GUIDELINES FOR THE DESIGN OF FLEXIBLE PAVEMENTS FOR LOW VOLUME RURAL ROADS

(First Revision)

Published by:

INDIAN ROADS CONGRESS

Kama Koti Marg,
Sector-6, R.K. Puram,
New Delhi-110 022

June, 2015

Price : ₹???
(Plus Packing & Postage)

First Published : June, 2007
First Revision : June, 2015

Printed by India Offset Press, Delhi- 110 064

1000 Copies

Contents

PERSONNEL OF THE HIGHWAYS SPECIFICATIONS AND STANDARDS COMMITTEE

(As on 12th January, 2015)

1.	Das, S.N. (Convenor)	Director General (Road Development) & Special Secretary to Govt. of India, Ministry of Road Transport & Highways, New Delhi.
2.	(Co-Convenor)	Addl. Director General, Ministry of Road Transport & Highways, New Delhi.
3.	Prasad, Vishnu Shankar (Member-Secretary)	Chief Engineer (R) S,R&T, Ministry of Road Transport & Highways, New Delhi.

Members

4.	Basu, S.B.	Chief Engineer (Retd.), MORTH, New Delhi
5.	Bongirwar, P.L.	Advisor, L & T, Mumbai
6.	Bose, Dr. Sunil	Head, FPC Divn. CRRI (Retd.), Faridabad
7.	Duhsaka, Vanlal	Chief Engineer, PWD (Highways), Aizwal (Mizoram)
8.	Gangopadhyay, Dr. S.	Director, Central Road Research Institute, New Delhi
9.	Gupta, D.P.	DG (RD) & AS (Retd.), MORTH, New Delhi
10.	Jain, R.K.	Chief Engineer (Retd.), Haryana PWD, Sonipat
11.	Jain, N.S.	Chief Engineer (Retd.), MORTH, New Delhi
12.	Jain, Dr. S.S.	Professor & Coordinator, Centre of Transportation Engg., Dept. of Civil Engg., IIT Roorkee, Roorkee
13.	Kadiyali, Dr. L.R.	Chief Executive, L.R. Kadiyali & Associates, New Delhi
14.	Kumar, Ashok	Chief Engineer (Retd.), MORTH, New Delhi
15.	Kurian, Jose	Chief Engineer, DTTDC Ltd., New Delhi
16.	Kumar, Mahesh	Engineer-in-Chief, Haryana PWD, Chandigarh
17.	Kumar, Satander	Ex-Scientist, CRRI, New Delhi
18.	Lal, Chaman	Director (Project-III), NRRDA (Ministry of Rural Development), New Delhi
19.	Manchanda, R.K.	Consultant, Intercontinental Consultants and Technocrats Pvt. Ltd., New Delhi
20.	Marwah, S.K.	Addl. Director General, (Retd.), MORTH, New Delhi
21.	Pandey, R.K.	Chief Engineer (Planning), MORTH, New Delhi

22.	Pateriya, Dr. I.K.	Director (Tech.), NRRDA, (Ministry of Rural Development), New Delhi
23.	Pradhan, B.C.	Chief Engineer (NH), PWD, Bhubaneswar
24.	Prasad, D.N.	Chief Engineer (NH), RCD, Patna
25.	Rao, P.J.	Consulting Engineer, Faridabad
26.	Raju, Dr. G.V.S.	Engineer-in-Chief (R&B), Rural Roads, Director Research and Consultancy, Hyderabad
27.	Representative of BRO	(Shri B.B. Lal), ADGBR, HQ DGBR, New Delhi
28.	Sarkar, Dr. P.K.	Professor, Deptt. of Transport Planning, School of Planning & Architecture, New Delhi
29.	Sharma, Arun Kumar	CEO (Highways), GMR Highways Limited, Bangalore
30.	Sharma, M.P.	Member (Technical), NHAI, New Delhi
31.	Sharma, S.C.	DG (RD) & AS (Retd.), MORTH, New Delhi
32.	Sinha, A.V.	DG (RD) & SS (Retd.), MORTH, New Delhi
33.	Singh, B.N.	Member (Projects), NHAI, New Delhi
34.	Singh, Nirmal Jit	DG (RD) & SS (Retd.), MORTH, New Delhi
35.	Vasava, S.B.	Chief Engineer & Addl. Secretary (Panchayat) Roads & Building Dept., Gandhinagar
36.	Yadav, Dr. V.K.	Addl. Director General (Retd.), DGBR, New Delhi
37.	The Chief Engineer (Mech.)	(Shri Kaushik Basu), MORTH, New Delhi

Corresponding Members

1.	Bhattacharya, C.C.	DG (RD) & AS (Retd.), MORTH, New Delhi
2.	Das, Dr. Animesh	Professor, IIT, Kanpur
3.	Justo, Dr. C.E.G.	Emeritus Fellow, 334, 14th Main, 25th Cross, Banashankari 2nd Stage, Bangalore
4.	Momin, S.S.	Former Secretary, PWD Maharashtra, Mumbai
5.	Pandey, Dr. B.B.	Advisor, IIT Kharagpur, Kharagpur

Ex-Officio Members

1.	President, Indian Roads Congress	(Bhowmik, Sunil), Engineer-in-Chief, PWD (R&B), Govt. of Tripura
2.	Honorary Treasurer, Indian Roads Congress	(Das, S.N.), Director General (Road Development), & Special Secretary to Govt. of India, Ministry of Road Transport & Highways
3.	Secretary General, Indian Roads Congress	Nahar, Sajjan Singh

GUIDELINES FOR THE DESIGN OF FLEXIBLE PAVEMENTS FOR LOW VOLUME RURAL ROADS

1 INTRODUCTION

1.1 This document is revision of the IRC:SP:72-2007 "Guidelines for the Design of Flexible Pavements for Low Volume Roads". The need for the revision arose to include design charts using stabilized base and sub – base courses as also to enable design of rural roads for traffic volume upto 2 MSA. Accordingly, a sub group consisting of Dr. I.K. Pateriya, Dr. Sudhakar Reddy, Dr. UC Sahoo and Shri S.C. Sharma was constituted to consider the proposed revision. This sub-group had several meetings and finalized the draft. The draft revised guidelines were deliberated before the Rural Roads Committee (H-5) in its meeting held on 16th December, 2014 and the modified draft was approved. Thereafter, the modified draft was placed before the Highways Specifications & Standard Committee (HSS) in its meeting held on 16th January, 2015. The HSS Committee approved the modified draft of revised guidelines which was then put up before the IRC Council in its meeting held on 20th January, 2015 at Bhubaneswar. Council authorized the convener of H-5 Committee for incorporating suggestions before publication of the revised guidelines as suggested by the Council.

1.1.1 The personnel of Rural Roads Committee (H-5) are as follows:-

Gupta, D.P.	--------	Convenor
Jain, N.S.	--------	Co-Convenor
Director (Projects-I), NRRDA (Solanki, N.C.)	--------	Member-Secretary

Members

Banerjee, A.K.	Kumar, Dr. Praveen
Bongirwar, P.L.	Kumar, Dr. Ashok
Dushaka, Vanlal	Parameswaran, Dr. (Mrs.) Lakshmy
Franco, Colin A.	Pateriya, Dr. I.K.
Goswami, Diganta	Raju, Dr. G.V.S.
Gupta, Mukesh C.	Sagne, A.A.
Gupta, S.K.	Sarkar, Prof. A.K.
Jain, Dr. M.C.	Satish, J.
Jain, Dr. P.K.	Sharma, S.C.
Kadiyali, Dr. L.R.	Singhvi, S.S.
Kalra, B.B.	Sun, M.M.
Kapaley, A.D.	Tongden, C.P.
Katare, P.K.	

1.2 Pre-requisites for suitable and Economical Designs

There are a number of important points to be considered while evolving suitable and economical designs for the low-volume rural roads in India. First and foremost is the aspect of practical implementability of the recommended designs within the available resources and level of expertise in rural areas, availability of equipment/plant for construction and maintenance as well as the level of quality control that can be effectively exercised in rural areas. To the extent possible, the use of locally available materials as such or after suitable processing has to be maximized in the larger interest of economy. The design life to be taken for purposes of pavement design should neither be too short to require expensive upgradation/rehabilitation at close intervals nor should it be so long as to require prohibitively high cost of initial construction. Ideally, maintenance considerations should be built into the design e.g. provision of adequate drainage, resistance to soil erosion along side slopes, adequate lateral support from shoulders etc. as would minimize subsequent maintenance requirements. Lastly, the designs should aim at providing the level of serviceability which should not fall below the minimum acceptable level during the design life, essentially amounting to evolving performance-based designs. All these important considerations and international experiences have to be kept in view while working out suitable and economical pavement designs for rural roads.

1.3 Earlier Design Approach (IRC:SP: 20-2002)

1.3.1 In the first edition of IRC:SP:20-2002, Rural Roads Manual (Ref. 1), the traffic parameter for pavement design is evaluated in terms of commercial vehicles per day, grouping together the heavy commercial vehicles like trucks, full-sized buses etc. with the much lighter commercial vehicles like tractors/tractor-trailers, pick-up vans, mini buses, tempos etc. The percentage of laden, unladen and overloaded commercial vehicles has not been considered in the traffic parameter.

1.3.2 The subgrade strength parameter is evaluated in terms of 4-day soaked CBR values except in areas with annual rainfall less than 500 mm and where the water table is 'too deep'.

1.3.3 A set of pavement design curves A, B, C and D for traffic categories 0-15, 15-45, 45-150 and 150-450 CVPD have been provided as also design catalogues with minimum base course thickness of 150 mm for Curves A and B and a minimum base course thickness of 225 mm for curves C and D. The sub-base course thicknesses have been arrived at by subtracting the minimum base course thickness from the total pavement thickness requirement, obtained from the pavement design curves.

1.3.4 In regard to the type of surfacing, all rural roads, except those (i) in an arid region with annual rainfall less than 500 mm and traffic upto 150 motorized vehicles per day (except two- wheelers) and (ii) in a region with annual rainfall less than 1000 mm and traffic upto 50 motorized vehicles per day (except two-wheelers) only, need to be provided with a bituminous surface treatment. The design of Unsealed Gravel Roads does not receive a separate treatment in IRC:SP:20-2002 (Ref 1). As a result, practically all rural roads being constructed in the country are black-topped.

1.4 Existing Design Approach (IRC:SP:72- 2007)

1.4.1 For purposes of pavement structural design in this Design Manual, the low volume rural roads are divided into the following categories:

Gravel/Aggregate-surfaced roads (Unpaved Roads);

Flexible Pavements (Paved Roads); and

Rigid Pavements

1.4.2 The international experiences, for the past several decades, with Gravel Roads notably in the USA (Ref 2) show that the 'maximum traffic level upto 100,000 Equivalent Standard Axle Load (ESAL) applications can be considered for Gravel Roads, while the practical minimum level (during a single performance period) is 10,000'. Below ESAL applications of 10,000, even Earth Roads are suitable.

Gravel is defined as a mix of stone, sand and fine-sized particles used as a sub-base, base or surfacing on a road, the material specifications for use in these layers being available in Clauses 401 and 402 of the MORD Specifications for Rural Roads. When the required gradation of gravel is not available in a natural form, the blending of naturally occurring materials in the required proportions may be resorted to.

1.4.3 For low volume rural roads, still carrying a sizable volume of truck and bus traffic, the maximum number of ESAL applications considered for flexible or rigid pavement is upto 1 million ESAL applications (Ref 2). The practical minimum traffic level for a flexible or rigid pavement is about 50,000 ESAL applications during a single performance period (Ref 2).

1.4.4 The pavement designs presented in the Manual for both, Gravel and Flexible Pavements (the rigid pavement designs are dealt with separately) are performance-based, drawing on the extensive experiences in the USA on Low Volume Road Design, as brought out in the AASHTO Guide for Design of Pavement Structures (Ref 2). The Serviceability rating system from 5 to 1 as per the PMGSY Operations Manual 2005 (in terms of Present Serviceability/Condition Index) (Ref. 3) has been adopted. For the low volume rural roads in India, a 'Terminal Serviceability Index' (i.e, the lowest index that will be tolerated before rehabilitation /strengthening or reconstruction becomes necessary) of 2.0 is considered suitable.

The thickness of gravel/aggregate-surface roads (unpaved roads) has been based on the following criteria:

(i) the serviceability loss over the design life is limited to 2.0, taking the initial serviceability index to be 4.0 just before opening the road to traffic, and the terminal serviceability of 2.0 when rehabilitation will be due, with or without provision of an overlay.

(ii) the allowable depth of rutting under 3 m straight edge does not generally exceed 50 mm.

The thickness of flexible pavements (paved roads) has been based on the Structural Number (SN) recommended by AASHTO for low volume roads for those of the US climatic zones which represent the climatic conditions of our country, for a 50% reliability level.

1.4.5 The design traffic parameter has been expressed in terms of the cumulative 80 kN (8.16 tonnes) ESAL applications during the design life. Seasonal variations by way of enhanced traffic during the harvesting seasons have also been considered.

1.4.6 For the evaluation of subgrade strength for new roads, the selection of moisture content has been dealt with scientifically instead of always insisting on 4-day soaked CBR values. For the rehabilitation or upgradation of existing rural roads, the use of Dynamic Cone Penetrometer (DCP) (mm/blow) has also been recommended for insitu subgrade strength evaluation.

