Rwanda Standards Board

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Second edition

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Feeder roads —

Part 1:

Guidelines for design

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In order to match with technological development and to keep continuous progress in industries, standards are subject to periodic review. Users shall ascertain that they are in possession of the latest edition

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Foreword

Rwanda Standards are prepared by Technical Committees and approved by Rwanda Standards Board (RSB) Board of Directors in accordance with the procedures of RSB, in compliance with Annex 3 of the WTO/TBT agreement on the preparation, adoption and application of standards.

The main task of technical committees is to prepare national standards. Final Draft Rwanda Standards adopted by Technical committees are ratified by members of RSB Board of Directors for publication and gazettment as Rwanda Standards.

DRS 267-1 was prepared by Technical Committee RSB/TC 009, *Building materials and civil engineering*.

In the preparation of this standard, reference was made to the following standards:

1) Rwanda Feeder Roads Standards — RFRS/Vr14/05/07BL — Final Report

2) ISO 6707-1: 2020, *Buildings and civil engineering works — Vocabulary — Part 1: General terms*

3) AASHTO 1993, *Guide for design of pavement structures*

4) Low Volume Roads — Volume 1: Pavement Design —Republic of Malawi

The assistance derived from the above source is hereby acknowledged with thanks.

This second edition cancels and replaces the first edition (RS 267-1: 2015), of which has been technically revised.

RS 267 consists of the following parts, under the general title *Feeder roads*:

— *Part 1: Guidelines for design*

— *Part 2: Guidelines for maintenance*

Committee membership

The following organizations were represented on the Technical Committee on *Building materials and civil engineering* (RSB/TC 009) in the preparation of this standard.

Institution of Engineers Rwanda

Ministry of Infrastructure (MININFRA)

NPD Ltd

Rwanda Transport Development Agency (RTDA)

Rwanda Public Procurement Authority (RPPA)

TECOS Ltd

University of Rwanda-College of Science and Technology (UR-CST)

Rwanda Standards Board (RSB) - Secretariat

Introduction

Road is one of the transport infrastructure which facilitates local and international exchange of goods and services. Adequate transport of agricultural products between different parts of the country contributes to the socio-economic development of local population through easy access to markets, modernization and commercialization of agriculture, creating possibilities for transporting modern agricultural inputs and machineries to farms hence creating new opportunities and value addition to raw products.

To enhance connectivity to agricultural market centres, guidelines on effective design, construction and maintenance of roads linking agricultural areas with commercial centres and/or processing plants are necessary to provide guidance on cost effectiveness of the roads as well as technical guidance to designers and contractors.

Regardless of the hierarchal classification of roads in Rwanda, road that links districts, productive areas or other urban centres to national roads and other low volume roads having less than 300 vehicle per a day and Equivalent standard Axle road less than 1 million during the design period either paved or unpaved are defined as "***Feeder roads***".

This standard provides designers and contractors of feeder roads with uniform set of guidelines, which address elements for design such as horizontal and vertical alignments, cross section, drainage, materials, pavement and seismic considerations. It also provides requirements specific to paved and unpaved feeder roads.

In this standard, the term" should" expresses recommendations, whereas "shall" expresses requirements.

Feeder roads — Part 1: Guidelines for design

1 Scope

This Draft Rwanda Standard provides guidelines for the design of feeder roads intended for a transport chain with one end in the agricultural fields and the other on the farm gate, the transport chain from the farm gate network to collection centre, post-harvest processing and storage facilities and a transport chain from one of the latter to local markets, processing centres, post-harvest storage facility centres to district roads.

This standard is applicable to classified roads. It excludes unclassified roads.

2 It applies to paved and unpaved feeder roads. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

RS ISO 22476–2, *Geotechnical investigation and testing — Field testing — Part 2: Dynamic probing*

RS 265, *Precast reinforced concrete pipe culvert — Specification*

3 Terms and definitions

For the purposes of this standard, the following terms and definitions apply.

