Islamic Republic of Afghanistan
Ministry of Rural Rehabilitation and Development

RURAL ROADS MANUAL

Version 2

English Version
Kabul, Afghanistan
2013
Executive Summary
This Rural Roads Manual is a temporary working document. There is an ongoing effort to combine efforts from all MRRD programs, especially the National Rural Access Programme (NRAP), the Ministry of Public Works, the World Bank and ANSA to come up with a unique highway and street manual that bridges all requirements. When this joint effort is complete, that will be the new standard. Until that document is accepted, the intention is to use this manual for current and future rural road projects.

Please contact Eng Mohammad Sediq Sahibzai for further comments seddiq@nrap.gov.af.

Many thanks to the Manual Development Committee:

Author:
Eng Mohammad Sediq Sahibzai; Head of Engineering & Technical Services Department, NRAP-MRRD

Review Team:
Eng Abdul Mateen Tamim        Road/Bridge Design Specialist NRAP-MRRD
Eng Yama Qiyam                Sr. Bridge Engineer NRAP-MRRD
Eng Zabiullah                 Sr. Road Engineer    NRAP-MRRD
Dr. Mark Lee                  ISAF Advisor
# Table of Contents

Executive Summary .................................................................................................................................................. 3

Acronyms ................................................................................................................................................................. 7

1. Introduction .......................................................................................................................................................... 8
   1.1 Country Context ............................................................................................................................................. 8
   1.2 Sectorial and Institutional Context ............................................................................................................... 8

2. Road Classification ............................................................................................................................................... 9
   2.1 Introduction .................................................................................................................................................. 9
   2.2 Uses and Benefits of Classification ........................................................................................................... 10

3. Planning and Alignment .................................................................................................................................. 13
   3.1 Planning of Rural Roads ............................................................................................................................. 13
   3.2 Planning Database ....................................................................................................................................... 13
      3.2.1 Database Development ....................................................................................................................... 13
      3.2.2 Habitation Level Data ....................................................................................................................... 13
      3.2.3 Road Inventory Data ......................................................................................................................... 14
      3.2.4 Map Based Data ............................................................................................................................... 14
   3.3 Concept of Network Planning ...................................................................................................................... 14
      3.3.1 Network Philosophy ......................................................................................................................... 14
      3.3.2 Utility Value ....................................................................................................................................... 15
      3.3.3 Selection and Prioritization Criteria ................................................................................................. 15
   3.4 Rural Roads Plan .......................................................................................................................................... 15
   3.5 Rural Roads Alignment and Survey .......................................................................................................... 15
   3.6 Governing Factors for Route Selection ..................................................................................................... 16
   3.7 Factors Controlling Alignment ................................................................................................................... 17
      3.7.1 Obligatory Points ............................................................................................................................... 17
      3.7.2 Traffic .................................................................................................................................................. 18
      3.7.3 Geometric Design ............................................................................................................................. 18
      3.7.4 Economy ............................................................................................................................................. 18
      3.7.5 Other Considerations ......................................................................................................................... 18
   3.8 Hill Road Considerations ............................................................................................................................ 18
3.9 Sand Dune Considerations ........................................................................................................... 19
3.10 Surveys ........................................................................................................................................ 19
  3.10.1 Reconnaissance ....................................................................................................................... 19
  3.10.2 Preliminary Survey ................................................................................................................ 20
  3.10.3 Determination of Final Centerline ..................................................................................... 21
  3.10.4 Final Location and Detailed Survey ................................................................................... 21
4. Geometric Design Standard ........................................................................................................... 22
  4.1 Introduction ............................................................................................................................... 22
  4.2 Functional Classification of Rural Roads .................................................................................... 22
    4.2.1 Terrain Classification ............................................................................................................ 22
    4.2.2 Design Speed ....................................................................................................................... 23
    4.2.3 Basic Principle of Geometric design .................................................................................... 23
    4.2.4 Cross-Sectional Elements ................................................................................................. 24
    4.2.5 Building and control lines: ................................................................................................. 24
    4.2.6 Roadway width .................................................................................................................... 25
    4.2.7 Carriageway width .............................................................................................................. 25
    4.2.8 Shoulder Width ................................................................................................................... 26
    4.2.9 Side Slopes .......................................................................................................................... 26
  4.3 Roadway Width at Cross-Drainage Structures ......................................................................... 26
    4.3.1 Culvert .................................................................................................................................. 26
    4.3.2 Bridge .................................................................................................................................. 27
    4.3.3 Causeway and Submersible Bridge ..................................................................................... 27
  4.4 Camber ........................................................................................................................................ 27
  4.5 Sight Distances ............................................................................................................................ 28
    4.5.1 Stopping sight Distance ....................................................................................................... 28
    4.5.2 Intermediate Sight Distance ............................................................................................. 28
    4.5.3 Overtaking sight distance................................................................................................... 28
  4.6 Horizontal Alignment .................................................................................................................. 29
    4.6.1 General Guidelines .............................................................................................................. 29
    4.6.2 Horizontal Curve ............................................................................................................... 30
    4.6.3 Super elevation .................................................................................................................... 30
    4.6.4 Minimum Curve Radii ........................................................................................................ 31
4.6.5 Transition Curve .......................................................... 32
4.6.6 Widening at Curves ...................................................... 32
4.6.7 Set Back Distance of Horizontal curves ......................... 34
4.7 Vertical Alignment .......................................................... 35
  4.7.1 Gradient .................................................................. 35
  4.7.2 Grade Compensation at curves ...................................... 37
  4.7.3 Vertical Curve .......................................................... 37
4.8 Alignment Compatibility .................................................. 39
4.9 Hair Pin Bends .................................................................. 39
4.10 Passing Places ............................................................... 40
4.11 Lateral and Vertical Clearance .......................................... 40
  4.11.1 Lateral Clearance ..................................................... 40
  4.11.2 Vertical Clearance ...................................................... 40
  4.11.3 Traffic Engineering Requirements ................................. 40
  4.11.4 Intersection with other road ......................................... 40
  4.11.5 Other Traffic engineering features ................................. 41
5. Pavement Design ............................................................. 42
  5.1 Parameters of Design ..................................................... 42
    5.1.1 Traffic ................................................................ 42
    5.1.2 Reliability (R) .......................................................... 42
    5.1.3 Environmental Effects ................................................. 42
    5.1.4 Serviceability .......................................................... 43
    5.1.5 Effective Roadbed Soil Resilient Modulus (MR) .......... 43
    5.1.6 Standard Error ......................................................... 43
    5.1.7 Determination of the Required Structural Number ........ 44
    5.1.8 Selection of Pavement Thickness Designs .................... 44
    5.1.9 Layer Coefficients (a_i)............................................... 45
    5.1.10 Drainage Modifying Factor (m_i) ................................. 51
    5.1.11 ZR = standard normal deviate .................................. 51
    5.1.12 Allowable Rutting .................................................... 51
    5.1.13 Aggregate Loss ........................................................ 51
5.2 Sample ............................................................................. 58
Acronyms

Afs Afghani
ADT Average Daily Traffic
ANDS Afghanistan National Development Strategy
AREDP Afghanistan Rural Enterprise Development Program
AWP Annual Work Plan
BOQ Bill of Quantity
CDC Community Development Council
CTA Chief Technical Advisor
DABS De Afghan Breshna Shirakat
DDA District Development Council
DDP District Development Plan
DPM Deputy Program Manager
FP Facilitating Partner
GIS Geographic Information System
GOA Government of Afghanistan
ICT Information Communication Technology
LIDD Local Institution Development Department
M&E Monitoring and Evaluation
MD Man Day
MDG Millennium Development Goal
MIS Management Information System
MOU Memorandum of Understanding
MRRD Ministry of Rural Rehabilitation and Development
NABDP National Area Based Development Programme
NGO Non-Governmental Organization
NPP National Priority Program
NRAP National Rural Access Programme
NSP National Solidarity Programme
O & M Operation and Management
PDP Provincial Development Plan
PM Program Manager
PRRD Provincial Rural Rehabilitation and Development
ToR Terms of Reference
TRC Technical Review Committee
UNDP United Nations Development Program
VPD Vehicles per day
1. Introduction

1.1 Country Context

Providing a good road network is very essential for the development of any country. In Afghanistan, there are about 40,000 villages located in different terrain conditions (e.g., plain, hilly and mountainous regions, deserts, etc.). The climate conditions also vary from place to place to an extent. Social, economic and educational developments of these villages greatly depend on accessibility. A large number of villages in rural Afghanistan are isolated from all-weather roads. The employment opportunities and necessities like, health, education, and social welfare cannot reach rural masses without a systematic and coordinated road network. Now, the realization has set in for the development of rural areas, development of a proper road network and connectivity of rural areas must be a priority.

The two decades of civil war did severe damage to the Afghan road network at all levels: from main highways to local access roads. As the nation started to emerge from the conflict in 2001, only a very small part of the road network was in good condition. Despite the lack of data at the time, it believed that the prolonged conflict had denied most of the rural population access to essential social services like markets, health centers, schools and government administrative offices. The cost of transportation on the limited functioning network was unaffordable to most rural people. The Ministry of Public Works (MOPW) had been responsible for maintaining major highways through its force account, which was weak, ill motivated, and hence ineffective. Prior to the conflict, MOPW mandated by law to collect toll fees on key corridors to finance maintenance, but had limited success. It did not have direct access to the tolls collected, but only through the Ministry of Finance (MoF). For rural roads, there has never been an institutionalized road maintenance system or funding mechanism in the country, except for some traditional ways whereby communities mobilized themselves to maintain the roads that otherwise would seriously affect their livelihoods.

Since 2002, Afghanistan has made remarkable progress in many areas such as health, education, microfinance, irrigation and rural livelihoods, as well as sound macro-economic management and gradual improvements in public financial management, aided by radical reform of the customs administration. Nevertheless, the country’s environment remains extraordinarily challenging. Governance and administrative capacity remains weak and the rule of law has yet to be widely institutionalized. Widespread poverty and low human development indicators persist. In particular, the country’s cereal harvest self-sufficiency rate remains low. Moreover, difficulties in importing wheat from neighboring countries make recurrent food shortages a threat. Access to electricity is still among the lowest in the world and much more needs to come available to increase rural productivity. Generally, development needs remain vast.

1.2 Sectorial and Institutional Context

As the country started to emerge out of the conflict in 2001, only 10% of the estimated 130,000 km of major and rural roads network at that time were in good condition. Rehabilitation of the core network whilst creating quick employment has been the government’s priority that underpinned the then transitional strategy to consolidate peace and stability. By virtue of its labor-intensive nature, rural road
rehabilitation was crucial to generate significant employment opportunities while opening up the isolated rural areas to basic services. In view of this, the Government formulated the National Emergency Employment Program (NEEP), a flagship program for creating short-term employment through restoration of the dilapidated rural infrastructure. After paving the way to other employment generation initiatives to emerge, NEEP evolved into the National Rural Access Program (NRAP) from 2005 to now, with a strong focus on provision of year-round access to basic social services for the rural population. World Bank and other donors starting from relatively simple emergency funding with a primary objective of creating employment in rural areas supported those projects. And then working up to more extensive involvement in building institutional capacity in the two ministries responsible for the sector, the Ministry of Public Works for secondary roads and the Ministry of Rural Rehabilitation and Development for tertiary roads. The most recent of these projects, NERAP, is currently in its fourth year and is expecting a 2013 completion. In continuation with NERAP, the Afghanistan Rural Access Project (ARAP) launched under the government’s NRAP program. As such, this will provide quality rural roads and employment generation to rural poor.

The World Bank via IAD and ARTF has also funded ARAP. In parallel, US-AID and the Asian Development Bank have focused their financing on major highways, with a view to restoring the national-level ring highway that links all major cities and main border crossing points.

In view of this the National Rural Access Program of the Ministry of Rural Rehabilitation & Development decided to develop the rural roads manual; this will help the engineers to design quality and economically viable rural roads and drainage structures in the country. This in term will help the engineers gain and grow the knowledge of rural roads designs within MRRD. This manual will define rural roads designs within all MRRD programs homogenously and accordingly, the design software selection as well.