1.5 Salient Features of Existing Designs

Some of the more important features of the existing designs are as under:

- Pavement designs for new roads as well as for the upgradation/rehabilitation of existing roads have been included.
- The recommended designs aim at maximizing the use of locally available materials including industrial waste (where possible)
- A simple procedure has been detailed for carrying out traffic counts, computing the ADT and the number of ESAL applications during the design life, selected as 10 years.
- Categorizing the subgrade strength in 5 classes and classifying the traffic into 7 ranges has simplified the presentation of design catalogues for both gravel roads and flexible pavements.
- The warrants for providing a bituminous surface treatment have been spelt out.
- The importance of monitoring the long-term performance of rural roads constructed with the recommended designs, by way of periodically carrying out condition, surveys cannot be overemphasized. Systematic condition

surveys should be carried out at regular intervals and data recorded on specified format.

1.6 Additions in Revised Guidelines (IRC:SP:72-2015)

1.6.1 Considering the growth of traffic on selected rural through routes and the modifications in IRC:37-2012 (with minimum traffic of 2 MSA for design), it has become necessary to include design charts for traffic more than 1 MSA and upto 2 MSA. Accordingly, two more traffic categories T8 and T9 have been included in the design catalogue.

1.6.2 The existing IRC:SP:72-2007 recommended a minimum thickness of 150 mm soil cement base and 100 mm soil cement sub-base for all rural roads. However, the design chart considering the strength of sub-grade and the design traffic was not available in these guidelines. The revised guidelines provide a design catalogue for cement stabilized base and sub-base courses on the basis of traffic and sub-grade strength.

1.6.3 It has been clearly brought out that all rural roads should be designed for a minimum sub-grade CBR of 5% (atleast fair).

1.6.4 Wherever stabilized base and sub-base courses are proposed to be used, the pavements shall be provided with a bituminous surface treatment.

1.7 Prerequisites for Successful Performance of Gravel Roads

All over the World, properly designed Gravel Roads have performed well, if due attention has been paid to the needed processing of gravels before use adequate drainage has been provided and timely maintenance measures have been taken. In several countries the unpaved road length is more than the paved road length. In India, however the unpaved road length constitutes less than half the total road length. While in most countries abroad, among the unpaved roads, it is the gravel roads, which are most popular, the unpaved roads in India are generally Water Bound Macadam Surfaced. Of late, with the World Bank assistance in some rural areas of India, Gravel Roads showing good performance even after about 5 years of service have developed the confidence of rural road engineers in the country. Indian Roads Congress has also brought out “Manual for Design, Construction and Maintenance of Gravel Roads”, IRC:SP:77-2008. Where conditions for Gravel Roads are however, not appropriate, other suitable pavement, composition can be adopted.

2 THE DESIGN PROCESS

For working out, suitable and economical pavement, designs for the low volume, rural roads, design procedures have been set forth for (a) new roads and for (b) upgradation/rehabilitation of existing roads. These procedures are outlined below:

2.1 New Roads

2.1.1 *Estimation of traffic:*

Where no road is existing at present, the estimation of the amount of traffic over the design life cannot be made directly on the basis of traffic counts. In such cases, it would be most expedient to carry out traffic counts on an existing road, preferably in the vicinity with similar conditions. Based on such traffic counts on an existing road catering to a known population and known amount of agricultural/industrial produce, the amount of traffic expected to ply on the new proposed road can be suitably worked out.

The detailed procedure for estimating design traffic is described in Para 3.

2.1.2 *Assessment of subgrade strength:*

It is necessary to scientifically carry out a soil survey and test the representative samples for standard IS classification tests, compaction tests and CBR. The depth of Ground Water Table (GWT) and its fluctuations, annual rainfall, and other environmental conditions that influence the subgrade strength must be investigated. During the soil survey, it must be ensured that even if the same soil type continues, atleast 3 samples must be collected per kilometre length, for simple soil classification tests based on particle size distribution and Atterberg limits. The entire length must be divided into uniform sections based on soil classification and Ground Water conditions. On each soil type, compaction and CBR tests shall be carried out to determine the strength of subgrade soil for design purposes. Normally, for each one kilometre length, atleast one CBR test value based on an average of 3 tests is required for each soil type.

A simple procedure for estimating CBR value of subgrade soil on the basis of soil properties is also suggested. The detailed procedure for assessing the CBR value for subgrade soil is described in Para 4.

2.1.3 *Determination of pavement thickness and composition:*

It is necessary to carry out a comprehensive field materials survey and the needed laboratory tests on representative samples to maximize the use of locally available materials (including industrial waste) for use in sub-base, base and surface courses as such or after suitable blending. Using the design traffic parameter and the subgrade strength parameter, the pavement thickness and composition can be determined from the Design Catalogue given in Para 8. The total thickness requirement and also the thickness of various layers have been arrived at, keeping in view the main objective of maximising the use of locally available materials. The soil can be improved by mechanical stabilization or by modification with a suitable additive like lime, lime-flyash/cement etc.

2.2 Upgradation/Rehabilitation of Existing Roads

2.2.1 *Traffic parameter:*

The amount of traffic expected to ply over the future design life of the existing road, can directly be based on actual traffic counts on the existing road. These traffic counts shall be carried out both during the lean non-harvesting season as also during the peak harvesting seasons. The cumulative traffic repetitions over the design life can be calculated considering the growth rate as per the potential in the area for generating traffic. The detailed procedure for estimating the design traffic is described in Para 3.

2.2.2 *Subgrade strength:*

For the upgradation/rehabilitation of an existing road, the subgrade strength will be determined by carrying out CBR test on a representative sample of sub grade soil remoulded to the field density and at the field moisture content, determined after the recession of monsoon. If, however, it is not found possible to determine the field moisture content immediately after the recession of monsoon, the subgrade strength shall be determined by the 4 days' soaked CBR test on a representative soil sample, compacted to field density in order to simulate the worst moisture condition.

Alternatively, the subgrade strength can be determined by carrying out DCP tests every 250 m in the subgrade at a distance of about 0.6 m to 1.0 m from the edge of the carriageway at the subgrade level in a staggered manner on each side of the carriageway. The salient details of a DCP test and a correlation with the CBR are given at Appendix C. In case the subgrade soil contains gravel or stone particles of size exceeding 20 mm, or if repeated DCP tests carried out in a stretch of one km give results varying by more than one-third of the average value, it is desirable to carry out soaked CBR test on remoulded soil specimens compacted at field dry density as per IRC guidelines.

2.2.3 *Overlay thickness requirement:*

The causes of poor condition of the pavement should first be determined from the data collected on the existing road. Many times, the poor performance is due to lack of proper drainage or lack of lateral support from the shoulders etc. In such cases, these deficiencies must be made up without resorting to any strengthening measures. If, however, from the design catalogues, it is found that the total pavement thickness requirement, determined from the existing subgrade strength and for the future growth of traffic during the design life, is more than the existing pavement thickness, then an overlay is to be provided. Considering design CBR of the sub grade soil and projected traffic at the end of design life, total thickness required should be calculated, using design catalogue given in **Figs. 4 or 6** (in case of stabilized base and sub base courses). In general the existing pavement layers are maintained unless the subgrade is made of black cotton soil or the existing pavement material deteriorated extensively due to excessive clay in the existing pavement layer. The thickness of the overlay is worked out as difference of total required thickness minus existing available thickness. For upgradation and strengthening, decision should be based on the cost economics and expected performance during design life, subjected to the following provisions:

(a) for traffic up to T_5 category : The additional WBM layers to be provided shall not exceed 150 mm comprising of two layers of WBM

(b) for traffic more than T_5 category and up to T_7 category (2 MSA) : The additional WBM layers to be provided shall not exceed 225 mm comprising of three layers of WBM.

(c) Where the subgrade soil is black cotton and the existing pavement, layers have been deteriorated due to existing clay present in the structure, the condition of the pavement shall be examined thoroughly and where it has been ascertained that the pavement shall be reconstructed as a new pavement efforts should be made to utilize the dismantled material obtained from existing pavement, to the extent possible subject to meeting the specifications. In such cases the subgrade may also be strengthened using any of the methods of stabilization or by replacement of poor subgrade soil. The pavement shall be designed on the basis of improved CBR as per catalogue.

(d) The specifications and properties of the material to be used in overlay should not be lower than that of the existing top layer. It should also be ensured that a soft layer is not sandwiched between two hard layers.

3 TRAFFIC PARAMETER

3.1. Composition of Rural Traffic

3.1.1 It is not only the traffic volume but also its composition that plays an important role in determining the pavement thickness and composition (Ref. 6,11&17). There is a wide variety of vehicles plying on rural roads, half or even more of the total number being non-motorized, mostly bicycles and animal drawn carts. Among the motorized vehicles, the two-wheeled motor cycles constitute a sizable proportion followed by tractors/tractor-trailers, jugads, pick-up vans, jeeps and cars. Heavy Commercial Vehicles (HCV) like full-sized trucks and buses are relatively very few in number, their proportion out of the total may be as low as 5%, sometimes even lower. The number of Medium-heavy Commercial Vehicles (MCV) like tractor-trailers and medium-sized trucks is generally much higher than the number of HCV. The number of animal drawn carts is on the decline. The number of tractors/tractor-trailers is gradually on the increase, while the number of motor cycles is increasing rapidly.

3.1.2 For purposes of pavement design, the large number of bicycles, motor cycles and pneumatic-tyred animal drawn carts are of little consequence and only the motorized commercial vehicles of gross laden weight of 3 tonnes and above (i.e. HCV and MCV) are to be considered.

3.2 Traffic Growth Rate

Some of the simple methods for estimating the traffic growth rates are given below:

3.2.1 *Trend analysis*

The past trend of growth is analysed and the rate established by fitting a relationship of the type $T_n = T_0 (I + r)"$ where n is the number of years, T_0 is the traffic in zero year, T_n is the traffic in the n^{th} year and r is the rate of growth in decimals. The future rate of growth can be fixed equal to or higher than the past rate depending on socio-economic considerations and future growth potential of the region where the road is located. Local enquiries in this regard are often very useful.

3.2.2 *Econometric Model*

The traffic growth rate can also be estimated by establishing econometric models, as per the procedure outlined in IRC:108 "Guidelines for Traffic Prediction on Rural Highways".

3.2.3 *Recommended Growth Rate*

In the absence of any specific information available to the designer, it is recommended that an average annual growth rate of 6% over the design life may be adopted.

3.3 Design Life

While selecting the design life of a pavement it must be borne in mind that at the end of the design life, the pavement will not have to be reconstructed all over again. It only means that at the end of the design life, it will only need to be strengthened, so that it can continue to carry traffic satisfactorily for a further specified period. It is necessary to carry out proper condition surveys atleast once a year, so that the nature and rate of change of condition will help identify as to when the pavement will require strengthening. A design life of 10 years is recommended for purposes of pavement design for gravel roads (with periodic re-gravelling) and for flexible pavements. This design life period of 10 years has been recommended to ensure that neither the strengthening will need to be carried out too soon nor will the design for a very long design period be unduly expensive by way of high initial investment required.

The aspect of stage construction is specially relevant to the very low volume roads (design traffic less than 0.1 MSA) which are initially designed and constructed as all-weather gravel roads. After monitoring their performance and the growth in volume and composition of traffic over 5 years or so, can be suitably strengthened and black-topped where necessary. Suitably postponing the metalling and black-topping of gravel roads can go a long way in connecting more of the unconnected habitations within the same investment.

The aspect of possible upgradation of a rural road to a higher category road at a future date must be kept in view, especially ensuring proper compaction of subgrade which serves as the very foundation of a pavement.

3.4 Computation of Design Traffic

3.4.1 *For Upgradation of Existing Road*

(i) Traffic census should be conducted over a period of atleast 3 days, both during the peak harvesting season and also during the lean season for various vehicle types, both motorised as well as non-motorised; the number of laden, unladen and overloaded commercial vehicles also to be recorded during the traffic counts. Generally, there are two or more harvesting seasons with intervening lean season. Traffic census will be carried out during one of the harvesting seasons and also during the lean season. The average duration of each harvesting season and likely change in the peak traffic during other harvesting seasons than the one during which the census has been taken shall be ascertained from local enquiries and suitably considered in estimation of traffic. In case any information regarding change in peak traffic during other harvesting seasons could not be ascertained through local enquiries, the traffic could be assumed to be the same as the traffic data collected during the harvesting season.

(ii) Average Daily Traffic (ADT) for 24 hours should be computed for each vehicle type, both during the peak-harvesting season and also during the lean season. Knowing the duration of harvesting season, (see **Fig. 1**, showing seasonal fluctuations in ADT) the total traffic during the year can be computed and consequently the Average Annual Daily Traffic (AADT) can be computed for each vehicle type.

