for Road and Bridge Works shall be applied over the base preparatory to laying of the surfacing.

**5.2.4 Preparation of premix**

Hot mix plant (or Mechanical mixer) of appropriate capacity and type shall be used for the preparation of the mix material. The hot mix plant shall have separate drum arrangements for heating aggregates. The temperature of the binder at the time of mixing shall be in the range of 150°C to 163°C and that of the aggregate in the range of 155° C to 163°C provided that the difference in temperature between the binder and aggregate at no time exceeds 14°C. Mixing shall be thorough to ensure that a homogeneous mixture is obtained in which all particles of the aggregates are coated uniformly and the discharge temperature of mix shall be between 130°C and 160°C.

The mix shall be immediately transported from the mixer to the point of use in suitable vehicles or hand barrows. The vehicles employed for transport shall be clean and the mix being transported covered in transit if so directed by the Engineer.

**5.2.5 Spreading and rolling**

The prepared material shall be spread by suitable means to the desired thickness, grades and cross- fall (camber) making due allowance for any extra quantity required to fill up depressions, if any. The cross-fall should be checked by means of camber boards and longitudinal levels laid out. Excessive use of blades or rakes should be avoided. As soon as sufficient length of bituminous material has been laid, rolling shall commence with 8 - 10 tonne rollers, smooth wheel tandem type, or other approved equipment. Rolling shall begin at the edge and progress toward the centre longitudinally, except that on superelevated and uni-directional cambered portions, it shall progress from the lower to upper edge parallel to the centre line of the pavement. When the roller has passed over the whole area once, any high spots or depressions, which become apparent, shall be corrected by removing or adding premixed material. Rolling shall then be continued until the entire surface has been rolled and all the roller marks eliminated. In each pass of the roller the preceding track shall be overlapped uniformly by at least 1/3 width. The roller wheels shall be kept damp to prevent the premix from adhering to the wheels. In no case shall fuel/lubricating oil be used for this purpose.

Excess use of water for this purpose shall also be avoided. Rollers shall not stand on newly laid material. Rolling operations shall be completed in every respect before the temperature of the mix falls below 100° C.

#### 5.3.6 Seal coat

A seal coat conforming to Clause 1305 or 1306 Standard Specifications of Roads and Bridge Works of the type specified in the Contract shall be applied to the surface immediately after laying the surfacing.

### 5.4 Opening to Traffic

No traffic shall be allowed on the road until the seal coat has been laid. After the seal coat is laid, the road may be opened to traffic according to the type of seal coat and as directed by the Engineer.

### 5.5 Surface Finish and Quality Control of Work

The surface finished of the completed construction shall conform to the requirements of Clause 1007 (11), (12), (13).

### 5.6 Arrangements for Traffic

During the period of construction, arrangement of traffic shall be made in accordance with the provision of Clause 112 Standard Specifications for Road and Bridge Works.

### 5.7 Measurement for Payment

Open graded premix surfacing shall be measured as finished work, for the area instructed to be covered, in square meters. The area will be the net area covered, and all allowance for wastage and cutting of joints shall be deemed to be included in the rates.

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