The experience and feedback from the engineers on adoption of these guidelines will enable upgradation of the guidelines at certain interval. It would be desirable to conduct workshops and trainings to explain various aspects of rural roads to the concerned engineers. We would highly appreciate and welcome the comments and feedback from MRRD programs, Engineers and all users, those comments will help us further improve the manual and get it to more usable state. The NRAP Engineering team expresses their thanks and appreciation to NRAP Management and MRRD leadership for encouraging the team to develop this manual and their timely and continuous technical and logistic support.

2. Road Classification

2.1 Introduction

Classification is the art and science of grouping objects according to one or more common features. It makes the mass of variable and complex components brief, concise and simple for better understanding and treatment. There are millions of kilometers of roads in different countries. Without classifying them in suitable groups, we will be in a jungle of information, knowing nothing about their characteristics. It
would also be impracticable for road agencies to deal with all of them individually. However, by grouping similar roads together, one standard design and uniform specifications shall apply to all. Similarly, framing plans and policies allows all of them in one go. Some sort of grouping or classification simplifies the working at Government and road agency level. The main uses and benefits of road classification are as follows.

2.2 Uses and Benefits of Classification

Some of the most important uses and benefits of road classification include the following.

i. Delineation of public responsibilities in the provision and standard of public roads
ii. Assignment of ownership of roads and responsibility for their management and financing
iii. System planning for road users travel modes, including non-motorized traffic; access management (access control); and, coordination with other modes of transport
iv. Assistance to road users for selecting a travel route from origin to destination
v. Assignment of (uniform) minimum standards, including permissible vehicle axle loads, weights and dimensions.
vi. Determination of the size of the public road network and its quality commensurate with what the country can afford at the time

1. Classification of Roads in Afghanistan

In Afghanistan, the classification of roads is in the making. There is no formally notified, accepted or adopted classification as such. The classification presented in this document follows the MoPW interim road note of 2005. This needs to be further developed on a national level in order to have an efficient road network planning system in the country. NRAP is planning to establish a sound road network management system within 2014 to have a finalized classification mechanism of roads as well.

2. Ministry of Public Works’ Approach

The classification of roads contained in the Interim Highway Standards by the Ministry of Public Works (March 2005), referred to in the First Interim Report (May 2005) of Master Plan for Road Improvement Project (ADB TA 4371: AFG) by Sheladia Associates Inc. Kabul/Afghanistan, are as follows.

Table: Classification of Roads in Afghanistan

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Regional Highways</td>
</tr>
<tr>
<td>2</td>
<td>National Highways</td>
</tr>
<tr>
<td>3</td>
<td>Provincial Highways</td>
</tr>
</tbody>
</table>
The definitions of above categories given in the above-referred report are as follows:

Regional Highways: (formerly Super Corridors) are (planned) for two-lane expansion to make four lanes, fostering regional trade and economic linkages between Afghanistan and the neighboring countries, Iran, Pakistan, Tajikistan, Turkmenistan and Uzbekistan. Regional Highways shall be four lanes wide with dual 7-metre carriageways with medians.

National Highways: promote trade and economic linkages and extend Regional Highways to provincial capitals contributing to peace, security, stability, economic growth and national integration.

Provincial Roads: improve the administrative, trade and economic contacts between district headquarters and respective provincial capital and between important district headquarters.

Rural Roads: Rural Roads consist of secondary and tertiary roads bring the hinterland in commercial contact with market and seats of power.

NRAP-MRRD has classified Rural Access Roads into Non-Standard and Minor Roads. The latter are further sub-divided into Tertiary and Secondary Roads as follows:

<table>
<thead>
<tr>
<th>Table: Sub-classification of Rural Access Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.No.</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
II. District Capital to National or State Highways

III. District Capital to District Capital

ADT= Average Daily Traffic, VPD=Vehicles per day

Source: NRAP “Technical Note-1, Low Volume or Rural Road Standard, October 2010.

Non-Standard Roads: The basic accesses and trails those that are not significant enough to require engineering design or standardization. Typically, very low Average Daily Traffic (ADT) volume < 50 vehicles per day.

3. **Mandate of MRRD:**

District to village and village to village as well as village to district of the rural roads network (Tertiary Roads) remain under the mandate of MRRD. In situations where the roads link a district to another district and MoPW does not include specific roads in their plans, the MoPW will officially request MRRD to carry out the implementation of such district-to-district roads. All rural road networks that link districts to provincial capitals and districts to other districts will remain the mandate of MoPW.

These responsibilities may be more systematic and standardized if the Rural Roads are fully the mandate of MRRD (i.e., both the secondary and tertiary). This will lead MRRD to establish an agency of Rural Roads under MRRD. MoPW is responsible for high-class roads in the country under their own structure. This eases the construction and maintenance of rural roads, meanwhile it will help to manage the rural road network under the hierarchies of rural development in the country so that the improvement of rural road networks can come under the overall rural development policy for MRRD.

The current institution setup of rural roads network is defragmented, and much coordination is required to get to the uniform standard and decision, due to involvement of two ministries. The experience of regional countries showed this as well, as now a day in most of the developing countries, the rural roads network management the mandate of Rural Development entities, and the high calls roads and railways are under the public works or highway authorities.

India, as a leading country in terms of transport infrastructure management has established a national rural roads agency, which works under Ministry of Rural Development, in the same time there are highway officials and agencies taking care of those economic and tools roads.
3. Planning and Alignment

3.1 Planning of Rural Roads

Considerable length of rural roads constructed during the last 10 years through Afghan government, National Programs, NGOs, other international organizations in the country. In spite of all these efforts, rural connectivity still remains quite poor. The network developed by the criteria of qualifying populations does not take necessarily into account the travel requirements of unconnected habitations, which results in sub-optimal road network. Thus, the roads in an area considered together with the accessibility requirements of the habitations and every unconnected habitation should be provided with connectivity through at least once road link.

A habitation or village can be defined as a cluster of population living in an area, the location that doesn’t change over time. A habitation considered connected only if it has an access through all-weather road. All-weather road is an engineering structure built using proper specification and design and with various cross drainage works as per the requirements except major river crossings. However, due to the interruption by traffic as permitted by its frequency and duration. The interruption is allowed six times a year with maximum one day at a time; or maximum of 72 hours in case another alternative access is available. Heavy snow falls in mountainous regions are not coming under this definition, as the heavy snow fall is an exception interruption.

Various agencies, under different programs without a common network development objective take up the construction of rural roads in the country, and therefore, it results into a sub-optimal network. Where, a consolidated program of developing an optimal network of roads based on a master plan will provide rationality of choice and can save any wastage or recourses. The network plan or master plan needs to be prepared at a level which is convenient from the point of map preparation and data collection to all stakeholders of the rural road sectors and thus the agencies have to be obliged to use it.

3.2 Planning Database

3.2.1 Database Development

Database Development: In order to prepare a scientific Master Plan for rural roads, it is necessary to build a comprehensive database for all habitation and the existing network of all types of roads and tracks, preferably in the computer environment. Various data items required for developing the rural road plan broadly identified under three categories: (1) habitation level data, (2) Road inventory data, and (3) Map data.

3.2.2 Habitation Level Data

A village/settlement/habitation located within a distance of 2.5 km from all-weather road or a connected settlement/habitation/village considered to already connected at this stage; though other countries consider only from 0.5 to 1.5 km, but due economic situation in Afghanistan it would be economically justified to consider it connected within 2 to 2.5 km. The habitation level data will include details on demographic (population) and infrastructure facility data (socio-economic functions or...
facilities available in habitation/settlement), which should be collected for each habitation. This obtained from the secondary sources, such as census records, revenue records, village survey, etc.

3.2.3 Road Inventory Data
A comprehensive inventory of all rural roads including highways constructed/improved under various rural development programs have to be prepared. For each road, the information on road geometry, road pavement condition, terrain, soil type and habitation connected by the road are to be collected. All existing roads that are 5m or more in width (e.g., cart tracks, footpaths, "jeepable" roads etc.,) should be included for preparing road inventory.

3.2.4 Map Based Data
The base map on GIS base should be prepared for the whole country with more detailed scale. If available the aerial photos and satellite imageries, etc., can also be used to further improve the accuracy of the map. The maps should show the village, district, provincial and any other higher order boundaries. It should show all types of roads (Regional Highways, National Highways, Provincial Roads, Rural Roads, and all other roads and cart tracks, foot paths built under various programs in the country) as per the inventories. The color codes and legends for preparation of the maps are important and need assigning properly.

Digital maps with proper registration, etc., should be prepared when the master planning is to be done in a compromised environment. For computerization of the data (map, road inventory, and habitation data), a geographic information system (GIS) platform may be used as stated. However, the data and analysis at the provincial level managed manually also.

3.3 Concept of Network Planning

3.3.1 Network Philosophy
Rural roads are part of the total road network system. A road network system basically consists of links (Roads of various categories, such as, Regional and National Highways, Provincial Roads, Rural Roads, Tracks and etc.). Roads, therefore, become links of a network, which facilitate the essential movement of persons and goods in an area and no individual road link can serve the same purpose then developed isolated. A road network, therefore, needs to be developed in such a way that the travel needs of the people or community in an area met to the maximum in a collective way at the lowest cost of development. In the rural areas, major part of their travel needs is comprised of travel to market place, education center and health center, thus, creation of an optimal road network is to be aimed to serve the habitations for access to such needs though a Master Plan.

There are a large number of methods to develop optimal network for rural roads. However, in practice, very little or no use of those have been possible so far, primarily due to non-availability of required data and the Master Plan.
3.3.2 Utility Value
Traditionally Rural Areas/Villages have been provided priority for an all-weather road connection solely based on its population size. However, the integrated development approach aims to provide the habitations with access to various services facilities, and it requires a different criterion based on a composite measure or index or utility value. The utility value for the habitation should consider a set of demographic, socio-economic, infrastructure and level of development data. This composite measure of development called as Utility Value (UV) of the habitation. Selection of the variables for computing the utility value made from the habitation level data. The chosen set of variables may be different in different times and economic situations of the country. Examples are, population, schools, colleagues/university, health centers, police stations, markets, number of days markets held, terrain, agriculture, mines, enterprises, and etc.

3.3.3 Selection and Prioritization Criteria
See prioritization criteria in previous sections.

3.4 Rural Roads Plan
The rural roads plan is a combined master plan of all the provinces for which the optimal network links for the habitations are shown in the descending order of priorities. Province-wise priorities list of roads for next 5 to 10 years shall be prepared and all the districts in a province are to be considered together for provincial level master plan to be prepared. However, in the province master plan all the districts will be available separately also with all information at district level, so that the implementation of road program is possible at district level too.

3.5 Rural Roads Alignment and Survey
The alignment of rural roads decided only after conducting proper survey and investigations. In general, most new roads will also have to follow the existing cart tracks and other such existing alignment. However, during rout location the following points considered:

i. Adoption of appropriate geometric design standards and safety requirements.
ii. Keeping to the high ground so as to avoid low laying areas and minimizing the drainage requirements.
iii. Following the land contours as far as practicable to reduce the extent of cut and fill
iv. Conforming to any property boundaries to the extent possible
v. Avoiding or minimizing the effect on vegetation
vi. As far as possible, alignment should not interfere at any stage with services, like, power transmission lines, water supply, mains, historical places, environmentally sensitive locations, private properties and or assets, etc.

Following special considerations are to be given due importance for the alignment in mountainous terrains:

i. When crossing mountainous ranges, the road should preferably cross the ridges at their lowest elevation. In certain cases, it may more expedient to negotiate high mountain ranges through
semi or full tunnels depend on need. The decision taken after considering the relative economics or the strategic requirements.

ii. While fixing the alignment the introduction of hair-pin bends should be avoided as far as possible. In unavoidable cases, the bends should be located on stable and flat hill slopes in due consideration of geometric design. But, a series of hair-pin bends on the same face of the hill should be avoided.

iii. As far as possible, attempt should be made to avoid unstable hill features, areas having perennial/potential landslides or settlement problems, areas subject to seepage/flow from springs, channels, etc.