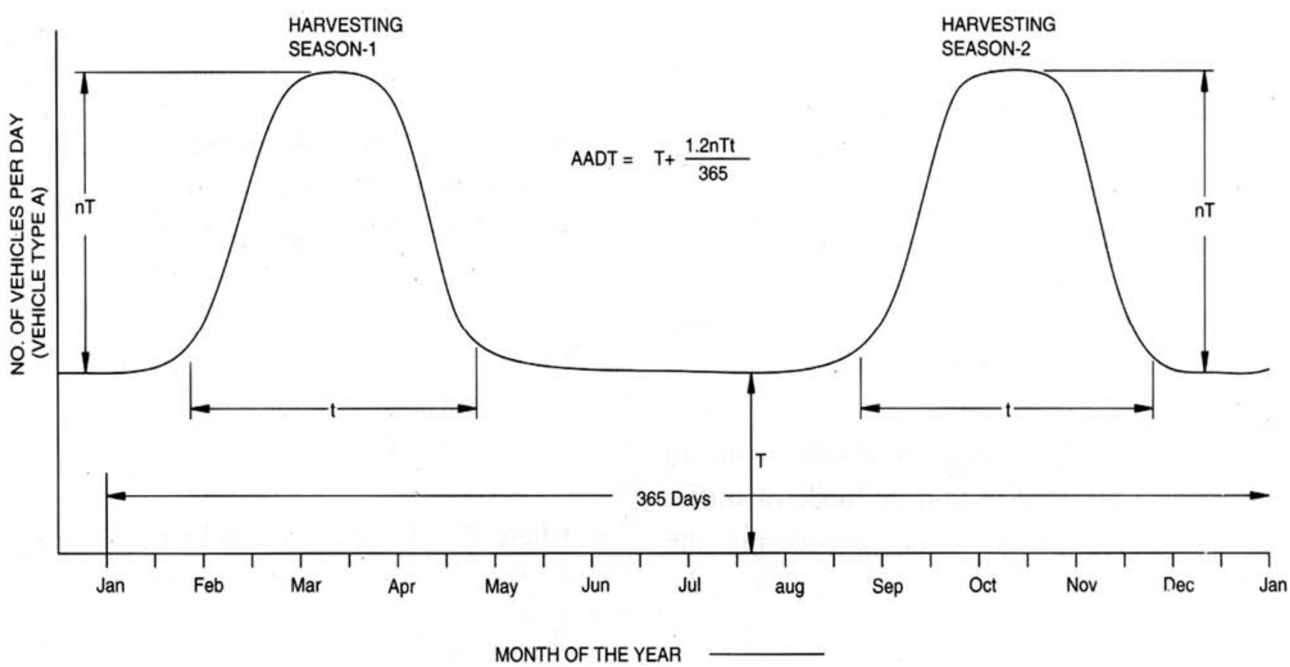


Fig. 1 Seasonal Variations in Rural Traffic

Although the number and duration of harvesting seasons can vary from one region to the other, typically two harvesting seasons during the course of a year are shown in Fig. 1. If T is the average number of commercial vehicles of a given category, plying per day during the lean season, the enhanced traffic during the peak season can be denoted by nT, over and above the lean season traffic T, the value of n varying widely from one region to the other. Typically, it takes about 40% of the duration of a harvesting season (t) to build up the traffic from lean-season level T to the peak. The peak traffic may continue for about 20% of the duration of harvesting period before coming down to the lean-season traffic level over a period of time, again about 40% of the total duration of the harvesting season. With these assumptions, the total number of repetitions (N) of a given vehicle type during the course of a year is given by:

$$N = T \times 365 + 2nT [0.6t]$$

Average Annual Daily Traffic (AADT)

$$\frac{1.2nTt}{365}$$

(iii) It should generally be possible to capture the peak traffic from the actual traffic from the actual traffic count taken during the harvesting season. Thus, if the duration of harvesting season, the peak traffic and the duration of peak traffic are known, the average additional traffic during harvesting season can be estimated on the basis of information collected during the traffic survey. Local enquiries are often useful in estimating average additional traffic during harvesting season.

(iv) In case of all roads where the projected traffic for 10 years design life is likely to be 1MSA and above, it should be mandatory to get the traffic survey carried out through a third party.

3.4.2 *New road*

In case of a new road, an approximate estimate should be made of traffic that would ply on the road considering the number of villages and their population along the road alignment and other socio-economic parameters. Traffic counts can be carried out on an existing road in the vicinity with similar conditions and knowing the population served as well as agricultural/industrial produce to be transported, the expected traffic on the new proposed road can be estimated. In general, new roads for providing connectivity to single habitations of smaller populations (below 500) should be designed for traffic category below T_3,

Likely traffic on the proposed road can also be estimated on the basis of O-D survey along the nearby existing roads which presently serve the villages proposed to be connected.

Due consideration should be given to the 'Diverted' and 'Generated' traffic anticipated as a consequence of the development of the proposed road, land use of the area served, the probable growth of traffic and the design life.

3.4.3 *Determination of ESAL applications*

For purpose of Pavement Design, only commercial vehicles with a gross laden weight of 3 tonnes or more along with their axle loading are considered. These may include inter alia the following:

Trucks (Heavy Medium)

Buses

Tractor-Trailers

The traffic parameter is generally evaluated in terms of a Standard Axle Load of 80 kN and the cumulative repetitions of the Equivalent Standard Axle Load (ESAL) are calculated over the design life.

Rural vehicles with single axle loads different from 80 kN, and tandem axle loads different from 148 kN can be converted into standard axles using the Axle Equivalency Factor.

$$\text{Axle Equivalency Factor} = \left(\frac{W}{Ws}\right)^4$$

where W = Single axle load (in kN) of the rural vehicle in question

Ws = Standard Axle Load of 80 kN or 148 kN in case of tandem axles.

The Equivalency Factors for converting to the Standard Axle Load of 80 kN (8.16 t) and Tandem Axle load of 148 kN (14.968 t) are given below.

Equivalency Factors for Different Axle Loads

Axle Load		**Load Equivalency Factors**	
(Tonnes)	kN	Single Axle	Tandem Axle
3.0	29.4	0.02	0.01
4.0	39.2	0.06	0.01
5.0	49.1	0.14	0.02
6.0	58.8	0.29	0.03
7.0	68.7	0.54	0.05
8.0	78.5	0.92	0.08
8.16	80.0	1.00	0.09
9.0	88.3	1.48	0.13
10.0	98.1	2.25	0.2
10.2	100.0	2.46	0.21
11.0	107.9	3.30	0.29
12.0	117.7	4.70	0.4
13.0	127.5	6.40	0.56
14.0	137.3	8.66	0.75
15.0	147.1	1l.42	0.98
16.0	157	-	1.27
17.0	166.8	-	1.62
18.0	176.6	-	2.03
19.0	186.4	-	2.52
20.0	196.2	-	3.09

The design traffic is considered in terms of cumulative number of Standard Axles to be carried during the design life of the road.

For single-lane and intermediate-lane roads, the design shall be based on the total number of commercial vehicles per day in both directions. For double-lane roads, the design should be based on 75% of the total number of vehicles in both directions.

3.4.4 *Vehicle damage factor*

The Vehicle Damage Factor (VDF) is a multiplier for converting the number of commercial vehicles of different axle loads to the number of standard axle load repetitions. It is defined as "equivalent number of standard axles per commercial vehicle". While the VDF value is arrived at from axle load surveys on the existing roads, the project size and traffic volume in the case of rural roads may not warrant conducting an axle load survey. It may be adequate to adopt indicative VDF values discussed below for the purpose of pavement design.

For calculating the VDF, the following categories of vehicles may be considered: -

i) Laden Heavy Commercial Vehicles (HCV)

Fully loaded HCV (comprising heavy trucks, full-sized buses) have a Rear Axle Load of 10.2 tonnes and a Front Axle Load, about half the Rear Axle Load i.e. 5 tonnes. The VDF works out to 2.58 (=2.44 + 0.14).

ii) Unladen/Partially Loaded Heavy Commercial Vehicles

Since the extent of loading of commercial vehicles is difficult to determine, a Rear Axle Load of 6 tonnes and a front axle load of 3 tonnes may be assumed for an Unladen/Partially Loaded HCY. The VDF works out to 0.31 (= 0.29 + 0.02)

iii) Overloaded Heavy Commercial Vehicles

The extent of overloading may vary widely from one situation to the other. However, if an overload of 20% is there, the VDF goes up to 5.35 (=5.06+0.29). However, if only 10% of the laden HCV are overloaded to the extent of 20% the VDF works out to 2.86 (= 0.9 x 2.58 + 0.1 x 5.35).

iv) Laden Medium-heavy Commercial Vehicles (MCV)

Fully loaded MCV (mostly comprising Tractor-Trailers) have a Rear Axle Load of 6 tonnes and a Front Axle Load of 3 tonnes. The VDF works out to 0.31 (= 0.29 + 0.02)

v) Unladen/Partially Loaded Medium-heavy Commercial Vehicles

Since the extent of loading of commercial vehicles is difficult to determine, a Rear Axle Load of 3 tonnes and a Front Axle Load of 1.5 tonnes may be assumed. The VDF works out to 0.019 (= 0.018 + 0.001).

vi) Overloaded Medium-heavy Commercial Vehicles

The extent of overloading may vary widely from one situation to the other. However, if an overload of 20% is there, the VDF goes upto 0.65 (= 0.61 + 0.04). If only 10% of the laden MCV are overloaded to the extent of 20%, the VDF = 0.344 (= 0.1 x 0.65 + 0.9 x 0.31).

Towards the computation of ESAL applications, the indicative VDF values (i.e. Standard Axles per Commercial Vehicle) are given below:

Vehicle Type	Laden	Unladen/Partially Laden
HCV	2.86	0.31
MCV	0.34	0.02

For pavement design, the number of:

(i) HCV : laden, unladen and overloaded

(ii) MCV : laden, unladen and overloaded must be obtained from actual traffic counts and, using appropriate VDF values, the number of Equivalent Standard Axles to be catered over the design life are worked out. If, however for some reason, it is not possible to carry out all the required traffic counts, recourse to local enquiries may be taken to estimate their proportions in as realistic a manner as possible

Assuming a uniform traffic growth rate r of 6% over the design life (n) of 10 years, the cumulative ESAL applications (N) over the design life can be computed using the following formula:-

$$N = T_0 \text{ x } 365 \text{ x } \left[\frac{(1+0.01r)^n - 1}{0.01r}\right] \times L$$

$$N = T_0 \text{ x } 365 \text{ x } \left[\frac{(1+0.06)^{10} - 1}{0.06}\right] \times L$$

$$= T_0 \text{ x } 4811 \text{ x } L$$

where, T_0 = ESAL per day = number of commercial vehicles per day in the year of opening x VDF

and L = lane distribution factor; L = 1 (One) for single lane/intermediate lane

and L = 0.75 for two-lane roads

3.4.5 In case the proportion of HCV and MCV in the traffic stream could not be ascertained, particularly for new roads, a reasonable estimate of design traffic in terms of cumulative standard axles can be obtained from Appendix A. This is based on typical vehicle composition observed on low volume roads

3.5 Traffic Categories:

For pavement design, the traffic has been categorized into nine categories (T_1 to T_9) as under:

Traffic Category	Cumulative ESAL Applications
T_1	10,000-30,000
T_2	> 30,000-60,000
T_3	> 60,000- 100,000
T_4	> 100,000-200,000
T_5	> 200,000-300,000
T_6	> 300,000-600,000
T_7	> 600,000-1,000,000
T_8	> 1,000,000- 1,500,000
T_9	> 1,500,000- 2,000,000

4 SUBGRADE STRENGTH EVALUATION

4.1 The Subgrade

4.1.1 **Definition:** As per MORD Specifications for Rural Roads (Ref 14), subgrade can be defined as a compacted layer, generally of naturally occurring local soil, assumed to be 300 mm in thickness (for low volume roads) just beneath the pavement crust, and is made up of in-situ material, select soil or stabilized soil that forms the foundation of the pavement, providing a suitable foundation for the pavement. The subgrade in embankment is compacted in two layers, usually to a higher standard than the lower part of the embankment. It should be well compacted to limit the scope of rutting in pavement due to additional densification during the service life of pavement. In cuttings, the cut formation, which serves as the subgrade, is treated similarly to provide a suitable foundation for the pavement. Where the naturally occurring local subgrade soils have poor engineering properties and low strength in terms of CBR, for example in Black Cotton soil areas, improved subgrades are provided by way of lime/cement treatment or by mechanical stabilization and other similar techniques, as explained in Paras 4.2.2 and 4.3.

4.1.2 The subgrade, whether in cutting or in embankment, should be well compacted to utilize its full strength and to economize on the overall pavement thickness. The current MORD Specifications for Rural Roads require that the subgrade should be compacted to 100% Maximum Dry Density achieved by the Standard Proctor Test (IS 2720-Part 7). The material used for subgrade construction should have a dry unit weight of not less than 16.5 kN/m^3.

4.1.3 *Soil surveys*

It is necessary that a soil survey along and around the road alignment is carried out following the laid down-procedures and that the results of all field and laboratory investigations are made available to the designer. During the soil surveys, the depth and fluctuations of GWT must be recorded. All the representative samples of subgrade soils must be subjected to the simple classification tests (wet sieve analysis, liquid and plastic limits) and the soil group shown against each representative sample, ensuring that at least 3 samples are taken per kilometre length even if the same soil type continues.

For each of the soil groups thus identified, atleast one CBR test should be conducted with the soil compacted to the Standard Proctor density and at a moisture content corresponding to the wettest state considered appropriate to the site conditions.

4.2 Subgrade Strength

4.2.1 *Design for new roads*

4.2.1.1 Subgrade CBR value

For the pavement design of new roads, the subgrade strength needs to be evaluated in terms of CBR value.