3.1

feeder road

road which links districts, productive areas or other urban centres to national roads

3.2

productive areas

centres for agricultural production activities, public utilities, community development centres, business centres, economic zones, dumping sites, administrative offices, natural ressources processing, tourist sites

3.3

Low Volume Road (LVR)

road having less than 300 vehicle per day and cumulative Equivalent standard Axle road less than 1 million for the design period

3.4

access road

lowest level of road in the network hierarchy with the function of linking traffic to and from community/public areas, either direct to adjacent urban centres or to the nearby road network;

3.5

unclassified road

roads that are not assigned to classes or categories

3.6

Average Daily Traffic (ADT)

total traffic volume during a given time period in whole days greater than one day and less than one year divided by the number of days in that time period

3.7

Average Annual Daily Traffic (AADT)

total yearly traffic volume in both directions divided by the number of days in the year

3.8

back slope

area proceeding from ditch bottom to the limit of the earthworks

3.9

bridge

structure erected for carrying a road over a river or any other gap with a single span-length or sum of span lengths of 4.0 m or more. Where the clear span is less than four metres, the structure is a culvert

3.10

carriageway

part of the road constructed for use by moving traffic, including auxiliary lanes, climbing lanes, and passing places but excluding shoulders

3.11

travelled way

That part of the carriageway used for the movement of vehicles, exclusive of auxiliary lanes, bus-bays and shoulders.

3.12

circular curve

usual curve configuration used for horizontal curves

3.13

clear zone

unencumbered roadside recovery area

3.14

climbing lane

auxiliary lane in the upgrade direction for use by slow moving vehicles and to facilitate overtaking, thereby maintaining capacity and freedom of operation on the carriageway

3.15

compound curve

curve consisting of two or more arcs of different radii curving in the same direction and having a common tangent or transition curve where they meet

3.16

cross-fall

tilt or transverse inclination of the cross-section of a carriageway which is not cambered, expressed as a percentage

3.17

cross-section

vertical section of the road at right angles to the centre line

3.18

deflection angle

successive angles from a tangent subtending a chord and used in setting out curves

3.19

design speed

a selected speed used to determine the various geometric design features of the roadway to ensure a safe operation of vehicles.

3.20

design traffic volume

number of vehicles or persons that pass over a given section of a lane or carriageway during a time period of one hour or more

3.21

design vehicle

vehicle whose physical characteristics and proportions are used in setting geometric design

3.22

design volume

volume determined for use in design, representing traffic expected to use the road

3.23

embankment

portion of the road prism composed of approved fill material, which lies above the original ground and is bounded by the side slopes, extending downwards and outwards from the outer shoulder breakpoints and on which the pavement is constructed

3.24

fill

material which is used for the construction of embankments

3.25

road function

objective of providing a particular road link in terms of being "national", "districts or "access"

3.26

horizontal curve/curvature

curve/succession of curves, normally circular, in plan

3.27

transition curve

curve in which the radius changes continuously along its length, used for the purpose of connecting a straight with a circular curve, or two circular curves of different radii

3.28

vertical curve

curve on the longitudinal profile of a road,

3.29

vertical alignment

direction and course of the centre line in profile

3.30

lane

strip of carriageway intended to accommodate a single line of moving vehicles

3.31

gradient

rate of rise or fall on any length or road, with respect to the horizontal. It is usually expressed as a percentage of vertical rise or fall in meters, 100 m of horizontal distance

3.32

guardrail

continuous barrier erected alongside a road to prevent traffic from accidentally leaving the roadway or from crossing the median

3.33

horizontal alignment

direction and course of the road centreline in plan

3.34

horizontal curve

curve in plan

3.35

object height

assumed height of a notional object on the surface of the roadway used for the purpose of determining sight distance

3.36

Passenger Car Equivalent Unit (PCU)

unit of road traffic, equivalent for capacity purposes to one normal private car which is thus the unit and other vehicles are converted to the same unit by a factor depending on their type and circumstances

3.37

passing sight distance

minimum sight distance on two-way single roadway roads that shall be available to enable the driver of one vehicle to pass another vehicle safely and comfortably without interfering with the speed of an oncoming vehicle travelling at the design speed, should it come into view after the overtaking manoeuvre is started

3.38

pavement

part of a road designed to withstand the weight or loading by traffic

3.39

reaction time

time taken by the driver to perceive the hazard ahead plus the time taken to activate the brake

3.40

safety barrier

continuous barrier erected alongside a road to prevent traffic from accidentally leaving the carriageway or verge or from crossing the central reserve

3.41

hard shoulder

part of the road outside the roadway, but at substantially the same level, for accommodation of stopped vehicles for emergency use, and for lateral support of base and surfacing courses

3.42

shoulder

That part of the verge adjacent to the carriageway designed to provide a safe stopping area in an emergency, a travel path for pedestrians and cyclists (where there is no other facility for them) and lateral support for the road pavement.