The location or the layout of the centerline of the road on the ground called the alignment. The horizontal alignment includes the straight path, the horizontal deviations and curves. Changes in gradient and vertical curves covered under vertical alignment of road. A new road aligned very carefully as improper alignment would mean either capital loss initially in construction as well as recurring loss in cost of maintenance and vehicle operation. Once the road is aligned and constructed, it is not easy to change the alignment due to increase in cost of adjoining land and construction of costly structures by the road side. The ideal alignment between two points should satisfy requirements as given under:

i. Short: It is desirable to have a short (or shortest) alignment between two terminal stations. A straight alignment would be the shortest, though there may be several practical considerations, which would require deviations from the shortest path.

ii. Easy: The alignment should be such that it is easy to construct and maintain the road with minimum subsequent problems; also, the alignment should be easy for the operation of vehicles with easy gradients and curves.

iii. Safe: The alignment should be safe enough for construction and maintenance from the viewpoint of stability of natural hill slopes, embankment and cut slopes and foundation for embankments. Since, it should be safe for the traffic operation in terms of safe geometric features.

iv. Economical: The road alignment considered economically only if the total cost including initial cost, maintenance cost and operational cost, is the lowest.

v. Sound: The alignment should be on the firm ground and should not be susceptible to large settlement, deformation, landslides, etc.

vi. Aesthetics: While selecting the road alignment, the aesthetics of the area should be borne in mind.

vii. Environment: The alignment should be decided giving due weightage to environment protection, particularly in hilly area. Tree cutting avoided as far as possible by suitably locating the road alignment. Further details provided in Environmental & Social Management Framework of the NRAP.

3.6 Governing Factors for Route Selection

i. The alignment should be as direct as possible so that there is maximum economy in cost of construction, maintenance and transportation.

ii. The grades, curvatures and profiles so designed as to be economical, consistent with the service requirements.

iii. While improving the existing alignment, the endeavor should be to utilize the existing facility as much as possible in order to minimize the cost and effort of land acquisition and construction.
iv. The alignment should not interfere at any stage with services, like, power transmission lines, water supply, mains etc.

v. Embankment and pavement account for major proportion of the road cost; therefore, availability of material for embankment and pavement construction kept in view while finalizing the alignment. Similarly, good sub-grade conditions would mean lower pavement cost and thus the sub-grade condition also affect the choice of alignment. To the extent possible, areas susceptible to subsidence (due to mining, etc.), marshy and low-lying areas prone to flooding, inundation and erosion avoided.

vi. While connecting population centers, the alignment should preferably skirt round the population pockets rather than pass through congested areas.

3.7 Factors Controlling Alignment

The various factors, which control the road alignment, listed as:

i. Obligatory points
ii. Traffic
iii. Geometric design
iv. Economics
v. Drainage
vi. Other considerations

3.7.1 Obligatory Points

There are control points governing the alignment of the roads. These control points maybe divided broadly into two categories:

- Points through which the alignment is to pass
- Points which the alignment should avoided

Obligatory points through which the road alignment has to pass may cause the alignment often deviate from the shortest path. The various examples of this category may be a bridge site, intermediate town, a mountainous pass or a quarry.

The road bridge across a river should be located only at a place where the river is straight and has firm banks and where the bridge abutment and pier properly founded. The road approaches to this bridge should not be on curve near the bridge and as far as possible skew crossings avoided. Thus, in order to locate a bridge across a river the road alignment may have to be changed.

The obligatory points, which avoided while aligning a road, include religious places, very costly structures, unsuitable lands, etc. Religious places include mosques, madrasas, graveyards, reserve forests, etc. Acquiring costly structures would mean heavy consumption resulting in increased cost. Marshy, peat and water logged areas are generally unsuitable for road construction and should be avoided as far as possible. However, if there is no alternative and the alignment taken across such as area, the construction and maintenance costs are likely to be very high due to special construction techniques adopted.
A lake, a pond or a valley, which falls on the path of a straight alignment, will also necessitate the alignment to deviate from the straight path and go round along the lake.

3.7.2 Traffic
In most of the cases, the people use certain routes traditionally. These may either be due to convenience, social connection with other areas, etc. The proposed alignment should keep in view this traffic flow pattern. At the same time, one should also have a fair judgment of future trends in mind.

3.7.3 Geometric Design
Geometric design factors, such as, gradient, radius of curve and sight distance would also govern the final alignment of the road. As far as possible, steep gradient avoided and limited to the ruling or design gradient. Thus, it may be necessary to change the alignment in view of the design speed and maximum allowable super-elevation. It may be necessary to make adjustment in the horizontal alignment of roads keeping in view the minimum radius of curve.

The absolute minimum sight distance, which should invariably be available in every section of the road, is the safe stopping sight for the fast moving vehicles. Also, there should be enough distance visible ahead for safe overtaking operations of vehicles. Hence, the alignment must be finalized in such a way that the obstructions to visibility do not cause restrictions to the sight distance requirements.

3.7.4 Economy
The alignment finalized based on the above factors should also be economical. Avoiding high banking, deep cutting, major crossing and balancing of the cuts and fills can decrease initial cost of construction. At the same time, care should be taken to see that it is not likely to involve costly maintenance and operational expenses.

3.7.5 Other Considerations
Various other factors that may govern the alignment are drainage considerations, hydrological factors, social obligations, etc. The vertical alignment guided by drainage considerations. The sub-surface water level, seepage flow and high flood level are also the factors kept in view.

3.8 Hill Road Considerations
In hill roads, additional care has to be taken for ecological considerations, such as:

i. Stability against geological disturbance
ii. Land degradation and soil erosion.
iii. Destruction and denudation of forest
iv. Interruption and disturbance to drainage system
v. Aesthetic considerations
vi. Siltation of water reservoirs

Special care must be taken to align the road along the stable side of the hill. A common problem in hill roads is that of landslides. Hillsides suffer from instability after road construction, due largely to the large amount of cutting and filling required to construct the road. Hillside drains provided for adequate drainage of water across the road. But since the cross drainage structures are minimal.
Different geometric standards are followed in hill roads with reference to gradient, curves and speed and they consequently influence the site distance, radius of curve and other related features. The selected route should be feasible from the point of attaining the ruling gradient. The alignment should involve least number of hair-pin bends and wherever unavoidable, these should be located on stable and less steep slopes. In hilly areas locations which get sunlight should be preferred over locations in the shade. The areas liable to snow should be avoided.

3.9 Sand Dune Considerations
The road should be so located that it causes minimum interface to the flow of sand-laden winds. Therefore, the roadway should merge with the line of the land as much as possible. In areas having longitudinal sand dunes, a location along the ridge or in the inter-dual space is preferred. Location along the face of the dunes avoided. Locations were sand is loose and unstable should be avoided. These locations are mostly in south and some areas in North regions on the country, the design engineers need to consider the said measures.

3.10 Surveys
Final location of the alignment is based on ground verification, and therefore, the engineering surveys are to be carried out. The surveys may be completed in four stages as below:

i. Reconnaissance
ii. Preliminary
iii. Determination of Final Center Line
iv. Final Location and Detailed Survey

To facilitate the survey team in the tentative selection of alternative alignments for subsequent detailed ground reconnaissance, it will be advisable, to make use of modern techniques, like, aerial survey, photogrammetric and remote sensing as well.

3.10.1 Reconnaissance
Keeping in view the obligatory points the next step will be to undertake reconnaissance survey in the following sequence:

- Study of topographical survey sheets, revenue maps if available, geological and metrological maps, and aerial photographs where available.
- Preliminary aerial survey reconnaissance (as against Aerial photographs, satellite images...) where applicable and available.
- Ground reconnaissance
- Final reconnaissance of inaccessible and difficult stretches

**Study of survey sheets and maps:** The study of topographical maps available in the scale of 1:50,000 (the Russian maps), i.e., 2 cm to 1 km showing towns, villages, rivers and terrain features with altitudes and contour lines at interval of 20 m and locate the obligatory and control points and to mark the probable alternative feasible routes on the topo sheet for further survey on the ground. A senior civil
engineer to select and mark the possible routes tentatively on the maps keeping in view the guiding principles should do such study.

The probable alignment can be located on the map from the following considerations per the details available on the map:

i. Alignment avoiding valleys, ponds and lakes
ii. When the road has to cross a row of hills, possibility of crossing through mountainous passes.
iii. Approximate locations of bridge sites for crossing rivers, avoiding bends on the river, etc.
iv. Achievable gradient in hilly area, when a road is to be connected between two stations.
   Alternative routes can be considered keeping in view the permissible gradients say the ruling gradient and limiting gradient.

Map study thus gives a rough guidance of the routes surveyed in the field.

**Aerial reconnaissance:** The aerial reconnaissance will also provide a perspective of the locality and it will help the final decision in the selection of alignment. Currently MRRD programs do not have access to Aerial photographs, but in the future these will be required to cover the survey of rural road network.

**Ground reconnaissance:** The second stage of survey for rout selection is the ground reconnaissance. The field survey party should inspect a fairly broad stretch of land along the proposed alternative routes found out during map study. The various feasible alternatives routes are further verified physically in the field by ground reconnaissance to select the final route. It consists of general examination of the ground by walking or riding along the probable route and collecting all essential and available data.

Only very simple instruments, like, Abney Level, Tangent Clinometers, Barometer etc., are required for the reconnaissance and collecting the data. All relevant details not available in the map are collected and noted.

Some of the details to be collected during ground reconnaissance are given below:

i. Valleys, ponds, lakes, marshy lands, ridges, hills, permanent structures, archeological structures, and other obstructions along the route, which may not be available from the map study.
ii. Gradient, length of gradient and radius of curves of alternative alignments.
iii. Number and types of cross drainage structures, maximum flood level and natural ground water level along the probable routes.
iv. Soil type along the routes from field identifications tests and observations of geological feature.
v. Sources of construction material, water and location of stone quarries
vi. When road passes through hilly or mountainous terrains, additional data regarding the geological formation, type of rocks, dip of strata, seepage flow, etc., may be observed so as to decide the stable and unstable sides of the hill for road alignment.

From the details collected during the reconnaissance, a few alternative alignments chosen for further studies that are based on the practical considerations observed at the site.

### 3.10.2 Preliminary Survey

The main objectives of the preliminary survey are:
i. To survey the various alternative alignments proposed after the reconnaissance and to collect all
the necessary details of topography, drainage and soil.

ii. To compare the different proposals in view of the requirements of a good alignment.

iii. To estimate the quantity of earthwork, materials and other construction aspects and to work
out the tentative costs of alternative alignment.

iv. To finalize the best alignment for all considerations.

The survey consists of establishing a base-line traverse, which is a series of straight lines along the
selected alignment. The preliminary survey carried out using suitable survey equipment, such as,
theodolite, Total Station, etc., depending on the degree of reliability and accuracy required. However, a
plane table survey would be sufficient in most cases where other equipment may not be available.
Levels should be taken along the traverse and across it. Levels will be along the centerline, taken at
intervals of 50m and at all intermediate breaks in ground. The cross sections taken at intervals of 100-
250 m in plain terrains, up to 50m in rolling terrains and up to 30 m in hilly areas. The benchmarks
established at interval of 200-250m. Physical features, such as, buildings, trees, monuments, utilities,
eexisting roads, canals, drainage channels, should be located by means of offsets. While the traverse is
being run, apart from the general information about traffic, hydrological data may be collected so as to
estimate the type number and approximate size of cross drainage structures. The soil survey data should
be collected from working out the details of earthworks, slopes, and stability of material. The data
regarding subsoil and surface drainage requirements, pavement type and approximate thickness
requirements collected during the preliminary survey. At critical locations like, sharp curves, hair-pin
bends, bridge crossings, etc. the plans should also show contours at 1 to 3 m intervals, particularly for
road in rolling or hilly terrains so as to facilities the final decision. Aerial photographic survey in case of
hilly areas is very much suited for preliminary survey when the distance and area to be covered are vast
or the terrain is not hospitable to physical survey.

3.10.3 Determination of Final Centerline
Making use of the maps from preliminary survey showing the longitudinal profiles, cross-sections and
contours, a few alternative alignment for the final center line of the road are drown and studied and the
best one satisfying the engineering, aesthetic and economic requirements is selected. Horizontal curves
are designed and the final centerline is marked on the map. The vertical curves are designed and the
profile is then determined.