The CBR of the subgrade can be estimated by any of the following methods:

(i) Based on soil classification tests and using Table 1 (Ref 4) which gives typical presumptive design CBR values for soil samples compacted to Proctor density at optimum moisture content and soaked under water for 4 days.

(ii) Using two sets of equations, based on classification test data, one for plastic soils and the other for non-plastic soils **(Appendix B),** for estimating soaked CBR values on samples compacted to Proctor density (Ref 18)

(iii) By conducting actual CBR tests in the laboratory.

The CBR tests should be conducted on representative samples of subgrade soil compacted by static compaction to 100% Standard Proctor dry density and tested at a moisture content corresponding to the wettest moisture condition likely to occur in the subgrade during its service life. An average of test values obtained from a set of 3 specimens should be reported. If high variations are observed in the test values from the set of 3 specimens, then an average of test values obtained from 6 specimens should be taken.

The methods (i), (ii) and (iii) above, come in handy where adequate testing facilities are not available or the project is of such a size as not to warrant elaborate testing procedures. Where actual CBR test results for a particular soil type show considerable variation, the methods (i), (ii) and (iii) above provide a useful guide in estimating the most appropriate soaked CBR value for the soil.

Subgrde Classification	Estimating Subgrade Moisture Content
I. Where the GWT is close enough to the ground surface to influence the subgrade moisture content. In non-plastic soils, GWT will influence the subgrade moisture content, if it rises to within 1 m of the road surface; in clays of low plasticity (PI<20), if GWT rises within 3 m of the road surface and in heavy clays (PI>40), if GWT rises within 7 m of the road surface. This category also includes coastal areas and flood plains where the GWT is maintained by the sea, by a lake or by a river, besides areas where GWT is maintained by rainfall	1. The most direct method is to measure the moisture content in subgrades below existing pavements in similar situations at the time of the year when the GWT is at its highest level. 2. The subgrade moisture content for different soil types can be estimated by using the ratio $\frac{\text{Subgrade Moisture Contents}}{\text{Plastic Limit}}$ which is about the same when GWT and climatic conditions are similar. 3. Where such measurements are not possible, the subgrade strength may be determined in terms of 4-day soaked CBR value
II Subgrades with deep GWT but where seasonal rainfall brings about significant changes in moisture conditions under the road	1. The subgrade moisture condition will depend on the balance between the water entering the subgrade through pavement edges/shoulders during rains and the moisture leaving the ground during dry periods. The design moisture content can be taken as optimum moisture content obtained from Proctor Compaction Test IS 2720 (Part 7) corresponding to maximum dry density or from the nomograph given in **Fig. 2**, whichever is higher. 2. The possibility of local perched GWT and effects of seasonal flooding should, however, also be considered while deciding on WT depth. Where such situations are encountered, the. subgrade strength may be determined in terms or 4-day soaked CBR value.

For determining the CBR value in the laboratory, the standard test procedure laid down in IS 2720 (Part 16) must be adopted.

4.2.1.2 Selection of moisture content for subgrade strength evaluation: The subgrade moisture conditions can be classified as under (Ref 5).

Table 1 Typical Presumptive Design CBR Values

Description of Subgrade Soil	IS Soil Classification	Typical Soaked CBR Value (%)
Highly Plastic Clays and Silts	CH, MH	* 2-3
Silty Clays and Sandy Clays	ML, MI CL, CI	4-5
Clayey Sands and Silty Sands	SC, SM	6-10

* Expansive clays like BC Soil may have a soaked CBR of less than 2%.

• A simple Free Swelling Index test (IS 2720-Part 40) should be determined on expansive clays.

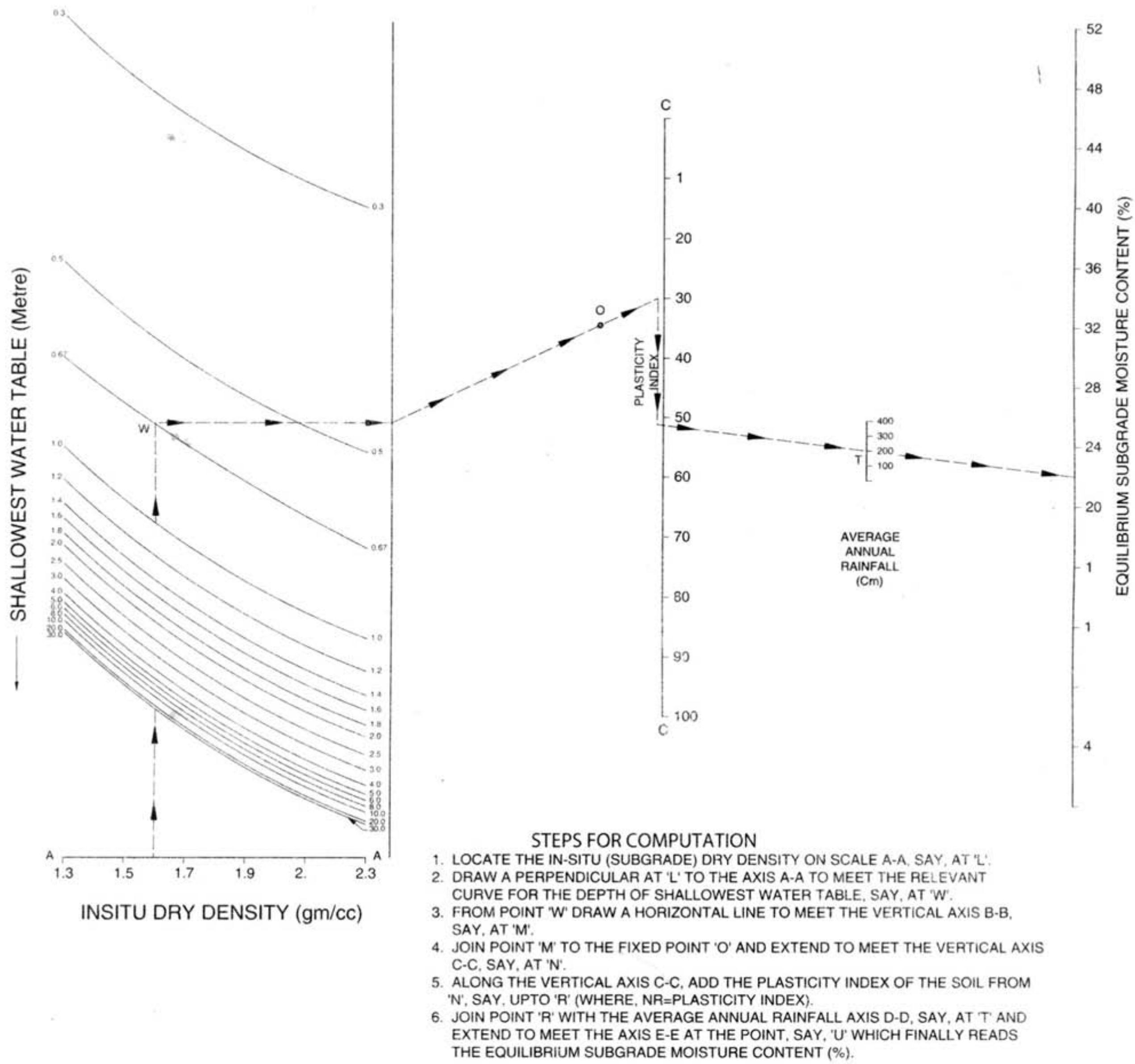


Fig. 2 Nomograph for the Computation of Equilibruim Subrade Moisture Content

4.2.2 *Expansive soil subgrade*

Expansive soils/ Black Cotton soils are basically montmorillonitic clays which display a tendency to swell or heave during the process of wetting and to shrink when dry, as evidenced by shrinkage cracks. When subjected to seasonal wetting and drying, a road built on an expansive soil subgrade will cause unevenness of the pavement surface. In order to prevent such an unsatisfactory performance of the road, the following precautions should be taken:-

Compact the expansive soils at relatively low dry density and at high moisture content, since expansive soils compacted to high density at low moisture content will undergo higher volumetric changes. Therefore, an expansive soil should be compacted to 95% Standard Proctor compaction at a moisture content 1 to 2% higher than the optimum.

It is good practice to provide the pavement crust on an improved non-expansive soil, adequately compacted, 0.6 m to 1.0 m in thickness and the pavement designed for the CBR of improved subgrade. However, where such a non-expansive buffer layer does not work out to be economical, a blanket course of coarse/medium sand or non-plastic moorum (PI<5) or lime-treated black cotton soil subbase can be provided, extending over the entire formation width, together with measures for efficient drainage.

4.2.3 *Upgradation/rehabilitation of existing roads:*

The insitu subgrade strength of an existing road will be determined in terms of CBR value obtained on representative subgrade soil samples remoulded to the insitu density at the field equilibrium moisture content, observed after the recession of the rainy season (**Fig. 3**). If, for some reason, it is not found possible to determine the field moisture content immediately after the recession of monsoon, the 4 days' soaked CBR value of the re-moulded subgrade soil samples, compacted to field density, may be determined. When the alternative of carrying out DCP tests is adopted, salient details are provided in the modified Appendix C, which relates to strength of the subgrade in terms of CBR at insitu moisture and density.

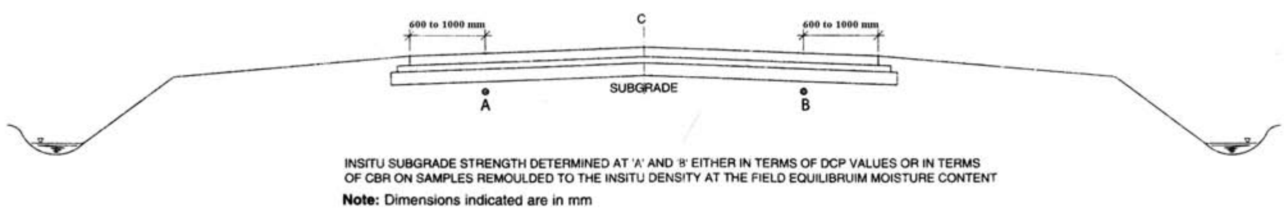


Fig. 3. Subgrade Strength Determination for Upgradation/Rehabilition of an Existing Road

4.3 Subgrade Strength Classes

The strength of subgrade for design of new roads shall not be less than the values specified below.

(a) The strength of subgrade for design shall not be less than 5% (atleast fair), even when the traffic volumes are low. In case the CBR of the subgrade soil is less than 5%, the subgrade should be stabilized to achieve a minimum design CBR of 5%, i.e. the quality of sub-grade for design purposes should be atleast fair. In order to use the Design Catalogue (Para 8), the subgrade strength is divided into the following classes:

Quality of	Class Subgrade	Range (CBR%)
Very Poor	S_l	2
Poor	S_2	3 - 4
Fair	S_3	5 - 6
Good	S_4	7 - 9
Very Good	S_s	10 - 15

Where the CBR of subgrade soil is 2 or less, the economic feasibility of replacing 300 mm subgrade with suitable soil needs to be explored and, if found feasible, the pavement should then be designed based on the CBR value of the improved subgrade. The option of replacement of sub-grade soil should be considered only when it is cheaper than the stabilization.

5 PAVEMENT COMPOSITION AND MAXIMISING USE OF LOCALLY AVAILABLE MATERIALS

5.1 Pavement Composition

5.1.1 *Sub-base course*

For granular sub-base, the materials generally used are natural sand, moorum, gravel, crushed stone, crushed slag, brick metal, kankar or combination thereof depending upon the grading required as per Clause 401 of the MORD Specifications for Rural Roads (Ref 14). For silty clays and clayey soils including Black-Cotton soils, a lime treated sub base may be provided as per Clause 403 of the MORD Specifications for Rural Roads (Ref 14), taking care that the lime shall have purity of not less than 70% by weight of quicklime (CaO) when tested in accordance with IS 1514. Where the lime of different calcium oxide content is to be used, its quantity should be suitably adjusted so that equivalent calcium oxide content is incorporated in the work. For soils which do not respond to lime treatment and where comparatively higher and faster development of strength and durability characteristics are needed, especially for water logged and high rainfall areas, cement treated subbase course can be provided, as per Clause 404 of the MORD Specifications for Rural Roads (Ref 14). The cement content for a cement treated subbase should be determined by mix design, yielding a 7-day unconfined compressive strength of not less than 1.7 MPa. From practical considerations, the thickness of subbase, where provided, shall not be less than 100 mm.

5.1.2 *Base course*

For rural roads designed for cumulative ESAL repetitions more than 1,00,000, unbound granular bases which comprise conventional Water Bound Macadam (WBM), Wet Mix Macadam (WMM) or Crusher Run Macadam Base are adopted as per Clauses 405, 406 and 411 of the MORD Specifications for Rural Roads (Ref 14). Where hard stone metal is not available within economical leads, a cement stabilized base can be provided as per Clause 404 of the MORD Specifications for Rural Roads (Ref 14).

For rural roads designed for cumulative ESAL repetitions less than 1,00,000, a Gravel base is recommended, except for a very poor subgrade strength (CBR=2) under the Traffic Categories of 30,000 to 60,000; and 60,000 to 100,000 ESAL applications and for poor subgrade strength (CBR=3 to 4) under the Traffic Category of 60,000 to 100,000 ESAL applications as shown in Fig. 4. The various grading, plasticity and other requirements for a Gravel base are detailed in Clause 402 of the MORD Specifications for Rural Roads (Ref 14).