3.43

side slope

area between the outer edge of shoulder or hinge point and the ditch bottom

3.44

sight distance

distance visible to the driver of a passenger car measured along the normal travel path of a roadway to the roadway surface or to a specified height above the roadway surface, when the view is unobstructed by traffic

3.45

single lane road

road consisting of a single traffic lane serving both directions, with passing bays

3.46

speed

rate of movement of vehicular traffic or of specified components of traffic, expressed in kilometres per hour (km/h)

3.47

road hump

physical obstruction, , placed transversely on the surface of the carriageway for the purpose of reducing traffic speed

3.48

super elevation

inward tilt or transverse inclination given to the cross section of a roadway throughout the length of a horizontal curve to reduce the effects of centrifugal force on a moving vehicle; expressed as a percentage

3.49

functional classification

grouping of streets and roads according to the character of the service they are intended to provide

3.50

design hourly volume

projected hourly volume that is used in the design

3.51

subgrade

the naturally occurring material on which the pavement is constructed.

3.52

median

portion of a divided road separating the travelled ways for traffic in opposite directions including inside shoulders

3.53

roadway

portion of a road, including shoulders, intended for vehicular use

3.54

stopping sight distance

distance required by a driver of a vehicle travelling at a given speed, to bring his vehicle to a stop after an object on the roadway becomes visible. It includes the distance travelled during the perception and reaction times and the vehicle braking distance

3.55

street

road which has become partly or wholly defined by buildings established along one or both frontages

3.56

tangent

portion of a horizontal alignment of straight geometrics

3.57

traffic

vehicles, pedestrians and animals travelling along a route

3.58

traffic flow

number of vehicles or persons that pass a specific point in a stated time, in both directions unless otherwise stated

3.59

traffic lane

part of a carriageway intended to accommodate a single stream of traffic in one direction

3.60

traffic volume

number of vehicles or persons that pass over a given section of a lane or a roadway during a time period of one hour or more. Volume is usually expressed in one of the terms: average annual daily traffic (AADT), Average Daily Traffic (ADT) and hourly volume

3.61

right-of-way or road reserve

strip of land legally awarded to the roads agency, in which the road is or will be situated and where no other work or construction may take place without permission from the roads agency. The width is measured at right angles to the centreline

3.62

road

way for vehicles and for other types of traffic which may or may not be lawfully usable by all traffic

3.63

competent authority local government authority, institution, agency or any other body entrusted by the Ministry in charge of roads with the duties to develop, manage and maintain roads

3.64

road side

general term denoting the areas adjoining the outer edges of the shoulders

3.65

flat terrain

terrain with largely unrestricted horizontal and vertical alignment; transverse terrain slope up to 10 %

3.66

rolling terrain

terrain with low hills introducing moderate levels of rise and fall with some restrictions on vertical alignment; traverse terrain slope 25 %

3.67

mountainous terrain

terrain that is rugged and very hilly with substantial restrictions in both horizontal and vertical alignment; transverse terrain slope above 25 %

3.68

steep terrain

steep country inclusive of switchback sections and side hill traverses; transverse terrain slope greater than 60 %. The terrain with this geological features needs special geometric design guidelines because of the engineering risks involved

3.69

Level Of Service (LOS)

measure used to quantify traffic flow and congestion by assigning quality levels of traffic based on performance measure such as speed, density, etc.

3.70

Decision Sight Distance (DSD)

The decision sight distance is the distance needed for a driver to detect an unexpected or otherwise difficult to-perceive information source or condition in a roadway environment that may be cluttered, recognize the condition or its potential threat, select an appropriate speed and path and initiate a complex manoeuvre

3.71

laterites

soil types rich in iron and aluminium, formed in hot and wet tropical areas

3. 72

soil stabilisation

process of mixing soil with materials to permanently alter their physical and chemical properties to increase or maintain the stability of soil or improve its strength or bearing capacity.

4 Symbols (and abbreviated terms)

AADT Annual Average Daily Traffic

AASHTO American Association of State Highway and Transportation Officials

ADT Average Daily Traffic

BF	Basic Access Farms
CBR	California Bearing Ratio
CF	Cross Fall
DCP	Dynamic Cone Penetrometer
DHV	Design Hourly Volume
DSD	Decision Sight Distance
DTV	Design Traffic Volume
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ESALs	Equivalent Single Axle Loads
GM	Silty Gravel
GWC	Gravel Wearing Course
HFL	Highest Flood Level
HSG	Hydraulic Soil Group
IRI	International Roughness Index
LS	Linear Shrinkage
LCVC	Length of the Crest Vertical Curve
LL	Liquid Limit
LVR	Low Volume Roads
LVRR	Low Volume Rural Roads
MDD	Maximum Dry Density
NCF	Normal Cross Fall

PCU Passenger Car Equivalent Unit

PL Plastic Limit

PSD Passing Sight Distance

ROW Right-Of-Way

SS Side Slopes

SSD Stopping Sight Distance

SW shoulder Width

TEF Traffic load Equivalent Factor

TFV Ten percent Fines Value

VPD Vehicle Per Day

5 Elements of design

5.1 General

5.1.1 Climatic zone

5.1.1.1 For the purposes of feeder roads or LVR designs, climatic zones shall be considered.

NOTE The places with mean annual rainfall greater than or equal to 1000 mm are considered wet zones and all other places shall be considered as dry zones. Map of Rwanda Climatology.