3.10.4 Final Location and Detailed Survey
The alignment finalized after the preliminary survey is to be translated on the ground by establishing the
centerline. The line established in the field should follow as closely as practicable the line finalized after
preliminary survey and conforming to the major and minor control points established and geometric
design standards. However, modifications in the final location may be made in the field as necessary. A
compass survey may be sufficient in normal course; where applicable, use the total station or other
available machine. The centerline staked at 50m interval in straight reaches and 25m interval on curves.
In hilly and mountainous reaches, the interval reduced to 20 and or 10m respectively. The points of
transit and intersection should be properly marked and referenced. Temporary benchmarks fixed at
intervals of about 250m. The leveling work is of great importance as the vertical alignment (especially in
hilly areas), earth works calculations and drainage details are worked from the levels noted. Normally, the earthwork computations are based on centerline levels in case of plain country. The cross-section levels taken up to the desired width at intervals of 30m or at closer intervals where there are abrupt changes of slopes. All river crossings, valleys surveyed in detail up to considerably greater distance on either side.

A detailed soil survey carried out to enable drawings of the soil profile. The depth up to which the sampling is done may be 1.5 to 3m below the ground line or finished grade of the road whichever is lower. The data collected during the detailed survey should be elaborate and complete for preparing detailed plans and estimates of the project.

The specific survey reports formats attached as annexes to this manual.

4. Geometric Design Standard

4.1 Introduction

These guidelines relating to geometric design standard intended and applied to rural roads. For these guidelines, the rural road shall include district road (DR) and village Road (VR) which come under the definition of rural roads. These provide accessibility to the villages in the rural area of country. Geometric design standard of the rural roads need not be restricted to the minimum values set out and milder values than the minimum should be preferred where the conditions are favorable and the cost is not excessive. Higher standards right in the initial stages may be warranted in cases where improvement of road geometric, (i.e., widening of the formation width) is anticipated due to increased traffic.

4.2 Functional Classification of Rural Roads

The rural roads in Afghanistan commonly referred to as:

   i. District Roads (DR)
   ii. Village Roads (VR) (one or both ends of these roads are connected to a village)

District roads are the roads serving rural area of production and providing them with outlet to market centers, headquarters, district or provincial development headquarters or major district roads, and would serve to connect villages with population 1000 and above or cluster of villages. Village roads are roads connecting village or Cluster/group of villages with each other and to the nearest road of a higher category, meanwhile these roads connect villages to markets, health centers, districts capitals or provinces. These two categories of roads are proposed together as “Rural road” with uniform standards as explained in chapter 1 classification of Roads.

4.2.1 Terrain Classification

The general slope of the country classifies the terrain across the area. The terrain is an important parameter terrain short isolated stretches of varying terrain should not be taken into consideration.

TERRAIN CLASSIFICATION
Terrain Classification | Cross Slope of the country
--- | ---
Plain | 0-10 per cent | More than 1 in 10
Rolling | 10-25 percent | 1 in 10 to 1 in 4
Mountainous | 25-60 per cent | 1 in 4 to 1 in 1.67
Steep | Greater than 60 per cent | Less than 1 in 1.67

4.2.2 Design Speed
Design Speed is a basic criterion for determining all geometric features of horizontal and vertical alignment. The design speeds for the rural roads should be taken as given in table below:

<table>
<thead>
<tr>
<th>Road Classification</th>
<th>Design Speed (Km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain Terrain</td>
<td>Rolling Terrain</td>
</tr>
<tr>
<td>Ruling</td>
<td>Min.</td>
</tr>
<tr>
<td>Rural Roads (DR and VR)</td>
<td>50</td>
</tr>
</tbody>
</table>

Normally ruling design speed should be the guiding criterion for the purpose of geometric design.
Minimum design speed may, however, be adopted where site condition and cost does not permit a design based on “Ruling Design Speed”

4.2.3 Basic Principle of Geometric design
These guidelines intended for uniform practices to achieve optimum design standards for rural roads. Generally, geometric features of a road do not allow for stage construction. Improvement of features, like grade, curvature and widening of cross drainage works can be very expensive and sometimes impossible in remote and hilly area. It is, therefore, necessary that ultimate geometric requirement of rural road should be kept in mind right in the beginning.

If stage construction is unavoidable, the permanent works, like, retaining walls, breast wall, and drain, which may have to be rebuilt, may be constructed using dry masonry. Interceptor drains may be located well at the beginning and culverts provided to full width to avoid the need for their widening subsequently.
The design standards recommended are absolute minimum. However, the minimum values applied only where serious restrictions are implied from technical or economical consideration. General effort should be exceed the minimum values as far as possible. Road should be designed so as to have minimum turns and the total number of curves in one kilometer should generally be less than six.

4.2.4 Cross-Sectional Elements

Road Land Width (Right of Way): Road land width (also termed the right-of-way) is the width of land acquired for road purpose. The desirable land width for rural road in different terrain is given in Table below:

TABLE. RECOMMENDED RURAL LAND WIDTH (Right of Way)

<table>
<thead>
<tr>
<th>Road Classification</th>
<th>Plain and Rolling Terrain</th>
<th>Mountainous and steep terrain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open Area</td>
<td>Built-up Area</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>Range</td>
</tr>
<tr>
<td>Rural Roads (DR and VR)</td>
<td>15</td>
<td>15-25</td>
</tr>
</tbody>
</table>

Note: (i) Additional land width as per requirement may be acquired at location involved deep cuts, high banks and unstable or landslide prone areas

(ii) The lower values of land width may be adopted where the traffic intensity is less than 100 vehicles per day, and where the traffic is not likely to increase due to situation, like, dead end, low habitation and difficult terrain conditions.

4.2.5 Building and control lines:
In order to prevent overcrowding and preserve sufficient space for future road development, it is advisable to lay down restriction on building actively along the rural roads.

TABLE 2.4. RECOMMENDED STANDARD FOR BUILDINGS AND CONTROL LINES

<table>
<thead>
<tr>
<th>Road Classification</th>
<th>Plain and rolling Terrain</th>
<th>Mountainous and steep terrain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open area</td>
<td>Built-up area</td>
</tr>
<tr>
<td></td>
<td>Overall width between Bldg. lines</td>
<td>Overall Width between control lines</td>
</tr>
</tbody>
</table>
4.2.6 Roadway width
Roadway width inclusive of parapet, side drains for rural roads for different terrain shall be as given in Table 2.5.

<table>
<thead>
<tr>
<th>Terrain Classification</th>
<th>Roadway Width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain and Rolling</td>
<td>7.5</td>
</tr>
<tr>
<td>Mountainous and steep</td>
<td>5.0 to 6.0</td>
</tr>
</tbody>
</table>

Notes: (i) For rural roads, where the traffic intensity is less than 100 motor vehicles per day, and where the traffic is not likely to increase (e.g., dead end, low habitation and difficult terrain conditions) the roadway width may be reduced to 6.0 m in case of plain and rolling terrain.
(ii) The roadway width given in the table 2.5 for mountainous and steep terrain is inclusive of parapet.
(iii) The roadway width for rural roads is a single lane carriageway of 3.75 m.
(iv) On horizontal curves, the roadway width shall correspond to the extra width of carriageway for curvature.
(v) On road subjected to heavy snowfall and landslides, where regular snow or debris clearance completed over long period to keep the road open to traffic, roadway width maybe increase by 1.5 m.

4.2.7 Carriageway width
The standard width of carriageway for both plain and rolling as well as mountainous and steep terrain shall be as given in Table 2.6 Typical Cross-sections of rural roads and given in Figures

<table>
<thead>
<tr>
<th>Road Classification</th>
<th>Carriageway Width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural Road (DR and VR)</td>
<td>3.75</td>
</tr>
</tbody>
</table>

1 If the land width is equal to the width between building lines indicated in the earlier section, the building line should be set back by 2.5 m from the road land boundary.
Note: For Rural road, the carriageway width maybe restricted to 3.0 m, where the traffic intensity is less than 100 motorized vehicles per day, and where traffic is not likely to increase due to situation, like, dead end, low habitation and difficult terrain. Double lane roads can are subjected to economic analysis to justify the need of 2\textsuperscript{nd} lane in rural areas, this will especially meet to district roads where the traffic are above 500 ADT.

4.2.8 Shoulder Width
Use tables 2.5 and 2.6 to obtain the width of the shoulder for rural roads in different terrain. Shoulder width will be one half the different between the roadway width and carriageway width.

4.2.9 Side Slopes
Side slop for rural road where embankment height less than 3.0 m is given In Table 2.7.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Slope (H:V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embankment in silty/sandy/gravelly soil</td>
<td>2:1</td>
</tr>
<tr>
<td>Embankment in clay or clayey slit or inundated condition</td>
<td>2 ½: 1 to 3:1</td>
</tr>
<tr>
<td>Cutting in silty/sandy/gravelly soil</td>
<td>1:1 to ½ :1</td>
</tr>
<tr>
<td>Cutting in disintegrated rock or conglomerate</td>
<td>¾:1 to 1/4 :1</td>
</tr>
<tr>
<td>Cutting in soft rock like shale</td>
<td>¾ 1 to 1/8 :1</td>
</tr>
<tr>
<td>Cutting in medium rock like sandstone,</td>
<td>1/12: 1 to 1/16:1</td>
</tr>
<tr>
<td>Cutting in hard rock like quartzite, granite</td>
<td>Near Vertical</td>
</tr>
</tbody>
</table>

4.3 Roadway Width at Cross-Drainage Structures
It is difficult to widen cross-drainage structure at a later stage. Therefore, the roadway width should be decided very carefully at the planning stage itself. Usually, a causeway and submersible bridge are on rural roads. High level bridge on rural road shall be provided only in exceptional cases on merit.

4.3.1 Culvert
The roadway width at culvert (measured from outside to outside of the parapet walls) shall be as given in Table 2.8.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Slope (H:V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culvert</td>
<td>Near Vertical</td>
</tr>
</tbody>
</table>
### 4.3.2 Bridge
The roadway width between the curb for minor and major bridges shall be as given in Table 2.9.

<table>
<thead>
<tr>
<th>Road Classification</th>
<th>Terrain (m)</th>
<th>Clear Roadway Width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural Road (DR and VR)</td>
<td>7.5</td>
<td>5.5</td>
</tr>
</tbody>
</table>

The roadway width specified in Table 2.9 is exclusive of parapet. For rural road, where the Traffic is less than 100 motorized vehicles per day and it is not likely to grow due to situation, like, dead end, low habitation and difficult terrain condition, the roadway width at bridge may be reduced to 4.25 m. otherwise standard is to be followed.

### 4.3.3 Causeway and Submersible Bridge
Roadway width at causeway and submersible bridge shall be as given in Table 2.10.

<table>
<thead>
<tr>
<th>Road Classification</th>
<th>Overall Roadway width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plain and Rolling</td>
</tr>
<tr>
<td>Rural Road (DR and VR)</td>
<td>7.5</td>
</tr>
</tbody>
</table>

### 4.4 Camber
The camber on straight of road should be as recommended in Table 2.11.

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Camber (Per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Rainfall (Annual)</td>
<td>High Rainfall (Annual)</td>
</tr>
</tbody>
</table>
At super-elevated road section, the shoulder should normally have the slope of same magnitude and direction as the pavement slope subject to the minimum cross-fall allowable for shoulder. The camber for earth shoulder should be at least 0.5 per cent more than that for the pavement subject to the minimum of 4 per cent. However, 1 per cent more slope than the camber for pavement is desirable.

4.5 Sight Distances

Visibility is an important requirement for the safety of travel on roads. For this, it is necessary that sight distance of adequate length should be available in different situation of permit drivers enough time and distance to control their vehicles so that chances of accidents are minimized. Three types of sight distance are relevant in the design of road geometry: stopping sights distance (SSD): Intermediate sight distance (ISD) and Overtaking sight distance (OSD).

4.5.1 Stopping sight Distance

The stopping sights distance is the clear distance ahead as needed by a driver to bring his vehicle to a stop before collision with a stationary object in his path, and is calculated as the sum of braking distance required at the particular speed plus the distance travelled by the vehicle during perception and brake reaction time.