5.1.3 *Surfacing*

For rural roads designed for cumulative ESAL repetitions, over 100,000, a bituminous surface treatment of 2-coat surface dressing or 20 mm premix carpet is recommended, as per MORD Specifications for Rural Roads (Ref 14). However, for rural roads designed for ESAL applications less than 100,000, a non-bituminous gravel surfacing is recommended as per Clause 402 of the MORD Specifications, except for the very poor subgrade strength (CBR=2) under traffic categories T_2 and T_3 and for the poor subgrade strength (CBR= 3 to 4) under Traffic Category T_2 only, where a bituminous surface treatment has been recommended, as shown in **Fig. 4**.

5.2 Maximizing Use of Locally Available Materials

5.2.1. *A variety of locally available materials can be used which may be grouped under the* following categories:

(i) Selected granular soil for use in subgrade.

(ii) Mechanical stabilization, stabilization with lime, cement, lime and flyash, as appropriate.

(iii) Naturally occurring softer aggregate like moorum, kankar, gravel etc.

(iv) Brick and overburnt brick metal.

(v) Stone metal

(vi) Industrial Wastes

Maximizing the use of locally available materials, suitable and economical designs can be worked out and the most suitable and economical design adopted.

5.2.2 Some of the important points in the use of these materials are discussed in subsequent paragraphs.

5.2.2.1 *Selected Granular soil:*

Well-graded soils with low plasticity have better engineering properties and should be reserved for use as the improved subgrade portion. Such soils can be identified by their high Proctor density and low PI values. The sampling and testing of borrow material shall be as per Clause 1803.2 of the MORD Specifications for Rural Roads, 2014.

5.2.2.2 *Stabilization of local soils*

A variety of techniques are available for stabilizing local soils for improving their engineering properties, but not all the techniques are applicable to all types of soils. A brief description of the stabilization mechanism and applicability of the individual techniques are given in Table 2 (Clause 408, Ref 14). This may be referred to for choosing the most appropriate technique for stabilizing the soil at site. The mix proportions are generally worked out in the laboratory based on soaked CBR.

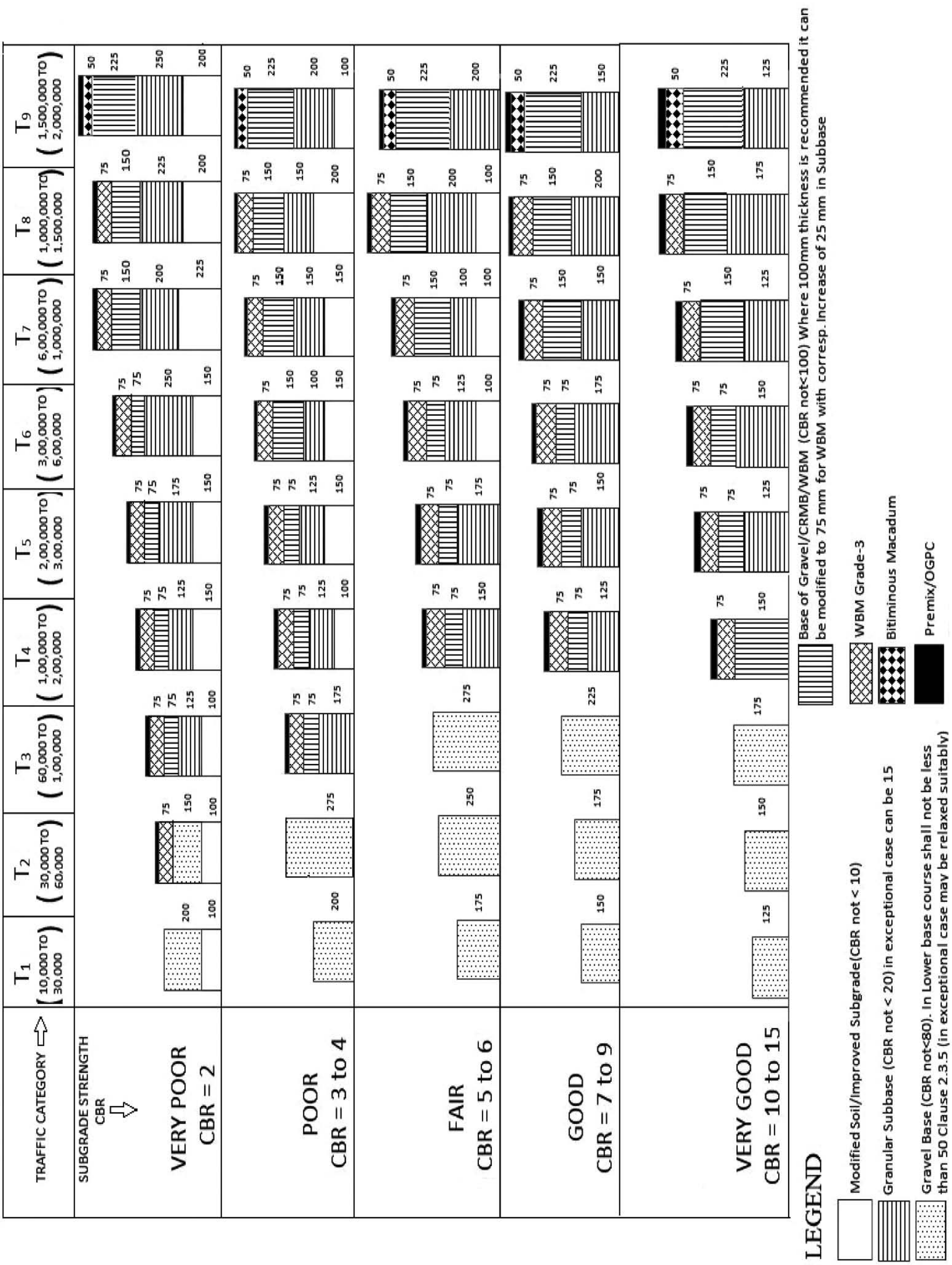


Fig. 4 Pavement Design Catalogues for Gravel/Granular Bases and Sub-bases

5.2.2.3 *Naturally occurring marginal aggregates*

Marginal aggregates like brick ballast, laterite, kankar, moorum, dhandla, etc. where available within economic leads, should be made use of in pavement construction to the maximum extent feasible. The material may occur in graded form or as discrete blocks or admixtured with soil. The manner of using these is indicated in Table 3 (Clause 408, Ref 14).

5.2.2.4 *Brick soling*

In alluvial plains where hard stone aggregate are normally not available within economical leads, the general specification adopted for sub-base and base courses is to provide brick soling. Either flat bricks or bricks on edge can be used depending on the thickness requirements. In case of flat bricks, two layers are desirable. The bricks should be of good quality and well burnt. Before laying, it is generally desirable to provide a cushion of sand above the earth subgrade.

5.2.2.5 *Water bound macadam*

Water bound macadam (WBM) is one of the most common specification adopted for construction of subbase, base and surfacing courses. Broken stone, overburnt brick metal, laterite, or kankar can be used as the coarse aggregate for WBM. For details of the WBM technique, reference may be made to Clause 405 of the MORD Specifications for Rural Roads (Ref 14).

Table 2 Mechanism and Requirement of Soil Stabilization Techniques (Ref.14)

S. No.	Technique	Mechanism	Application
1	2	3	4
1.	Mechanical Stabilization	Blending missing fractions (eg. clay with sand and sand with clay) so as to produce a mass of maximum possible density with plasticity within limits. A smooth grading similar to that given by Fuller's grading rule ** is adopted to work out the proportion of the missing fractions to be blended.	Sands, moorum/gravel having missing fractions and clayey soils can be stabilized by this technique.
2.	Lime Stabilization	Lime in hydrated form reacts with the clay minerals in the soil to cause (i) immediate reduction in plasticity and increase in CBR because of cationic exchange, flocculation and agglomeration which may be reversible under certain conditions, and (ii) long term chemical reaction with the clay minerals to produce cementitious products which bind the soil for increased strength and stability.	Medium and heavy clays having a PI of at least 10 and containing at least 15% of materials finer than 425 micron are suitable. However, some soils though containing clay fractions may not produce the long-term chemical reaction because of the presence of organic matter (>2%), or soluble sulphate/carbonate (>0.2%), etc. For lime stabilization to be successful, it will be desirable to test the soil for lime reactivity. A soil whose 7 -day unconfined compression strength increases by at least 3 Kg/cm^2 with lime treatment can be considered lime reactive.

S. No.	Technique	Mechanism	Application
1	2	3	4
3.	Cement Stabilization	The hydrated products of cement bind the soil particles, the strength developed depending on the concentration of cement and the intimacy with which the soil particles are mixed with cement. A high cement content of the order of 7-10% can produce a hard mass having a 7-day compressive strength of 20 kg/cm^2 or more, and this usually goes by the term soil-cement. However, a smaller proportion of 2-3% cement can improve the CBR value to more than 25, and the material goes by the term "cement-modified soil", which can be advantageously used as sub -base/base for rural roads.	Generally, granular soils free of high concentration of organic matter not greater than 2%, or deleterious salts (sulphate and carbonate not greater than 0.2%) are suitable. A useful rule for soil selection is that the plasticity modulus (product of PI and fraction passing 425 micron sieve) should be less than 250 and that the uniformity coefficient should be greater than 5.
4.	Lime Flyash Stabilization	Lime chemically reacts with the silica and alumina in flyash to form cementitious compounds which binds the soil.	Soils of medium plasticity (PI -5-20) and clayey soils not reactive to lime can be stabilized with lime and flyash.
5.	Bitumen Stabilization	Bitumen binds the soil particles	Clean graded sands can be stabilized by this technique.
6.	Two-stage Stabilization	This generally applies to heavy clays. The clay is treated with lime in the first stage to reduce plasticity and to facilitate pulverization. In the second stage, the resulting soil is stabilized with cement, bitumen, lime or lime -flyash.	Heavy clays with PI > 30

** Fuller's grading rule is given by :

$$\text{Per cent passing sieve} = 100 \times \left[\frac{\text{aperture size of sieve}}{\text{size of the largest particle}}\right]^{\frac{1}{2}}$$

Table 3 Manner of using Soft Aggregates in Pavement Construction (Ref. 14)

S. No.	State of Occurrence of Material	Manner of using in Pavement Construction	Test/Quality Requirement
1.	In block or large discrete particles	As water bound macadam without screenings/filler in accordance with IRC:19, after breaking the material into required sizes.	Wet aggregate impact value (IS:5640) not to exceed 50, 40 and 30 when used in sub -base, base and surfacing respectively.
2.	Graded form without appreciable amount of oil	Directly as a granular layer for sub -base/base or surfacing	PI should be 4-10 when used as surfacing and should not exceed 6 when used in lower courses. Evaluated for strength by soaked CBR.
3.	As discrete particles mixed with appreciable amount of soil such as soil -gravel mixtures	Directly as soil-gravel mix for sub -base, base or surfacing	The material should be well graded and the PI restricted as for SI. No.2. Evaluated by soaked CBR.

6 PAVEMENT DESIGN OF GRAVEL/SOIL-AGGREGATE ROADS

6.1 General

6.1.1 Gravel/Soil-Aggregate is a mix of stone, sand and fine-sized particles used as a subbase, base or surfacing on a road. The gradation and plasticity requirements for use in subbase, base and surfacing are given in Clauses 401 and 402 of the MORD Specifications for Rural Roads (Ref 14). The required properties of road gravels may or may not be available in naturally occurring gravels. The aggregate gradation can be obtained by crushing, screening and blending process as may be necessary. Fine aggregate, passing IS Sieve 4.75 mm consists of natural or crushed sand and fine mineral particles. The physical requirements of aggregates are given in Clause 402 of the MORD Specifications for Rural Roads (Ref. 14). The Indian Roads Congress has also brought out separately manual for Design, Construction and Maintenance of Gravel Roads (Ref. 20)

6.1.2 For gravel (aggregate-surfaced) roads, when the subgrade CBR is above 2, the traffic level considered is upto 60,000 repetitions of 80 kN ESAL. However, where the subgrade CBR is above 5, a gravel/aggregate-surfaced road can take upto 1,00,000 ESAL applications during the design life (Ref 2).

6.1.3 It is to be recognized that Gravel/Aggregate-surfaced roads can serve low volume traffic adequately for many years, provided they are well-maintained, by regularly replenishing lost gravel and periodic regravelling. These roads are relatively much easier to maintain compared to black-topped roads, involving a much lower level of resources, skills and equipment. Essentially, the maintenance measures are aimed at repairing or reducing the damage caused by the combined effects of weather and traffic and to provide the desired level of serviceability, by performing the following maintenance tasks:

(a) Grading to restore a good cross-profile to enable water to be drained off and torestore gravel from the shoulders to fill up potholes and corrugations. Tractor-towed grading equipment can be used or even labour-based reshaping can be resorted to.

(b) Dragging, to correct minor defects on the road surface, using a tractor-towed drag.

(c) Patching of potholes can be carried out by manual methods.

(d) Regravelling, by adding new gravel, before surface starts deteriorating rapidly, using only agricultural tractors and manual labour. Regravelling may be justified periodically say every 3 to 5 years, depending on traffic and climatic conditions.

(e) Dust control by using surface gravel with relatively higher percentage of fines as per Clause 402 of MORD Specifications. In arid and semi-arid areas, it may be necessary to periodically spread natural clay or to spray hygroscopic products like low cost chlorides of calcium, magnesium or sodium. Thin bituminous surface treatment as dust pallaiative may also be considered where dust control by the above-suggested methods IS not practicable or effective.