5.1.1.2 Designer should also consider the following four climatic seasons:

i) Season 1, short dry season which extends from December of the preceding year to the end of February of the succeeding year;

ii) Season 2, long rainy season, which extends from February to the end of May;

iii) Season 3, long dry season which extends from June to the end of August; and

iv) Season 4, short rainy season, which extends from October to the end of November.

5.1.2 Terrain classes

Terrain class shall be determined by the number of five-meter contours crossed by a straight line connecting the two ends of the concerned LVR; independent of a road's selected alignment. Terrain classification is shown in table 1.

Table 1 — Terrain classification

S/N	Terrain class	cross slope (%)
1	Plain	0 - 10
2	Rolling	> 10 - 25
3	Mountainous	> 25 - 60
4	Steep	> 60

5.1.3 Environmental considerations

5.1.3.1 Prior to approval of any LVR construction project, an Environment Impact Assessment (EIA) shall be done by expert and approved by a Competent Authority to ascertain acceptable impact to the environment.

5.1.3.2 There shall be a direct relationship between good road engineering practices and sound environmental management. Choices that can affect the potential for adverse environmental impacts should be assessed, these should include the following:

a) finding the correct road alignment or location to cross a watercourse or a wetland at the narrowest place;

b) being aware of the boundaries of protected areas;

c) considering the possibility of a road diversion around an urbanized village to minimize the potential for traffic safety or dust issues; and

d) considering the quality and dimensions of a road going through an urbanized area, and the option to seal it, widen it, enhance the quality of the shoulders, create pedestrian lanes.

5.1.3.3 The following environmental issues should be considered:

a) road construction related disruptions to the local hydrology and watershed function;

b) damage to fragile wetland ecosystems, stream courses, drainage ways, and the biodiversity assets they contain;

c) improper road construction or lack of maintenance creates standing or stagnant water situations;

d) proper environmental management of borrow pit and quarry sites;

e) improved road conditions may lead to better access to rural forestry assets such as woodlots, small plantations, and even natural forest;

f) sourcing timber needed for road furniture or structures in an unsustainable manner;

g) social conflict because of perceived inequities with the road building;

h) improved road conditions and traffic safety;

i) providing traffic control devices, that is, road humps, to slow traffic through villages and other populated areas;

j) improved roads lead to more noise and road dust; and

k) road camps and their placement and decommissioning.

5.1.4 Functional classification

The road design parameters for low traffic volume in which the feeder roads fall in, should rely on the maximum design traffic volumes of 300 VPD.

5.1.5 Projection for future demand

5.1.5.1 Geometric design of new roads or improvement of existing roads should not usually be based on current traffic volumes alone, but should consider future traffic volumes expected to use the facility.

5.1.5.2 The design life and traffic design volume should be for seven years on gravel roads corresponding to the period of re-gravelling on a regularly maintained gravel road.

5.1.5.3 For paved feeder roads, the design life should depend on the type of surfacing selected.

Type of surfacing	Design life
Asphalt concrete	20
Double surface treatment/double chip seal	12
Cape seal	15
Cement concrete road	30
Stone paved roads	Variable

5.1.6 Level Of Service (LOS)

5.1.6.1 The quality of traffic service provided by specific road facility under specific traffic demands shall be defined by means of Levels Of Service (LOS). There should be six LOS:

A. **Free flow:** traffic flows at or above the posted speed limit and motorists have complete mobility between lanes. The average spacing between vehicles should be about twenty-seven-car lengths. Motorists have a high level of physical and psychological comfort. The effects of incidents or point breakdowns are easily absorbed.

B. **Reasonably free flow**: LOS A speeds shall be maintained, manoeuvrability within the traffic stream should be slightly restricted. The lowest average vehicle spacing should be about sixteen-car lengths. Motorists still have a high level of physical and psychological comfort.