4.5.2 Intermediate Sight Distance

Intermediate sight distance is defined as twice the stopping sight distance.

4.5.3 Overtaking sight distance

Overtaking sight distance is the minimum sight distance that should be available to a driver on a two way road to enable him to overtake another vehicle. The prevision of sight distance is by the large not feasible on hill roads and also not considered for single lane roads, the design value for these sight distance and criteria for their measurement are given in Table 2.12 and 2.13 respectively.

TABLE 2.12. DESIGN VALUE OF STOPPING INTERMEDIATE AND OVERTAKE SIGHT DISTANCE

<table>
<thead>
<tr>
<th>Speed (Km/h)</th>
<th>Design Values (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopping sight distance</td>
<td>Intermediate Sight Distance</td>
</tr>
</tbody>
</table>
### TABLE 2.13. CRITERIA FOR MEASURING SIGHT DISTANCE

<table>
<thead>
<tr>
<th>Sight distance</th>
<th>Driver eye Height (m)</th>
<th>Height of Object (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safe stopping sight distance</td>
<td>1.2</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>1.2</td>
</tr>
</tbody>
</table>

In addition to these, on valley curves, night visibility governs the design; the following sections will cover the application of sight distance criteria for geometry design.

### 4.6 Horizontal Alignment

#### 4.6.1 General Guidelines

i. The alignment should be as directional, fluent and matching well with the surrounding topography as a possible and also to avoid abrupt changes.

ii. On new roads the curves should be designed to have the largest practical radius generally not less than the ruling value corresponding to ruling design speed given in table 2.2

iii. Absolute minimum values based minimum speed may be used where economics of construction and site condition so dictates. The radii below the absolute minimum should not be provided.
iv. Straight section executing 3 km length should be avoided. A curvilinear alignment with long curve is better from point of safety and aesthetic.

v. Sharp curves should not be sufficiently long and have suitable transition, since these can be extremely hazardous.

vi. Curve should be sufficiently long and have suitable transition curves at either end to eliminate the shock due to application of centrifugal force. For deflection angle less than 1 degree no curve is required to be designed.

vii. Reverse curve maybe needed in difficult terrain, sufficient length between two curves shall be provided for introduction of requisite transition curve.

viii. To avoid distortion in appearance, the alignment should co-ordinate with the longitudinal profile.

4.6.2 Horizontal Curve

In general, Horizontal curve should consist of circular portion flanked by spiral transition at both ends, design speed, super elevation and coefficient of side friction affect the design of circular curves, length of transition curve is determined on the basis of rate of change of centrifugal acceleration or the rate of change of super elevation.

4.6.3 Super elevation

Super elevation to be provided on curve is calculated from the following formula:

\[ e = \frac{v^2}{225R} \]

Where  
\( e \) = Super elevation in meter per meter
\( V \) = Design speed in Km/hr
\( R \) = Radius of the curve in meters

Super elevation is obtained from the above expression should, however, be kept limited to the following values:

Plain and rolling terrain                  7 per cent  
Snow bound area                            7 Per cent  
Hilly area but not snow bound       8-10 Per cent

Alternative formulas can be used refereeing the ASSHTO Green Book for Highway Geometric Design.

Fig 2.4 indicates the super-elevation rates and radius of curvature for various design speed on this basis. For safety reasons super elevation should be used for all roads regardless of traffic volumes. The only exception is for very large radius curve. When the super elevation calculated is less than the minimum camber required for drainage of surface water no super-elevation is provided. Table 2.16. Shows the radii of horizontal curve for different camber beyond which extra super elevation section achieved gradually over the full length of the transition curve. In case where the transition curve is not provided
for some reason, two third super elevations may be attained on the straight and the balance one-third on the circular curve, keeping in view pavement surface drainage, super elevation should not be less than the rate of camber appropriate for the type of wearing surface.

TABLE 2.14. RADII BEYOND WHICH SUPER ELEVATION NOT REQUIRED

<table>
<thead>
<tr>
<th>Design Speed (Km/h)</th>
<th>Radius (m)</th>
<th>4 Percent camber</th>
<th>3 Percent camber</th>
<th>2.5 percent camber</th>
<th>2.0 percent camber</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>70</td>
<td>90</td>
<td>110</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>100</td>
<td>130</td>
<td>160</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>140</td>
<td>180</td>
<td>220</td>
<td>270</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>180</td>
<td>240</td>
<td>280</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>280</td>
<td>370</td>
<td>450</td>
<td>550</td>
<td></td>
</tr>
</tbody>
</table>

The change from normal cross sectional to a super elevation section made gradually. The normal cambered section of road is changed into super elevation section into two stages. First stage is the removable of the adverse camber in outer half of the pavement. In the second stage, Super elevation is gradually built-up over the full width of the carriageway so that the required super elevation is available at the beginning of the circular curve. There are three different methods for attaining the super elevation:

i. Revolving pavement about the centerline
ii. Resolving pavement about the inner edge of the pavement
iii. Resolving pavement about the outer edge

For rural roads, the first method, i.e., revolving pavement about the centerline will be suitable in most of the situations, since vehicle have the frequently use the shoulders in the case of single lane roads, the shoulder slope on super elevation section should be of the same magnitude and direction as the pavement slope. The required super elevation on shoulder attained simultaneously with the pavement in the same manner in case transition curves are provided, Super elevation is attained over length of transition curve.

4.6.4 Minimum Curve Radii
On new roads, horizontal curve must be designed to have the targeted practical radius generally more than the value corresponding to the ruling design speed. However, absolute minimum values based on
minimum design speed restored to economics of construction or the site condition so dictate. While improving existing roads, curve having radii corresponding to absolute minimum standard will not be flattened unless it is necessary to realign the road for some other reasons. The minimum curve radii for horizontal curves corresponding to the ruling minimum, and absolute minimum design speeds are in Table 2.15.

**TABLE 2.15. MINIMUM RADII OF HORIZONTAL CURVES**

<table>
<thead>
<tr>
<th>Road Category</th>
<th>Plain Terrain</th>
<th>Rolling Terrain</th>
<th>Mountainous Terrain</th>
<th>Steep Terrain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area Not affected by snow</td>
<td>Areas affected by snow</td>
<td>Area not Affected by snow</td>
<td>Area Affected by snow</td>
</tr>
<tr>
<td>Ruling Minimum</td>
<td>Ruling Minimum</td>
<td>Absolute Minimum</td>
<td>Ruling Minimum</td>
<td>Absolute Minimum</td>
</tr>
<tr>
<td>Rural Road (DR &amp; VR), (m)</td>
<td>90</td>
<td>60</td>
<td>60</td>
<td>45</td>
</tr>
</tbody>
</table>

**4.6.5 Transition Curve**

Spiral curve should be used for transition. This is necessary for vehicle to have smooth entry from a straight section into a circular curve. The transition curve also improves aesthetic appearance of the road besides permitting gradual application of the super elevation and extra widening of carriageway needed at the horizontal curve. Transition curve is provided at the both ends of horizontal curve.

Minimum length of transition curve for varicose radii is giving in Table 2.16. For deriving values of the individual’s elements like shift, tangent distance, apex distance, etc., and working out co-ordinate to lay the curves in the field, it is convenient to use curve tables, for this, reference may be made to IRC or AASHTO Geometric design guides.

**4.6.6 Widening at Curves**

At sharp horizontal curve, it is necessary to widen the carriageway to facilitate safe passage of vehicle, the extra width to be provided to horizontal curve are given in Table 2.17. By increasing the width at an approximately uniform rate along the transition curve required widening should be achieved; the extra width should be continued over the full length of the circular curve. The widening should be done on
both sides of the carriageway, except that on hill roads it will be preferable if the entire widening is done only on the inner side of the curve.

### TABLE 2.16. MINIMUM LENGTH OF TRANSITION CURVE FOR DIFFERENT SPEEDS AND CURVE RADII

<table>
<thead>
<tr>
<th>Pain and Rolling Terrain</th>
<th>Mountainous and steep Terrain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curve Radius (m)</td>
<td>Design Speed (km/h)</td>
</tr>
<tr>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Transition Length (m)</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>NA</td>
</tr>
<tr>
<td>60</td>
<td>NA</td>
</tr>
<tr>
<td>90</td>
<td>75</td>
</tr>
<tr>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>150</td>
<td>45</td>
</tr>
<tr>
<td>170</td>
<td>40</td>
</tr>
<tr>
<td>200</td>
<td>35</td>
</tr>
<tr>
<td>240</td>
<td>30</td>
</tr>
<tr>
<td>300</td>
<td>25</td>
</tr>
<tr>
<td>360</td>
<td>20</td>
</tr>
<tr>
<td>400</td>
<td>20</td>
</tr>
<tr>
<td>500</td>
<td>NR</td>
</tr>
<tr>
<td>600</td>
<td></td>
</tr>
<tr>
<td>700</td>
<td></td>
</tr>
<tr>
<td>800</td>
<td></td>
</tr>
<tr>
<td>900</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
</tr>
</tbody>
</table>

NA. Not applicable        NR. Transition not required
### TABLE 2.17 WIDNING OF PAVEMENT AT CURVE

<table>
<thead>
<tr>
<th>Radius of Curve (m)</th>
<th>Up to 20</th>
<th>21-60</th>
<th>Above 60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra widening for 3.75 m Wide single lane Carriageway, (m)</td>
<td>0.9</td>
<td>0.6</td>
<td>Nil</td>
</tr>
</tbody>
</table>

### 4.6.7 Set Back Distance of Horizontal curves

Requisite sight distance should be available across the inner side of the horizontal curve. Lack of visibility in the lateral direction may arise due to obstruction. Like, wall, hill cut, wooded area, high slope, etc. the sight distance is measured along the middle of the inner lane. However, on single lane road, sight distance is measured along the centerline of the carriageway the setback distance is calculated using the following equation:

\[ m = R - (R - n) \frac{S}{2} \]

Where \( \frac{S}{2} \) is \( \frac{S}{2(R - n)} \) radians

\( m \) = the minimum set-back distance from the center line of the road in meters

\( R \) = Radius of the center line of the road in meters

\( n \) = distance between the center line of the road and the inside lane in meters

\( S \) = required sight distance in meters

Utilizing the above equation the design values of the set-back distance corresponding to safe stopping

### TABLE 2.18. RECOMMENDED SET-BACK DISTANCE FOR SINGLE LANE CARRIGEWAY

<table>
<thead>
<tr>
<th>Radius Circular Curve (m)</th>
<th>Set-Back Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S=20 m (V=20 km/h)</td>
</tr>
<tr>
<td>14</td>
<td>3.4</td>
</tr>
<tr>
<td>15</td>
<td>3.2</td>
</tr>
<tr>
<td>20</td>
<td>2.4</td>
</tr>
<tr>
<td>23</td>
<td>2.1</td>
</tr>
<tr>
<td>30</td>
<td>1.7</td>
</tr>
</tbody>
</table>
### 4.7 Vertical Alignment

The designer has to always keep an eye on economy in selection the alignment and the longitudinal profile; it is general practice to follow as closely as possible the natural terrain profile. Desirably there should be no change within the distance of 150 m. two vertical curves in same direction with a short tangent should be avoided. The longitudinal profile should be co-coordinated suitably with the horizontal alignment. Decks of small drainage structure (Culverts and minor bridges) should follow the same profile as the flanking road section without any break in the grade line.

#### 4.7.1 Gradient

The rate of rise or fall with respect to the horizontal along the length of road expressed as ratio or a percentage is termed as the “gradient”. Gradient should be carefully selected keeping in view the design speed and terrain. Various levels of gradients, which are generally adopted for road are as given below:

1. **Ruling gradient:** It is a gradient, which in the normal course must never be exceeding in any part of road.
2. **Limiting gradient:** It is a gradient steeper than the ruling gradient, which may be used, in restricted length where keeping within the ruling gradient is not feasible.
3. **Exceptional gradient:** It is a gradient steeper than the limiting gradient, which may be used in short stretches only in extraordinary situation.
Gradient up to the ‘ruling gradient’ shall be the normal course in design. The ‘Limiting Gradient’ used where the topography of a place compels this or where the adopting of gentler gradient would involve additional cost. In such case also, the length of continuous grades steeper than the ruling gradients should be as short as possible.