6.2 Design Chart

The gravel base thickness required for the five subgrade strength classes (S_1, S_2, S_3, S_4, and S_5) and for the traffic categories of cumulative ESAL repetitions 10,000-30,000 (T_1); 30,000-60,000 (T_2) and 60,000-100,000 (T_3) are shown in **Fig. 4**. A chart to convert a portion of the Aggregate Base Layer thickness to an equivalent thickness of subbase (Ref 2) with an intermediate CBR value between the base and subgrade is shown in **Fig. 5**. and **Table 4**. It must, however, be ensured that a minimum 100 mm thickness of gravel base is always provided. Besides grading requirements specified for gravel base and surfacing (Ref 14), the minimum soaked CBR of 80 for the gravel base material is often considered an additional requirement. In case, gravel base material of above specifications is not available, one layer of WBM grade –III of 75 mm thickness may be proposed at the top and the balance 25 mm thickness should be added in the thickness of granular sub-base.

Table 4 To Convert Portion of the Aggregate Base Thickness to an Equivalent Thickness of Subbase with Minimum Base Thickness 100 mm

Design Base Thickness (mm)	Base Thickness Provided (mm)	Thickness of Subbase (mm)					
		CBR - 15%	CBR - 20%	CBR - 25%	CBR - 30%	CBR - 40%	CBR - 50%
150	100	100	100	100	100	75	75
175	100	150	150	150	150	125	125
200	100	200	200	175	175	150	150
225	100	250	250	225	225	200	200
250	100	300	275	250	250	225	225
275	100	350	325	300	300	275	275

6.3 Surface Gravel

The thicknesses provided in the Design Catalogue (**Fig. 4**) are the Gravel base thicknesses and the base gravel conforms to Clause 402, Table 400.2 of the MORD Specifications for Rural Roads. This material may not form a durable crust to keep the material bound together on a Gravel Road and is difficult to maintain. It is, therefore, recommended that the gravel base shall be covered with the surface gravel material conforming to Table 400.3, Clause 402 of the MORD Specifications for Rural Roads. The thickness of the surface layer will generally vary from 40 to 50 mm depending on the traffic and quality of material. This thickness of the surface gravel is in addition to the gravel base thickness calculated from design as this is for protecting the gravel base and may require re-gravelling.

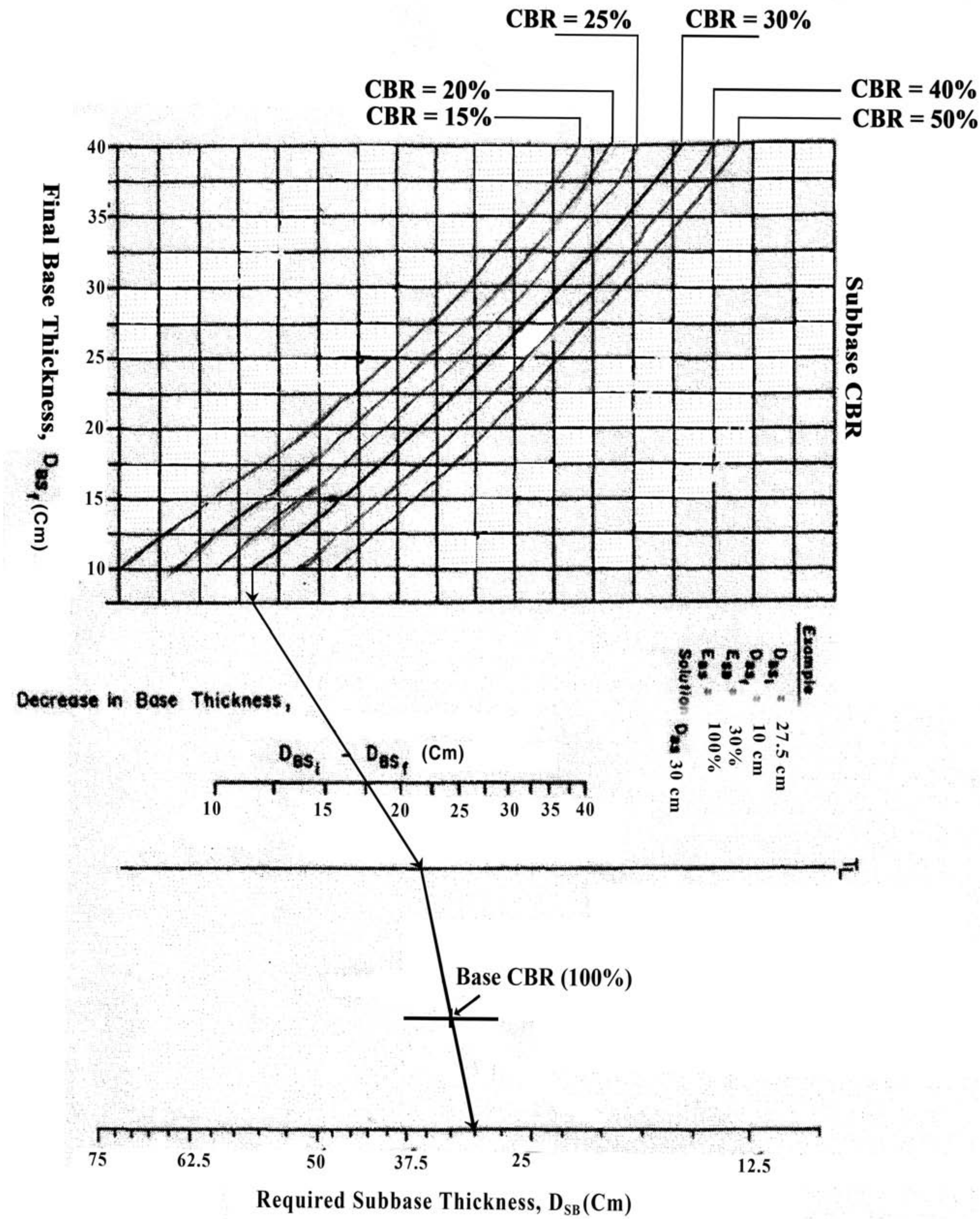


Fig. 5 Chart to Convert a Portion of the Gravel/Soil - Aggregate Base Layer Thickness to an Equivalent Thickness of Subbase (Ref. 2)

7 DESIGN OF FLEXIBLE PAVEMENT FOR TRAFFIC OVER 100,000 CUMULATIVE ESAL REPETITIONS

7.1 Subbase Materials

7.1.1. *Granular sub-base*

Granular sub-base materials conforming to Clause 401 of the MORD Specifications for Rural Roads (Ref 14) are recommended for use. These specifications suggest three gradings and specify that the materials passing 425 micron sieve should have liquid limit and plasticity index as indicated below

Climate	Liquid Limit	Plasticity Index	Remarks
Areas having annual rainfall more than 1000 mm	<35	<10	Design traffic upto 1 million standard axles (MSA)
Areas having annual rainfall less than 1000 mm	<40	<15	Design traffic upto 1 MSA
All areas irrespective of rainfall	<25	<6	Design traffic more than 1 MSA

The soaked CBR value should not be less than 20. In case the subbase material of the requisite soaked CBR value is not available within economical leads, the subbase material meeting any of the prescribed gradings and other requirements with a soaked CBR value of not less than 15 can be permitted with the approval of the competent authority.

7.1.2 *Stabilized soil sub-base*

For silty clays and clayey soils, including Black Cotton soils, treatment with lime offers an appropriate and cost effective technique which may be in the form of modification by way of reducing the PI or in the form of a stabilization technique for attaining the needed strength as per Clause 403 (Ref 14). For soils which do not respond to lime treatment and where comparatively higher and faster development of strength and durability characteristics are needed, especially for water logged and high rainfall areas, soil stabilization with cement is most appropriate. For cement treated soil subbase courses, the relevant specifications are contained in Clause 404 (Ref 14). The cement content for a cement treated subbase should be determined by mix design, yielding a 7-day unconfined compressive strength of not less than 1.7 MPa. From practical considerations, the thickness of subbase, where provided, shall not be less than 100 mm.

7.1.3 *Use of marginal aggregates/industrial wastes*

While the use of Marginal Aggregates has been covered in Para 5.2.2.3, the material characterization of industrial wastes must be carried out as per Clause 410 of the MORD Specifications for Rural Roads (Ref 14). Soils of medium plasticity (PI 5-20) and clayey soils not reactive to lime alone can be stabilized with lime and flyash as per Clause 409 (Ref 14).

Similarly slags from Iron and Steel industries meeting the requirements as per Clause 410 (Ref 14) can also be used in subbase courses.

7.1.4 *The thickness of subbase where provided shall not be less than 100 mm.*

7.2 Base Course Materials

7.2.1 Gravel base material

For traffic upto 1,00,000 ESAL applications, gravel/soil-aggregate meeting the requirements laid down in Clause 402 (Ref 14) of the MORD Specifications for Rural Roads is found to be both suitable and economical.

It may be pointed out that for the successful performance of a non-bitumenised gravel road surface, a gravel surfacing material meeting the requirements laid down in Clause 402 (Ref 14) for gravel surfacing materials must be provided.

For higher traffic ranges, over 1,00,000 ESAL repetitions, higher types of base materials involving the use of crushed stone material or soil-cement will be needed, and the road surface black-topped.

7.2.2 *Macadam base course*

Conventionally, the WBM base courses have been used in India even for the low volume rural roads. However, the cost of WBM becomes uneconomical in areas where hard stone has to be carted from long distances, sometimes as much as 300 km; in such cases, the possibility of using a soil-cement base course must be explored. WBM must be laid as per the specifications laid down in Clause 405 (Ref 14), taking special care to see that the screenings and binding material meet the required engineering properties and are used in the specified quantities. Improved crushed stone base courses by way of Wet Mix Macadam and Crusher Run Macadam can be used, following the specifications laid down in Clauses 406 and 411 (Ref 14) respectively.

7.2.3 *Soil-cement base*

Where hard stone has to be carted from long uneconomical leads, the use of soil-cement often offers an appropriate option. The soil-cement mix should be designed to attain a minimum laboratory 7-day unconfined compressive strength of 3 MPa. Special consideration must be given to pulverization of soil clods to the specified requirements and thorough mixing as laid down in Clause 404 (Ref 14). For clayey soils, pre-treatment with lime may be needed before stabilization with cement.

7.2.4 The Thickness of base shall be as per pavement design catalogue for soil cement bases but should not be less than 100 mm.

7.3. Bituminous Surfacing

7.3.1. *The need*

Bituminous surfacing is a relatively expensive item, and its use should be made judiciously. Even when used, the specification will not generally be higher than one/two-coat surface dressing provided as per Clause 505 (Ref 14) or 20 mm thick open-graded premix carpet as per Clause 506 (Ref 14). A thin bituminous surfacing serves the following purposes.

- Improves the riding quality
- Seals the surface, thus preventing the entry of water which would otherwise weaken the pavement structure.
- Protects the granular base from the damaging effects of traffic

7.3.2 *Warrants for bituminous surfacing*

Pneumatic-tyred fast moving vehicles like the commercial rural vehicles damage unprotected granular bases and create dust nuisance. Also, the operating costs of such vehicles is highly influenced by the smoothness of the road pavement. Bituminous surfacing will be advantageous where subgrade is poor (CBR less than 4), the design traffic exceeds 60,000 ESAL applications, and annual rainfall generally exceeds 1000 mm. Broad guidelines for providing a bituminous surface treatment over a well-drained gravel road surface, considering the above influencing factors viz. (i) Subgrade strength, (ii) traffic volume and (iii) annual rainfall in the area are given in **Table 5**.

Table 5 Guidelines for Providing a Bituminous Surface Treatment

Annual Rainfall	**Type of Surfacing**			
	Traffic Category			
	T_1 (ADT < 100)	T_2 (ADT = 100 - 150)	T_3 (ADT = 150 - 200)	T_4 (ADT > 200)
Over 1500 mm/year	Gravel	BT	BT	BT
1000-1500 mm/year	Gravel	Gravel	BT	BT
Less than 1000 mm/year	Gravel	Gravel	Gravel	BT

Recommended surfacings are shown in the Design Catalogues (**Fig. 4**).

As part of the stage development strategy, it is often desirable to postpone the provision of a bituminous surface treatment for the first few years of its service life during which the pavement may undergo any undulations and the entire pavement system, including the drainage system, gets stabilized.

7.3.3 *Type of bituminous surfacing*

For the low volume rural roads, when a bituminous surfacing needs to be provided, two alternatives viz, Surface Dressing and 20 mm Premix Carpet are generally available. The recently revised and vastly improved IRC specifications for Surface Dressing adopt the concept of Average Least Dimension (ALD) of stone chips and take into account, the factors of traffic, type of existing surface, climate and type of chipping. A standardised chart (Ref 19) is used for the determination of design binder content and chipping application rate. The adoption of the revised IRC specifications make Surface Dressing both suitable and economical for low traffic volume conditions, as borne out by its popularity in several countries abroad. In all cases of traffic categories T_1 to T_4, surface dressing should be preferred as bituminous surfacing. However, 20 mm Premix Carpet can be used as an alternative to Surface Dressing for traffic categories T_5 to T_9. Further, in all cases of stabilized base and sub-base courses it is recommended that bituminous surface treatment as surface dressing or premix carpet be provided using polymer modified bitumen or cold mix technology.