Exceptional gradient, are the meant to be adopted only in very difficult situation and for short length not exceeding 100 m at a stretch. In mountainous and steep terrain, successive stretches of exceptional gradient separated by minimum length of 100 m having gentler gradients. Recommended gradient for different classes of terrain except at hair-pin bends are given in Table 2.19 the rise in elevation over a 2 km length shall not exceed 100 m in mountainous terrain and 120 m in steep terrain. In hilly terrain, gradient should be such that it negotiated with the least change of gears by heavier vehicles to save time and operate cost.

<table>
<thead>
<tr>
<th>Terrain</th>
<th>Ruling Gradient</th>
<th>Limiting Gradient</th>
<th>Exceptional Gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain and rolling</td>
<td>6.5 per cent</td>
<td>8 per cent</td>
<td>10 per cent</td>
</tr>
<tr>
<td>(Speed up to 60km/hr)</td>
<td>(Speed up to 40 km/hr)</td>
<td>(Speed up to 25 Km/hr)</td>
<td></td>
</tr>
<tr>
<td>Mountainous terrain and steep terrain</td>
<td>7 per cent</td>
<td>9 per cent</td>
<td>12 per cent</td>
</tr>
<tr>
<td>Mountainous Steep terrain (Special Cases)</td>
<td>7 per cent</td>
<td>15 per cent</td>
<td>17 per cent</td>
</tr>
<tr>
<td>(Roads open to all vehicles)</td>
<td>(Roads open only to cars and pickup trucks)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the plain area, as the road is used by slow moving bullock carts and motors vehicles, gradient adopted should be such that it will not have adverse effect on bullock cart traffic.

With gradient of 10% or greater, it may be advised to pave the road segment, to provide traction for vehicles and to reduce maintenance cost. This should be assessed on a case by case basis. As a general guideline, all roads with a gradient between 6% and 10% should at least have a gravel surface. Above 10%, if the road is not already to be surface dressed, other solutions for earth and gravel roads such as stone block or locally made concrete blocks surface dressing should be considered. In these cases, the availability of local material assessed.
4.7.2 Grade Compensation at curves
At horizontal curves, the gradient should be eased by an amount known as the ‘Grade Compensation,’ which is intended to offset the requirement of extra tractive effort at curves. This is calculated from the following formula:

\[
\text{Grade Compensation (Per Cent)} = \frac{(30+R)}{R}
\]

Subject to a maximum of 75/R, where R is the Radius of the curve in meters.

Since grade compensation is not necessary for gradients flatter than 4 per cent, while compensation of the Grade they need not be eased beyond 4 per cent.

4.7.3 Vertical Curve
Vertical curves introduced for smooth transition at grade changes. Both summit curves and valley curves designed as parabola. The length of the vertical curve is controlled by sight distance requirement, but curve with greater are aesthetically better. Curves provided at all grade changes exceeding those given in Table 2.20. For satisfactory appearance, the minimum length should be as given in the Table 2.20.

<table>
<thead>
<tr>
<th>Design Speed Km/h</th>
<th>Maximum Grade Change (Per Cent) Not Requiring a Vertical curve</th>
<th>Minimum length of Vertical curve (meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 35</td>
<td>1.5</td>
<td>15</td>
</tr>
<tr>
<td>40</td>
<td>1.2</td>
<td>20</td>
</tr>
<tr>
<td>50</td>
<td>1.0</td>
<td>30</td>
</tr>
</tbody>
</table>

Vertical curves are required to provide smooth transition between gradients. They may be crest curves (at the top of slope) or sag curves (at the bottom of slopes).

Vertical curves designed to provide enough distance for approaching vehicles to see each other and to stop safely. They are specified in terms of their lengths.

The minimum length of curve is defined from the equation:

\[
L = KA
\]

Where:
- \( L \) = length of vertical curve (in meter)
- \( A \) = algebraic difference in approaches and exist grades
- \( K \) = a factor depending on design speed, and related to the time required for vehicles to stop safely.
The values of K will be different for crest and sag curves, and for single lane and double lane roads as given in the table below:

<table>
<thead>
<tr>
<th>Design Speed Km/hr</th>
<th>Minimum K values for Crest Curves</th>
<th>Minimum K Values for Sag Curves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Two lane road</td>
<td>Single lane road</td>
</tr>
<tr>
<td>25</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>40</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>50</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>60</td>
<td>18</td>
<td>36</td>
</tr>
</tbody>
</table>

For the basic access approach, the K value for a 25km design speed should be used where possible, to ensure adequate sight distance at the crest of hills.

**Summit Curve**

The length of summit curve is governed by the choice of sight distance according to the operating condition of the road. The required length may be calculated from the formula given in Table 2.21.

**TABLE 2.21. LENGTH OF SUMMIT CURVE**

| When the length of the curve exceed the required sight distance, i.e. L is greater than S | \[ L = \frac{NS^2}{4.4} \] | \[ L = 2S \frac{4.4}{N} \] |
| When the length of the curve is less than required sight distance i.e. L is less than S | \[ L = \frac{NS^2}{9.6} \] | \[ L = 2S \frac{9.6}{N} \] |

Where

N= deviation angle, i.e., the algebraic difference between the two grades

L= length of parabolic vertical curve in meters

S= sight distance requirement in meters

**Valley Curve**

The length of valley curves should be such that for night travel, the headlight beam distance is equal to the stopping sight distance. The length of curve may be calculated using formula given in Table 2.22. The
engineers can select the alternate formula compatible with the design software in use. For references, see AASHTO guides for road geometric design.

**TABLE 2.22. LENGTH OF VALLEY CURVE**

<table>
<thead>
<tr>
<th>Case</th>
<th>Length of Valley Curve</th>
</tr>
</thead>
<tbody>
<tr>
<td>when the length of the curve exceed the requirement sight distance, i.e., L is greater than S</td>
<td>$L = \frac{NS^2}{1.5 + 0.035S}$</td>
</tr>
<tr>
<td>when the length of the curve is less than the required sight distance, i.e., L is less than S</td>
<td>$L = \frac{1.5 + 0.035S}{N}$</td>
</tr>
</tbody>
</table>

Where

N= deviation angle, i.e., the algebraic difference between the two grades

L= length of parabolic vertical curve in meters

S= Stopping sight distance in meter

**4.8 Alignment Compatibility**

As a general rule, changes in horizontal and vertical alignment should be phased to coincide with each other, i.e., the vertical curve should roughly extend from the commencement to the end of the corresponding horizontal curve. Preferably, the horizontal curves should be somewhat longer than the vertical curve. Sharp horizontal curve should not be introduced at or near the top of the summit vertical curve or the lowest point of valley curve.

**4.9 Hair Pin Bends**

A hair-Pin bend may be designed as a circular curve with transition at each end. Alternatively, compound circular curves may be provided. The following design criteria should be followed normally for the design of hair-pin bends:

- Minimum design speed: 20 Km/hr
- Minimum roadway width at apex: 7.5 m
- Minimum radius for the inner curve: 14.0 m
- Minimum length of transaction curve: 15.0 m

Gradient
<table>
<thead>
<tr>
<th>Maximum</th>
<th>1 in 40 (2.5 per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>1 in 200 (0.5 per cent)</td>
</tr>
<tr>
<td>Super elevation</td>
<td>1 in 10 (10 per cent)</td>
</tr>
</tbody>
</table>

The inner and outer edge of the roadway should be concentric with respect to centerline of the pavement. Where a number of hair-pin bends to enable the driver to negotiate the alignment smoothly. Widening of hair-bends is a difficult and costly process. Moreover, gradient tend to become sharper, as widening can be achieved generally only by cutting the hillside. These points should be kept in view at the planning stage, especially where a series of hair-pin bends is involved. At hair-pin bends, preferably the full roadway width should be provided with surfacing.

4.10 Passing Places

On hill roads passing places are required to facilitate crossing of vehicles. These are provided at the rate of 2 to 3 per kilometer. The exact location should be judiciously decided on the basis of site conditions, the length of passing place should be about 20 to 30 m long with a carriageway width of 5.5 m.

4.11 Lateral and Vertical Clearance

4.11.1 Lateral Clearance

It is desirable that the full roadway width at the approaches carried through the underpass. This implies that the minimum lateral clearance (i.e., the distance between the extreme edge of the carriageway and the face of the nearest support whether a solid abutment, pier or column) should be equal to the normal shoulder width.

4.11.2 Vertical Clearance

The minimum vertical clearance of 4.5 m should be ensure over the full width of the roadway at all underpasses, and similarly at overhanging cliffs, the vertical clearance should be measured in reference to the highest point of the carriageway, i.e., the crown or the super elevated edge of the carriageway as the case maybe. Due allowance for any future raising/strengthening of the pavement should also made.

4.11.3 Traffic Engineering Requirements

The rural roads are low volume (Traffic) low speed roads with maximum design speed of 50 kph. The geometric design are detailed in this chapter adequately fulfills the requirements of traffic that is likely to use rural roads. However, a few features need careful consideration to maintain safety and convenient of the vehicle using these roads.

4.11.4 Intersection with other road

A rural Road quite often meets or crossing another road of higher category in such situation the junction layout is required to be provided in such a way that the safety of the vehicle leaving the higher category of road and joining the rural road or those which join the higher category of road from the rural road is maintain adequately. As the higher category of the road will normally have wider right of-way provision,
the interaction is flared along the higher category of road. The rural road should not meet the other road at an angle other than 90°. Thus wherever such condition prevails, effort should be made to realign the road near the junction and make it a right angled junction.

4.11.5 Other Traffic engineering features
The Rural roads are designed and constructed as single land road with selected or unsealed surface depending on traffic and other criteria. Thus, there is no requirement of pavement marking regarding the signs; the following requirement should be met.

Stop Sign: When rural road shall have all the necessary direction signs as per the requirement of road signage.

Kilometer stone: The rural road shall have kilometer stone of standard size as given by NRAP with Top pounded portion painted in orange color.
5. Pavement Design

5.1 Parameters of Design

5.1.1 Traffic
The total load applications due to all the mixed traffic within the design period converted to the 18-kip ESAL ($W_{18}$). For more details see the Traffic Counting Sheet.

$$W_{18} = D_0 * D_L * w_{18}$$

$D_0$ = a directional distribution factor, expressed as a ratio, that accounts for the distribution of ESAL units by direction.

$D_L$ = a lane distribution factor, expressed as a ratio, that accounts for the distribution of traffic when two or more lanes are available in one direction. The following table may be used.

Table–1: Recommended values for lane distribution Factor, $D_L$

<table>
<thead>
<tr>
<th>No. of lanes in each direction</th>
<th>Fraction 18-kip ESAL in Design Lane, $D_L$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>0.80 – 1.00</td>
</tr>
<tr>
<td>3</td>
<td>0.60 – 0.80</td>
</tr>
<tr>
<td>4</td>
<td>0.50 – 0.75</td>
</tr>
</tbody>
</table>


$W_{18}$ (Tone year) = the cumulative two-direction 18-kip ESAL, see traffic count unite:

5.1.2 Reliability ($R$)
The concept of incorporating the reliability factors into the design procedure was developed to ensure that the various design alternatives would allow for inherent design and construction variability and so they would perform as they were intended in the design period.

Table-2: Recommended levels of reliability for various functional classifications

<table>
<thead>
<tr>
<th>Functional Classification</th>
<th>Recommended Levels of Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>85 – 99.9</td>
</tr>
<tr>
<td>Rural</td>
<td>80 – 99.9</td>
</tr>
<tr>
<td>Interstate and other freeways</td>
<td>80 - 99</td>
</tr>
<tr>
<td>Principal arterials</td>
<td>80 - 95</td>
</tr>
<tr>
<td>Collectors</td>
<td>50 - 80</td>
</tr>
</tbody>
</table>


5.1.3 Environmental Effects
The AASHTO design equations were developed from the results of the road tests over a two year period. The long term effects of temperature, moisture, and material aging on pavement performance indirectly accounted for in the road test data.
Also, if the effects of swell clay and frost heave of sub-grade soil on the performance of the pavement in a specific region are significant, the loss of serviceability over the design period estimated and added to that due to traffic loads.