8 RECOMMENDED PAVEMENT DESIGNS

The recommended flexible pavement designs for low-volume rural roads with granular sub bases and bases are given in **Fig. 4**. A chart to convert portion of the gravel/soil aggregate base layer thickness to an equivalent thickness of sub-base is given in **Fig. 5** and **Table 5**. Design charts using stabilized sub bases and bases are given in **Fig. 6** The salient features of the design catalogues are as under:

(i) There are five subgrade strength classes S_1, S_2, S_3, S_4, & S_5 covering a range of CBR values from 2 to 15, for each of which, the pavement thickness and composition requirements are given under different traffic categories in terms of ESAL applications

(ii) The traffic parameter has been categorized into 9 categories as under:

- T_1 10,000 to 30,000 ESAL applications
- T_2 > 30,000 to 60,000 ESAL applications
- T_3 > 60,000 to 1,00,000 ESAL applications
- T_4 > 1,00,000 to 2,00,000 ESAL applications
- T_5 > 2,00,000 to 3,00,000 ESAL applications
- T_6 > 3,00,000 to 6,00,000 ESAL applications
- T_7 > 6,00,000 to 10,00,000 ESAL applications
- T_8 > 10,00,000 to 15,00,000 ESAL applications (1 MSA to 1.5 MSA)
- T_9 > 15,00,000 to 20,00,000 ESAL applications (1.5 MSA to 2 MSA)

(iii) Based on long-term performance of gravel roads for low-volume rural traffic in a large number of countries, developed and developing, gravel roads perform satisfactorily up to about 60,000 ESAL applications during the design life of 10 years for any subgrade CBR above 2 (Ref. 2). If, however, the subgrade

CBR is above 5, Gravel roads can perform satisfactorily upto about 1,00,000 ESAL applications, during the design life of 10 years, (Ref. 2) as shown in **Fig. 4**.

(iv) Black-Topped Flexible pavements need to be designed for a minimum ADT of 200 or design traffic of 1,00,000 ESAL applications, during the design life of 10 years.

(v) A minimum 150 mm thick base course should be provided in the flexible pavement designs for ESAL applications from 1,00,000 to 10,00,000.

(vi) Design catalogue for using stabilized soil sub-bases and soil cement bases is given in Fig. 6, indicating minimum required thicknesses.

(vii) The recommended thicknesses in flexible pavement designs are generally multiples of 75 mm or 100 mm as required by practical considerations in the implementation of these designs.

(viii) All the recommended designs are amenable to further strengthening at a future date.

(ix) For flexible pavement designs with a design traffic over 20,00,000 ESAL applications, IRC:37-2012 may be referred to. However, thick bituminous layers may not be warranted and could be substituted by granular construction.

(x) In areas susceptible to frost action, all black-topped flexible pavements in the Design Catalogue (**Figs. 4 and 6**), need to be provided with a minimum pavement thickness of 450 mm (300 mm sub-base + 150 mm base), even when the CBR value of the subgrade warrants a smaller thickness.

(xi) The Gravel base thickness requirements for Gravel Roads as given in the Design Catalogue (**Fig. 4**) need to be increased in areas susceptible to frost action (Ref 2), as under:

Cumulative ESAL Applications

Subgrade Class	**T_1 (10,000-30,000)**	**T_2 (30,001-60,000)**	**T_3 (60,001-1,00,000)**
S_1(CBR = 2)	250 mm	Flexible Pavement	Flexible Pavement
S_2(CBR = 3 to 4)	225 mm	"	"
S_3(CBR = 5 to 6)	200 mm	325 mm	425 mm
S_4(CBR = 7 to 9)	175 mm	300 mm	400 mm
S_5(CBR = 10 to 15)	150 mm	275 mm	375 mrn

A pavement design problem illustrating the use of recommended pavement design catalogue is given in Appendix D.

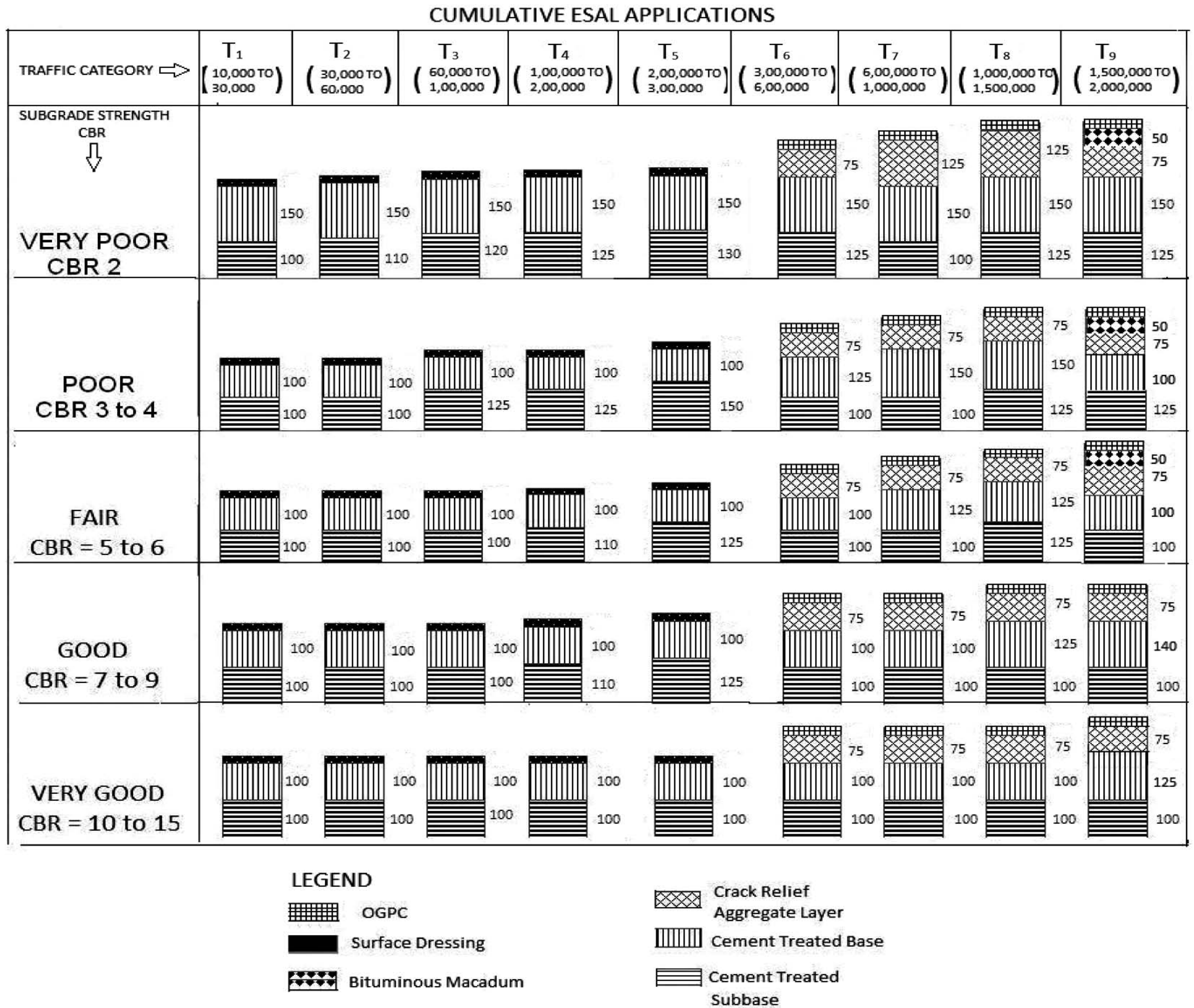


Fig. 6 Pavement Design Catalogues for Cement Treated Bases and Sub-Bases

9 DRAINAGE AND SHOULDERS

9.1 Drainage Design

It must be recognized that a scientifically worked out drainage design is a vital part of the design of pavement system as a whole. The pavement design recommended in this Manual is based on the assumption that (i) proper cross-slopes are provided over the carriageway and roadside shoulders to shed off the rainwater quickly (ii) top of the subgrade/improved subgrade is raised sufficiently, preferably not less than 300 mm above the GL and not less than 600 mm above the highest GWT. (iii) adequately designed roadside ditches/drains are provided, and (iv) all cross-drainage structures are provided as per requirements.

Besides the drainage requirements as above, it is also necessary to provide drainage of pavement layers especially where the sub grade is of relatively low permeability e.g. a clay subgrade. While no separate drainage layer is considered necessary for rural roads, it is necessary that atleast half the subbase layer thickness, subject to a minimum of 100 mm should be extended across the shoulders. However, this being a costly affair should be used selectively only in the those cases where the subgrade is clayey and the shoulders are also made up of earthern material with very poor drainage characteristics. In the sub-base material, the percent passing 75 micron sieve must not exceed 5%. Typical cross-section showing drainage of layers is shown in **Fig. 7**.

9.2 Shoulders

For the successful performance of a rural road pavement, it is necessary that adequate lateral support be provided by roadside shoulders. These are all the more important when the pavement materials are unbound in nature. The shoulder material should be selected using the same principles as for gravel roads or a subbase to carry construction traffic. The shoulder material should normally be of subbase quality compacted to a thickness of 100 mm. Where the anticipated traffic on the shoulders is high e.g high percentage of animal-drawn carts, gravelled shoulders need to be provided over 1m width from the edge of the carriageway as per MORD Specifications for Rural Roads Clause 407. It is advisable if atleast the outer edge of shoulder is grassed with an appropriate species to prevent erosion. Where shoulders are not gravelled, and the traffic volume is very low, it is advantageous to grass the whole of the shoulder.

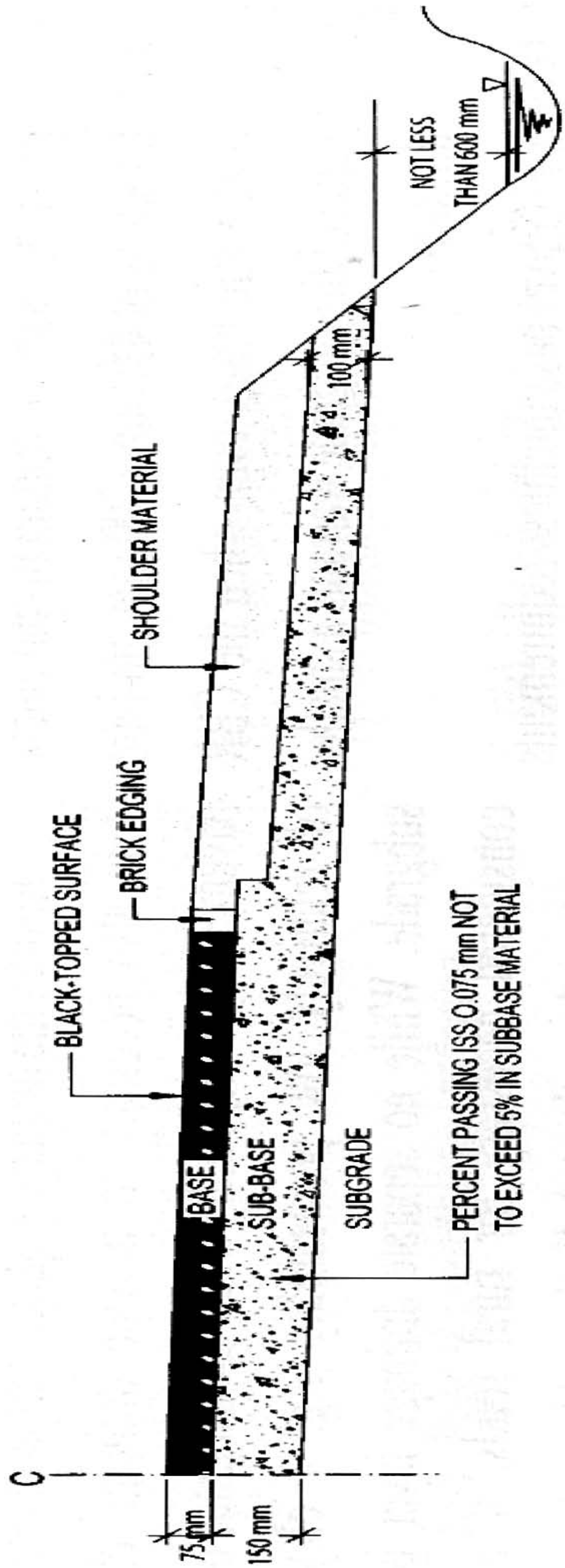


Fig. 7 Extended Sub-base

REFERENCES

l. IRC:SP:20-2002 Rural Roads Manual

2. AASHTO Guide for Design of Pavement Structures, AASHTO, 1993

3. PMGSY Operations Manual, National Rural Road Development Agency, February 2005.

4. Unsealed Roads Manual, Guidelines to Good Practice, Australian Road Research Board, 1993

5. Overseas Road Note 31, Overseas Centre, TRL, UK, 1993

6. Document on Rural Road Development in India Vol. II, CRRI, 1990

7. Report of the Committee on Norms for Maintenance of Roads in India, MOST, 2000

8. Gravel Roads, Maintenance and Design Manual, Federal Highway Administration, 2000

9. Low Cost Road Surface (LCS) Project, Intech Associates, 2002

10. Road Design Manual, Republic of Kenya, (Part III), 1987

11. Economic Design of Low-Traffic Roads, OECD,1987

12. Sharma S.C et al 'Application of Neural Networks to Estimate AADT on Low-Volume Roads, Journal of Transportation Engineering, Vol. 127 No.5, ASCE, September/October 2001

13. IRC:SP:26-1984 Report Containing Recommendations of IRC Regional Workshops on Rural Road Development, Indian Roads Congress, New Delhi, 1984.

14. MORD Specifications for Rural Roads, Indian Roads Congress, New Delhi, 2014 (First Revision).

15. IRC:37-1984 Guidelines for the Design of Flexible Pavements (First Revision), Indian Roads Congress, 1984.

16. IRC:37-2001 Guidelines for the Design of Flexible Pavements (Second Revision), Indian Roads Congress, 2001.

17. Study of Social and Economic Impact of Rural Roads, Diversified Agriculture Support Project, U.P, Final Report, L.R. Kadiyali & Associates, New Delhi, 2004.

18. Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures-Final Report Part 4-Low Volume Roads, prepared for NCHRP, Transportation Research Board, USA, March 2004.

19. Manual for Construction and Supervision of Bituminous Works of MoRT&H, published by Indian Roads Congress, 2001.

20. IRC:SP:77-2008, Manual for Design, Construction and Maintenance of Gravel Roads, Indian Roads Congress 2008.

21. IS:2720 (Part XVI) Methods of test for soils. (Part XVI) Laboratory Determination of CBR. - 1987

APPENDIX A

Cumulative ESAL Applications for 10-year Design Life

ADT*	CVPD	Break-up of Commercial Vehicles		Cumulative ESAL Applications
		HCV	MCV	
100	25	0	25	19,380
150	35	5	30	60,969
200	50	10	40	96,482
300	75	15	60	1,49,952
400	100	20	80	1,92,961
500	125	25	100	2,57,225
1000	300	60	240	6,63,120

* Includes both motorized and non-motorized vehicles

Assumptions

1. A commercial vehicle (CV) is defined as a vehicle of gross laden weight of 3 tonnes or more. For purposes of pavement design, the commercial vehicles comprise of the following categories:
    - Heavy Commercial Vehicles (HCV) comprising heavy trucks and full-sized buses.
    - Medium-heavy Commercial Vehicles (MCV) comprising Tractor-trailers/ Jugads, Mini buses, Pick-up Vans.
2. Since the extent of loading of a commercial vehicle is different to determine, the Single Axle Loads (Rear Axle) of laden and unlades (including partially loaded) vehicles in the HCV category can be assumed as 10.2 tonnes and 5 tonnes respectively. For the MCV, the Single Axle Loads (Rear Axle) of a laden and unladen (including partially loaded) vehicles can be assumed as 6 tonnes and 3 tonnes respectively. The Light Vehicles (LV) even when fully laden will have a gross laden weight of less than 3 tonnes and hence need not be considered for pavement design.
3. Amongst the commercial vehicles per day (CVPD), the HCV vary from 0 to 20% of CVPD while MCV constitute over 80% of CVPD.
4. Ten (10) percent of CVPD are overloaded to the extent of 20% of the maximum permissible load.
5. For traffic up to ADT = 100, it is assumed that no HCV ply on the road i.e.,HCV = 0.
6. Laden and Unladen Vehicles under each category are equal in number.

APPENDIX B

QUICK ESTIMATION OF CBR (REF. 18)

Plastic Soil

CBR	=	75/(+0.728 WPI), $R^2 = 0.67$
where WPI	=	Weighted Plasticity Index = $P_{0.075}$ X PI
$P_{0.075}$	=	% Passing 0.075 mm sieve in decimal
PI	=	Plasticity Index of the soil, %

Non-Plastic Soil

CBR	=	$28.091\ (D_{60})^{0.3581}$, $R^2 = 0.84$
Where D_{60}	=	Diameter in mm of the grain size corresponding to 60% finer.

Soil Classification can be used for preliminary report preparation

APPENDIX C

A TYPICAL DYNAMIC CONE PENETROMETER (DCP)

SALIENT FEATURES OF DCP TEST

The Dynamic Cone Penetrometer is a simple device developed in UK for rapid in situ strength evaluation of subgrade and other unbound pavement layers. Essentially, a DCP measures the penetration of a standard cone when driven by a standard force, the reported DCP value being in terms of the penetration of the standard cone, in mm per blow of the standard hammer. The figure above shows a typical DCP. The standard steel cone with an angle of 600 has a diameter of 20 mm. The standard 8 kg drop hammer slides over a 16 mm dia steel rod with a fall height of 575 mm.

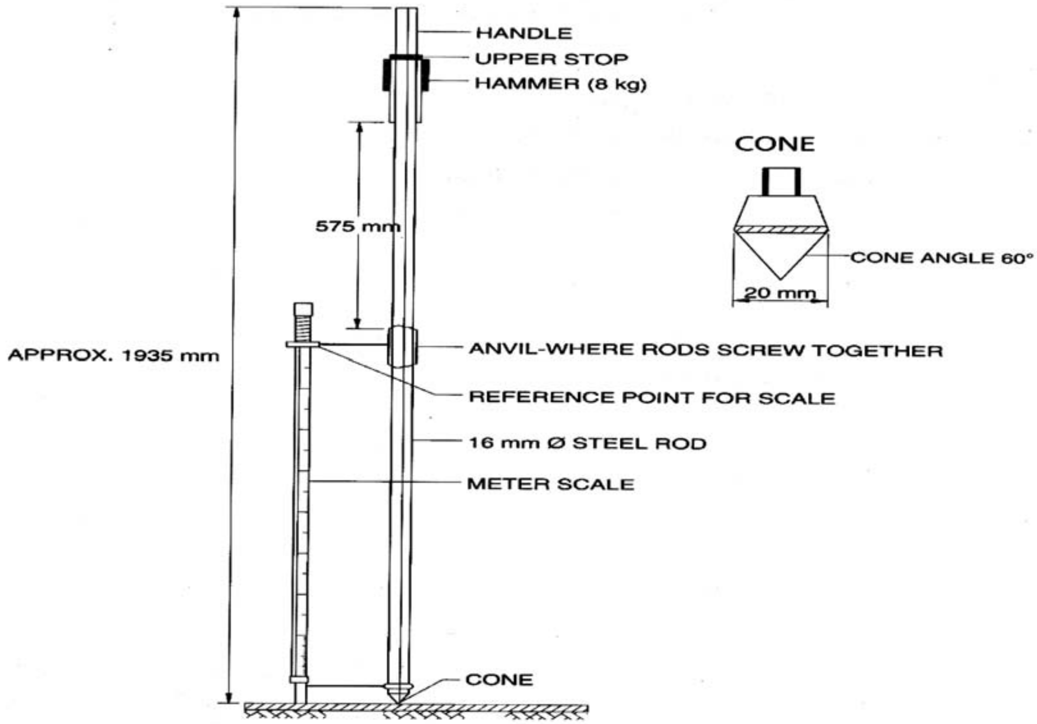
Basically, the penetration (in mm) per blow is inversely proportional to the strength of the material. Thus, higher the CBR value of a material being tested, lower will be the DCP value in mm/blow. Besides the measurement of subgrade strength, the DCP tests can be conducted to determine the boundaries between pavement layers with different strengths and their thicknesses. The measurements can be taken upto 1.2 m depth with an extension rod.

While one person holds the DCP instrument in a vertical position, another person carefully drops the weight and the third takes the readings of penetration. The penetration of the cone can be measured on a graduated scale. The readings are taken with each blow of the weight. The field data is reduced in terms of penetration versus corresponding number of blows. The number of blows and depth readings are recorded on the Dynamic Cone Penetrometer Test form. The cone is case-hardened but requires replacing. When used on subgrade materials the cone can be expected to last 30 to 40 tests before replacement.

The DCP test is specially useful for bituminous pavement rehabilitation design and is being used extensively in several countries.

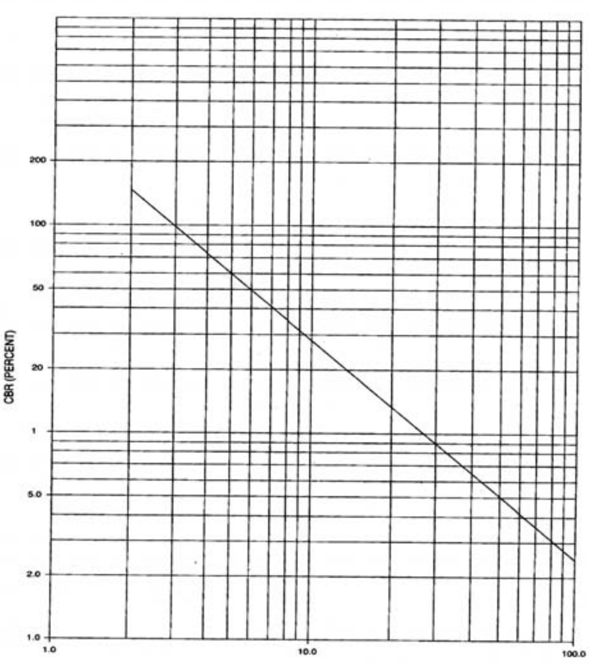
DCP-CBR Relationship (Ref.5)

SALIENT FEATURES OF DCP TEST (Appendix –C)



A Typical Dynamic Cone Penetrometer (DCP)

SALIENT FEATURES OF DCP TEST (Appendix-C)



(CONE ANGLE = 60°)

DCP-CBR Relationship (Ref. 5)

APPENDIX D

ILLUSTRATIVE EXAMPLE

Twenty four hour traffic counts over a period of 3 days taken on a single lane rural road during the peak harvesting season, yielded the following results for the Average Daily Traffic:

Animal-drawn carts (Pneumatic Tyred)	25
Bicycles	457
Full-sized trucks	9
Agricultural Tractor-Trailers and Jugads	55
Cars and Jeeps	15
Motor cycles	200
Total	761

(Motorised and Non-motorised Vehicles per day)

There are two harvesting seasons in the area, each having a duration of about 2 ½ months, the harvesting season traffic remaining at its peak for 15 days. The above traffic count data was collected 2 years before opening the road to traffic.

The depth of the Ground Water Table was found to be about 10 m below Ground Level. The average annual rainfall in the region is of the order of 750 mm. The soil survey results show the subgrade soil type to be CL with a plasticity index of 13. The maximum dry density and optimum moisture content were found to be 1.68 gm/cc and 12% respectively. The CBR sample prepared at OMC, and compacted to MDD, yielded a CBR of 5. The locally available materials include river gravel and sand besides an overly plastic moorum with excessive fines. Determine the most appropriate pavement thickness and composition requirements.

Design Calculations

1. Computation of Design Traffic Parameter

Since the lean-season traffic data is not available, it is assumed that the peak harvesting season traffic is double the traffic during the non-harvesting season. Referring to **Fig. 1**, n = 1, t = 75 days.

Average Daily Traffic during the non-harvesting season = 761/2 = 380

$$\text{AADT} = 380 + \frac{1.2 \times 380 \times 75}{365}$$

$$= 380 + 94 = 474$$

Before opening of the road to traffic, AADT = 474 $(1.06)^2$ = 532, assuming an intial growth rate of 6%.

From the given traffic count data, the proportions of HCV and MCV out of the ADT of 532 work out as under:

Heavy Commercial Vehicles (HCV) = 6

Medium Heavy Commercial Vehicles (MCV) = 38

The Animal-drawn carts being pneumatic tyred have not been considered for design purposes.

Therefore, Commercial Vehicles Per Day (CVPD) to be considered for design purposes = 6 +38 = 44. Since the traffic count data does not give the proportion of unladen and laden vehicles, it is assumed that these are equal in number.

Taking the VDF values from para 3.4.4, the ESAL applications per day = 16.35 Cumulative ESAL applications over 10 years @ 6% growth rate.

= 4811 X 16.35

= 78,660

2. Evaluation of Subgrade Strength

Since the GWT is too deep to influence the subgrade moisture, the design moisture may be close to the optimum moisture content. Referring to the Nomograph in **Fig. 2**, for insitu dry density of 1.68 gm/cc, GWT depth of 10 m PI of 13 and average annual rainfall of 75 cm, the Equilibrium Moisture Content works out to about 11%. The optimum moisture content of 12% being higher, the CBR value of 5 may be taken for subgrade strength.

3. Pavement Thickness and Composition

For cumulative ESAL applications of 78,660, referring to the Traffic category in the range 60,000 to 1,00,000 and the Subgrade category of CBR 5 to 6, in **Fig. 4**, any one of the following two alternate designs may be adopted, based on cost economics

(a) Using gravel base and sub-base : A 275 mm Gravel Base should be provided as per. **Fig. 4**. However, considering minimum gravel base thick ness of 100 mm, balance 175 mm thickness can be converted to equivalent sub-base thickness using fig 5 or **Table 5**. The specifications for a Gravel Road as per Clause 402 of the Specification for Rural Roads should be adopted.

(b) Using cement treated base and sub-base : A total thickness of 200 mm as per fig 6 should be provided. However, cement stabilized base may be of thickness 100 mm and the balance 100 mm thickness may be of cement treated sub-base. The specifications for a cement stabilized base and sub-base, as per Clause 404 of the Specification for Rural Roads should be adopted.