5.1.4 Serviceability
Initial serviceability and terminal serviceability indexes must be established to compute the change in serviceability (ΔPSI) in the design equation given in the AASHTO design chart for flexible pavement. The initial serviceability index is a function of pavement construction quality. Typical values from the AASHTO road test were 4.2 and 4.5, respectively, for flexible and rigid pavements. The terminal serviceability index is the lowest index that is tolerable for pavements before it requires rehabilitation. A terminal index of 2.5 is suggested by the AASHTO Guide for major highway pavements, whereas a value of 2.0 suffices for other pavements. In addition, the change in serviceability (ΔPSI) should also include the loss of serviceability during the design period due to the potential sub-grade swelling and frost heave.

5.1.5 Effective Roadbed Soil Resilient Modulus (MR)
The basis for sub-grade soil property in the current version of the Guide is resilient modulus. An effective roadbed soil resilient modulus established that is equivalent to the combined effect of the sub-grade resilient modulus of the entire seasonal resilient module. It is given from Table 16-12 of AASHTO standard (1993).

Or we can select the volume of $M_R$ from the following equations.

1- For fine-grained soils with a soaked CBR between 5 and 10%, use the following equation to correlate CBR to resilient modulus($M_R$):

Design $M_R$ (psi) = 1500 x CBR

2- For non-fine-grained soils with a soaked CBR greater than 10%, use the following equation:

Design $M_R$ (psi) = 3000 x CBR$^{0.65}$

5.1.6 Standard Error
$S_o$ = combined standard error of the traffic prediction and performance prediction. This variable defines how widely the two basic design inputs, traffic and performance, can vary. For instance, traffic estimated at 2,000,000 ESALs over 20 years. However, actual traffic may turn out to be 2,500,000 ESALs over 20 years due to unanticipated population growth. Similarly, pavement design factors may turn out to be different than estimated. What these two brief examples are expressing is that structural design input values can vary from those initially chosen and the equation must account for this somehow. The more these values vary, the higher the value of $S_o$.

For example, the basic 1993 AASHTO Guide flexible design equation is:
The right side of the above equation is then augmented with $S_0$ (to account for input value variability) and $Z_R$ (to establish a confidence level that a certain design will perform as intended) to obtain the final form of the equation:

$$\log_{10}(W_{18}) = Z_R \times S_0 + 9.36 \times \log_{10}(SN + 1) - 0.20 + \frac{\log_{10} \left( \frac{\Delta PSI}{4.2 - 1.5} \right)}{\frac{1094}{(SN + 1)^{0.15}}} + 2.32 \times \log_{10}(M_r) - 8.07$$

Values of $Z_R$ are always negative. Therefore, the quantity $(Z_R \times S_0)$ is always negative and will serve to decrease the predicted number of 80 KN (18,000 lb.) ESALs that a particular design can accommodate.

At first glance it may seem unusual that the quantity $(Z_R \times S_0)$ is added to the right side of the equation rather than multiplied. However, if the logarithm on the left side of the equation is removed through algebraic manipulation, it can be seen that the quantity $(Z_R \times S_0)$ would then be multiplied with the resulting equation.

It will be given from $(0.35 - 0.5)$

### 5.1.7 Determination of the Required Structural Number

The AASHTO design chart for flexible pavement represents the monograph for determining the design structural number (SN) required for the specific input conditions. The required inputs are

- Estimated future traffic ($W_{18}$)
- Reliability ($R$)
- Overall standard deviation ($S_0$)
- Effective roadbed soil resilient modulus ($M_r$)
- Design serviceability loss ($\Delta PSI$)

### 5.1.8 Selection of Pavement Thickness Designs

The Structural Number (SN) characterizes the pavement structure. The Structural Number is an abstract number expressing the structural strength of a pavement required for given combinations of soil support ($M_r$), total traffic expressed in ESALs, terminal serviceability and environment. The Structural Number is converted to actual layer thicknesses (e.g., 150 mm (6 inches) of HMA) using a layer
coefficient \(a\) that represents the relative strength of the construction materials in that layer. Once the structural number is determined, it is necessary to determine the thickness of the various layers in a flexible pavement that will provide the required load carrying capacity that corresponds to this design structural number, according to the following equation:

\[
SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3
\]

Where \(a_i\) = layer coefficient of layer \(i\)

\(D_i\) = thickness of layer \(i\), inch

\(m_i\) = drainage modifying factor for layer \(i\)

5.1.9 Layer Coefficients \(a_i\)

The AASHTO flexible pavement layer coefficient is a measure of the relative effectiveness of a given material to function as a structural component of the pavement. It is given from AASHTO coefficient chart for different layers.
depends on the quality of drainage and percentage of time the pavement structure is saturated. The quality of drainage is measured by the length of time it takes for water to be removed from the base or subbase.

**General Procedure for Selection of Layer Thickness**

The procedure for selecting the pavement layer thickness usually starts from the top, as shown in Figure 16-18.

1. Using $E_2$ as $M_r$ and Figure 16-11, determine the structural number $SN_1$ required to protect the base, and compute the thickness of layer ($D_1$):

   \[ D_1 \geq \frac{SN_1}{a_1} \]  

   (16-9)

   For practical reasons, the chosen thickness may not be exactly equal to the computed thickness. For example, the layer thickness is usually rounded up to the nearest one-half inch. In addition, for reasons of practicality and economy, certain minimum thicknesses are recommended by AASHTO as Table 16-8 indicates. Subsequent calculations should use the values for $D$ and $SN$ actually used rather than the calculated value. These values are designated by an asterisk in the equations.

2. Using $E_2$ as $M_r$ and Figure 16-11, determine the structural number $SN_2$ required to protect the subbase, and compute the thickness of the layer ($D_2$):

   \[ D_2 > \frac{(SN_2 - SN_1^*)}{a_2} \]  

   (16-10)
3. Using the roadbed soil resilient modulus and Figure 16-11, determine the structural number \( SN_3 \) required to protect the roadbed soil and compute the thickness of layer 3 \( D_3 \):

\[
D_3 \geq (SN_1 - SN_1^* - SN_3^*)/a_{gm2}
\]  

(16-11)

**EXAMPLE 16-3**

Flexible Pavement Design by the AASHTO Method

A flexible pavement is to be designed for a rural Interstate highway to carry a design ESAL of \( 3.0 \times 10^6 \). It is estimated that the subbase for the pavement structure will be exposed to moisture levels approaching saturation approximately 5 percent of the time, and the overall quality of the drainage is “Fair.” The base will be exposed to saturation-level moisture approximately 10 percent of the time.

The following additional information is available:

- Resilient modulus of the asphalt concrete at 68°F = 420,000 psi \( (a_1 = 0.42) \)
- The granular base CBR = 70 and \( M_s = 24,000 \) \( (a_2 = 0.13) \)

(1) Scale derived by correlation obtained from Illinois.
(2) Scale derived on NCHRP project (4).
An untreated granular subbase has a CBR = 9 and $M_r = 10,000$ ($a_3 = 0.075$). The subgrade has a CBR = 1 and $M_r = 1,500$. Reliability level = 85 percent. Standard deviation = 0.45. Serviceability loss = 2 percent.

Design the pavement by the AASHTO method.

**Solution**

By Figure 16-11, $SN_1 = 2.45$.

By Eq. 16-9, $D_1 \geq \frac{SN_1}{a_1} = 2.45/0.42 = 5.8$ in. Use $D_1 = 6.0$ in.

$SN_1^* = D_1^* a_1 = 6 \times 0.42 = 2.52$.

By Figure 16-11, $SN_2 = 3.5$.

By Eq. 16-10, $D_2 \geq \frac{(SN_2 - SN_1^*)}{a_2 m_2} = (3.5 - 2.52)/0.13(0.95) = 7.9$ in. Use $D_2^* = 8$ in.
By Figure 16-11, $SN_3 = 5.5$
By Eq. 16-10, $SN_2^* - SN_1^* = D_2a_2m_2 = 8(0.13)(0.95) = 0.988$
$SN_2^* = 2.52 + 0.988 = 3.50$
By Fig. 16-11, $SN_3 = 6.5$
By Eq. 16-11, $D_3 \geq (SN_3 - SN_1^* - SN_2^*)/a_3m_3 = (6.5 - 2.52 - 3.50)/0.075(0.90) = 7.1$ in. Use $D_3^* = 7.5$ in.

By the AASHTO method, the pavement has a 6-in. surface, an 8-in. base, and a 7.5-in. subbase.

16-13 CONCLUSION

In recent years, a great deal of progress has been made in developing more reliable pavement structural design methods. Formerly, design procedures relied heavily on subjective engineering judgments based on evaluations of pavement performance under service conditions. As more is learned about the mechanical properties of paving and subgrade materials and the mechanics of pavement failure, engineers
(1) Scale derived by averaging correlations from Illinois, Louisiana and Texas.
(2) Scale derived on NCHRP project (4).

FIGURE 16-17 Variation in a for cement-treated bases with base strength parameter. (Courtesy American Association of State Highway and Transportation Officials.)

TABLE 16-7 Recommended m, Values for Modifying Structural Layer Coefficients of Untreated Base and Subbase Materials in Flexible Pavements

<table>
<thead>
<tr>
<th>Quality of Drainage</th>
<th>Less Than 1%</th>
<th>1%–5%</th>
<th>5%–25%</th>
<th>Greater Than 25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>1.40–1.35</td>
<td>1.35–1.30</td>
<td>1.30–1.20</td>
<td>1.20</td>
</tr>
<tr>
<td>Good</td>
<td>1.35–1.25</td>
<td>1.25–1.15</td>
<td>1.15–1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Fair</td>
<td>1.25–1.15</td>
<td>1.15–1.05</td>
<td>1.00–0.80</td>
<td>0.80</td>
</tr>
<tr>
<td>Poor</td>
<td>1.15–1.05</td>
<td>1.05–0.80</td>
<td>0.80–0.60</td>
<td>0.60</td>
</tr>
<tr>
<td>Very poor</td>
<td>1.05–0.95</td>
<td>0.95–0.75</td>
<td>0.75–0.40</td>
<td>0.40</td>
</tr>
</tbody>
</table>
5.1.10 Drainage Modifying Factor (mi)
The drainage modifying factor depends on the quality of drainage and percentage of time the pavement structure is saturated. The quality of drainage is measured by the length of time it takes for water to be removed from the base of sub-base. It is given from the AASHTO standard for flexible pavement design (1993).

5.1.11 ZR = standard normal deviate
The standard normal table value corresponding to a desired probability of exceeding levels. For example, a designer may specify that there should only be a 5 % chance that the design does not last a specified number of years (e.g., 20 years). This is the same as stating that there should be a 95 % chance that the design does last the specified number of years (e.g., 20 years). Then, the reliability is 95 % (100 % - 5 %) and the corresponding ZR value is -1.645 (see 1993 AASHTO Guide, Table 4.1, p. I-62).

So we can use the following table for selecting of standard normal deviate.

<table>
<thead>
<tr>
<th>ZR = standard normal deviate</th>
<th>Reliability (R)</th>
<th>Road types</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.841 to -1.645</td>
<td>80 to 95</td>
<td>Regional High way</td>
</tr>
<tr>
<td>-0.674 to -1.645</td>
<td>75 to 95</td>
<td>National High way</td>
</tr>
<tr>
<td>-0.524 to -1.282</td>
<td>70 to 90</td>
<td>Provincial Road</td>
</tr>
<tr>
<td>0 to -0.841</td>
<td>50 to 80</td>
<td>Rural Roads</td>
</tr>
</tbody>
</table>

5.1.12 Allowable Rutting
In this design guide, rutting is considered only as a performance criterion for aggregate-surfaced roads. Although rutting is problem with asphalt concrete surface pavements, no design model suitable for incorporation into this guide is available at this time. It is important to note that the fur depth failure predicted by the aggregate-surfaced road model does not refer to simple surface rutting (which can be corrected by normal balding operations), but to serious rutting associated with deformation of the pavement structure and roadbed support. The allowable rut depth for an aggregate-surfaced road is dependent on the average daily traffic. Typically, allowable rut depths range is 1 to 1.5 inches for aggregate-surfaced road. 1.5 inches is for highway and 1 is for provincial road.

5.1.13 Aggregate Loss
For aggregate-surfaced road, an additional concern is the aggregate loss due to traffic and erosion. When aggregate loss occurs, the pavement structure becomes thinner and the load-carrying capacity is reduced. This reduction of the pavement structure thickness increases the rate of surface deterioration.

To treat aggregate loss in the procedure, it is necessary to estimate (1) the total thickness of aggregate that will be lost during the design period, and (2) the minimum thickness of aggregate that is required to keep a maintainable working surface for the pavement structure.

\[ G_{17\text{YEARS}} = \left( \frac{T^2}{(T^2+50)} \right) \times \left[ f \left( 4.2 + 0.0092T + 0.88R^2 + 1.88VC \right) \right] \]
GL\textsubscript{7YEARS} = total aggregate loss in 7 years, in inches
T = 7 years traffic volume in both direction in thousands of vehicles
R = Annual rainfall, in inches
VC = Average percentage gradient of the road

\[ f = \text{aggregate types coefficient} \]

<table>
<thead>
<tr>
<th>Aggregate Type</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateritic gravels</td>
<td>0.037</td>
</tr>
<tr>
<td>Quartzic gravels</td>
<td>0.043</td>
</tr>
<tr>
<td>Volcanic gravels</td>
<td>0.028</td>
</tr>
<tr>
<td>Coral gravels</td>
<td>0.059</td>
</tr>
</tbody>
</table>

General Procedure for Selection of Layer Thickness:

1. Selection of layers thickness from layer wise SN: The procedure for selection the pavement layer thickness usually starts from the top. See the AASHTO flexible pavement design chart for layer coefficient (\(a_i\)) or see the AASHTO pavement design equation.

2. Using \(M_r\) and \(a_1\) the coefficient chart determines the structural number \(SN_1\) required, protecting the base and computing the thickness of layer \((D_1)\):
\[ D_1 \geq SN_1/a_1 \]

3. Using \(M_r\) and \(a_2\) coefficient chart determine the structural number \(SN_2\) required protecting the base and computing the thickness of layer \((D_2)\):
\[ D_2 > (SN_2 - SN_1^*)/a_2m_2 \]

4. Using \(M_r\) and \(a_3\) coefficient chart determine the structural number \(SN_3\) required protecting the base and computing the thickness of layer \((D_3)\):
\[ D_3 \geq (SN_3 - SN_2^* - SN_1^*)/a_3m_3 \]
Selection of layers thickness with trail method:
The selection of layers thickness with trail method is dependent on general SN. See the following equation.

\[ SN = D_2a_2m_2 + D_3a_3m_3 \]

First find the General SN from following equation.

\[
\log_{10}(W) = Z \times S_o + 9.36 \times \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2 - 1.5}\right)}{1094} + 2.32 \times \log_{10}(M_x) - 8.07
\]

Secondly, select the primary thickness for bas-course and sub-base and put in the following trail equation.

\[ SN \leq D_2a_2m_2 + D_3a_3m_3 \]

When the both side of equation become equal than the base-course and sub-base layers thickness is ok.

For more information see to the excel sheet calculation.

Workout Design example with trail method:

Design parameters which are given from the tables of the AASHTO standard:

\[ R = 75 \]
\[ S_o = 0.4 \]

Traffic Count:

As we found 160 ADT and this is less than 500, so we should use 500 ADT for this pavement design.
Cumulative Traffic during analysis period for one day \((T) = \frac{((1+r)^n - 1)}{r} \times T_1 = ((1+0.026)^n -1) \times 500/0.026 = 3785\) vehicles per day

From traffic count we know 55% is all cars and 45% is all trucks.

**Truck Classification:**

ADT rate estimated from traffic survey.

- ADT (Mixed): 500 Vehicles
- Cars (A): 58%
- All Trucks (T): 42%
  - Single Truck with 2 axle, 4 tires (B): 33.5% of (T)
  - Single Truck with 2 axle, 6 tires (C): 33.5% of (T)
  - Single Truck with 3 axle, more than 6 tires (D): 26% of (T)
  - Tractor, Semi-tractor with 5 axle or more (E): 7% of (T)

50% of (D) is Overloaded truck - 12 Ton single axle truck (F)

And we can calculate ESAL as following tables:

<table>
<thead>
<tr>
<th>No</th>
<th>Class</th>
<th>Number of Vehicles</th>
<th>Truck Factor</th>
<th>ESAL(_{W18})</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>2195.3</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>532.55</td>
<td>0.017</td>
<td>9.053</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>532.55</td>
<td>0.41</td>
<td>218.34</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td>413.3</td>
<td>1.26</td>
<td>520.78</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>E</td>
<td>111.3</td>
<td>1.67</td>
<td>185.83</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>207.0</td>
<td>4.5</td>
<td>931.5</td>
<td></td>
</tr>
<tr>
<td>Sub Total</td>
<td></td>
<td>3992</td>
<td></td>
<td>1866</td>
<td></td>
</tr>
</tbody>
</table>

Truck factor is used from AASHTO, chapter 16, flexible pavement design

**ESAL\(_{W18}\) one day = 1866**

For more information see traffic survey count sheet.

Cumulative ESAL during analysis period for one year \(= (T_{\text{one year}}) = T \times 365 = 681,090\) vehicles per day

**Designed ESAL = D_0 \times D_L \times T_{\text{one year}} = 0.5 \times 1 \times 681,090 = 340,545**

\(D_0 = \text{division factor} = 0.5\)

\(D_L = 1.0\)

Layers Coefficient:
a₂ = 0.13
a₃ = 0.105

Note: ai is given from AASHTO pavement design standard coefficient chart, see design criteria.

If we see to the geotechnical report the sub grade minimum CBR is more than 9%. But we will give 8% CBR from IRD requirement.

Sub grade Design Mₚ (psi) = 1,500 x CBR
MR = 1,500 X 8 = 12,000psi

Required parameters:
SN = ?
D₂ = ?
D₃ = ?

Design Procedure:

\[
\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN + 1) - 0.20 + \frac{\log_{10} \left( \frac{\Delta PSI}{4.2 - 1.5} \right)}{1094} + 2.32 \times \log_{10}(MR) - 8.07
\]

\[
\log_{10}(340545) = -0.654 \times 0.4 + 9.36 \times \log_{10}(SN + 1) - 0.2 + \frac{\log_{10} \left( \frac{\Delta PSI}{4.2 - 1.5} \right)}{1094} + 2.32 \times \log_{10}(12000) - 8.07
\]

SN = 2.03

Trail-1:
If we select D₂ = 10cm or 3.937inch and D₃ = 20cm or 7.874inch hence:

SN ≤ D₂*a₂*m₂ + D₃*a₃*m₃

2.03 ≤ 3.937 x 0.13 x 1 + 7.874 x 0.105 x 1

2.03 ≥ 1.338

Result if field we should try again.
Trail 2:

If we select \( D_2 = 10.0 \text{cm} \) or 3.973 inch and \( D_3 = 38 \text{cm} \) or 14.8 inch, hence:

\[
SN \leq D_2 a_2 m_2 + D_3 a_3 m_3
\]

\[
2.03 \leq 3.973 \times 0.13 \times 1 + 14.80 \times 0.105 \times 1
\]

\[
2.03 \leq 2.05
\]

Result is good.

Now we should calculate aggregate loss:

\[
G_{7\text{YEARS}} = \left[ \frac{T^2}{(T^2+50)} \right] \times [f (4.2+0.0092T+0.88R^2+1.88VC)]
\]

From design criteria:

\( T = 340.54 \)

\( F = 0.037 \)

\( R = 3.26 \)

\( VC = 0.05 \)

\[
G_{7\text{YEARS}} = \left[ \frac{340.54^2}{(340.54^2+50)} \right] \times [0.037 (4.2+0.0092*340.54+0.88*3.26^2+1.88*0.05)]
\]

\[
G_{7\text{YEARS}} = 0.621 \text{inch} = 1.577 \text{cm}
\]

Allowable Rutting:

It is typically given 1 inch or 2.54 cm.

Result for Gravel Pavement:

Aggregate Loss = 1.577cm

Allowable rutting = 2.54cm

\( D_{2\text{final}} \) (Surface Course thickness) = \( D_2 + GL + \) Allowable rutting depth

\[
D_{2\text{final}} = 10.0 + 1.577 + 2.54 = 14.177 \text{cm} = 15 \text{cm}
\]

\( D_3 \) (base Course thickness) = 40cm
5.2 Sample

See to the pavement design excel sheet for more information:

### Aggregate Surfaced Pavement Structural Design, 1993 AASHTO

<table>
<thead>
<tr>
<th>Variable Parameters</th>
<th>Soil Resilient Modulus (MPa) - PSi</th>
</tr>
</thead>
<tbody>
<tr>
<td>W_15</td>
<td>340.545</td>
</tr>
<tr>
<td>Z_r</td>
<td>-0.654</td>
</tr>
<tr>
<td>S_0</td>
<td>0.4</td>
</tr>
<tr>
<td>L_PSI</td>
<td>2.5</td>
</tr>
<tr>
<td>M_r</td>
<td>12000</td>
</tr>
<tr>
<td>SN</td>
<td>2.03</td>
</tr>
</tbody>
</table>

#### 1993 AASHTO Guide basic design equation for flexible pavements

\[
\log_{10} W_{15} = Z_0 S_0 + 9.26 \log_{10} [SN+1] - 0.2 + \left( \log_{10} \left( \frac{S_0}{4.2 - 1.5} \right) \right) \left( \frac{0.4 + 1094(SN+1)^{0.59}}{} \right) + 2.32 \log_{10} M_r - 8.07
\]

| 5.530 | 5.54 |

#### Soil Resilient Modulus (MPa) equation by psr

<table>
<thead>
<tr>
<th>M_P SI = 3000 CBR</th>
<th>if CBR &gt; 10</th>
<th>24310</th>
</tr>
</thead>
<tbody>
<tr>
<td>M_P SI = 1500 CBR</td>
<td>if 5 ≤ CBR ≤ 10</td>
<td>12000</td>
</tr>
<tr>
<td>CBR &gt; 25</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>5 ≤ CBR ≤ 10</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

#### Layers Thickness Trail equation

| a2 | 0.13 | m2 | 1 | D2, cm | 10 |
| a3 | 0.103 | m3 | 1 | D3, cm | 30 |
| SN | D1 = a1'm1 + D2 = a2'm2 |

#### Aggregate Loss equation

\[
G_{7 YEARS} = \left[ \frac{T^2}{(T^2 + 50)} \right] \cdot \left( 4.2 + 0.0092T + 0.88R + 1.88V_G \right)
\]

<table>
<thead>
<tr>
<th>GL_YEARS</th>
<th>Total aggregate loss in 7 years, in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>Traffic volume in both direction in thousand of vehicles</td>
</tr>
<tr>
<td>R</td>
<td>Annual rainfall, in inch</td>
</tr>
<tr>
<td>V_G</td>
<td>Average percentage gradiant of the road</td>
</tr>
</tbody>
</table>

#### Variable Parameters

| T  | 340.545 |
| R  | 3.28    |
| V_G| 0.050   |
| T | 0.037   |

#### Allowable Rutting (r), Inch

Typically, allowable rut depths (r) range is 1 inch for major aggregate surfaced Road, so r = 1 inch = 2.54 cm

<table>
<thead>
<tr>
<th>D2</th>
<th>D3</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.117</td>
<td>15 cm</td>
</tr>
<tr>
<td>38.000</td>
<td>40 cm</td>
</tr>
</tbody>
</table>
6. References:

AASHTO Green Book of 2007
AASHTO Guide for design of pavement structure, 1993
AASHTO LRFD Bridge Design 2007
AASHTO Road Side Design
Highway Design Indian Roads Congress
IRC Road Geometric Design
IRC Rural Roads Standard
MPW (Ministry of Public Work) Standard
NRAP Technical Manual
Road Classified (AASHTO): Rural System - Collector Major