C. **Stable flow at or near free flow**: Ability to manoeuvre through lanes should be noticeably restricted and lane changes shall require more driver awareness. Minimum vehicle spacing should be about eleven-car lengths. Minor accidents may still have no effect but localized service may have noticeable effects and traffic delays may form behind the accident. This should be the target LOS for some urban and most rural roads.

D. **Approaching unstable flow**: Speeds slightly decrease as traffic volume slightly increases. Freedom to manoeuvre within the traffic stream shall be limited and driver comfort levels decrease. Vehicles should be spaced about eight-car lengths apart. Level D should be a common goal for urban streets during peak hours, as attaining LOS C would require prohibitive costs and social impact via bypass roads and lane additions.

E. **Unstable flow**: operating at capacity: Flow becomes irregular and speed varies rapidly because there are virtually no usable gaps to manoeuvre in the traffic stream and speeds rarely reach the posted limit. Vehicle spacing should be about six-car lengths. Any disruption to traffic flow, such as merging ramp traffic or lane changes, can create a shock wave affecting downstream traffic. Any incident can create serious delays. The drivers' level of comfort becomes poor.

F. **Forced or breakdown flow**: Every vehicle moves in lockstep with the vehicle in front of it, with frequent slowing required. Travel time should not be predicted, with generally more demand capacity.

5.1.6.2 In the case of feeder roads, LOS D shall be used for all types of terrains.

5.1.7 Design vehicle

5.1.7.1 Feeder roads should be designed to accommodate safely and conveniently all vehicles types and dimensions for which they have been designed. The design shall ensure that the vehicle can negotiate the road geometry (see figure 1).

5.1.7.2 Four general classes of design vehicles are indicated in table 2.

Table 2 — Design vehicles

Design vehicle in types	Symbol	Dimensions				
		Length	Width	Height	Minimum turning radius	Wheel base
	Passenger cars					
Passenger cars	DV1	5.8	2.1	1.3	7.31	3.35
	Buses					
Single unit bus	DV2	12.1	2.6	4.1	12.8	7.6
Articulated bus	DV3	18.3	2.6	3.4	12.1	6.7 + 5.9
	Trucks					
Single unit truck	DV4	9.1	2.6	4.6	12.8	6.1
Semi-trailer	DV5	18.2	2.6	4.6	12.65	5.5 + 10.0
Rigid truck and drawbar trailer combination	DV6	22.0	2.6	4.6	12.0	4.6 + 8.2
Interlink (with a short truck tractor)	DV7	22.0	2.6	4.6	12.0	4.1+6.52*+7.94
Semi-trailer with long trailer	DV8	21.0	2.6	4.6	13.7	6.1 & 12.8
*Distance between SU rear wheels and trailer front wheels						

5.1.7.3 The design vehicle should be compared to the intermediate semi-trailer WB-12 (SI), (WB-40-imperial) as shown in figure 1a and Figure 1b.

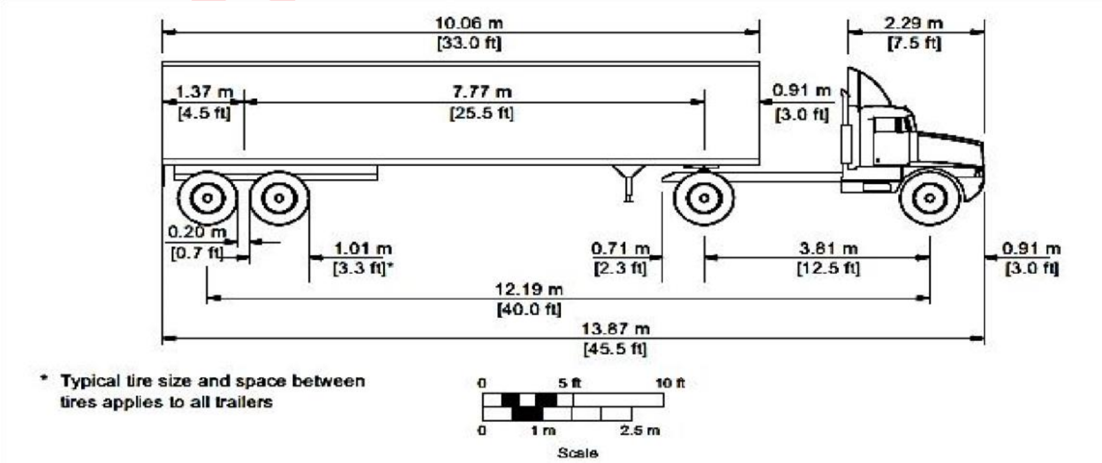


Figure 1a — Typical tire size and space between tires applies to all trailers

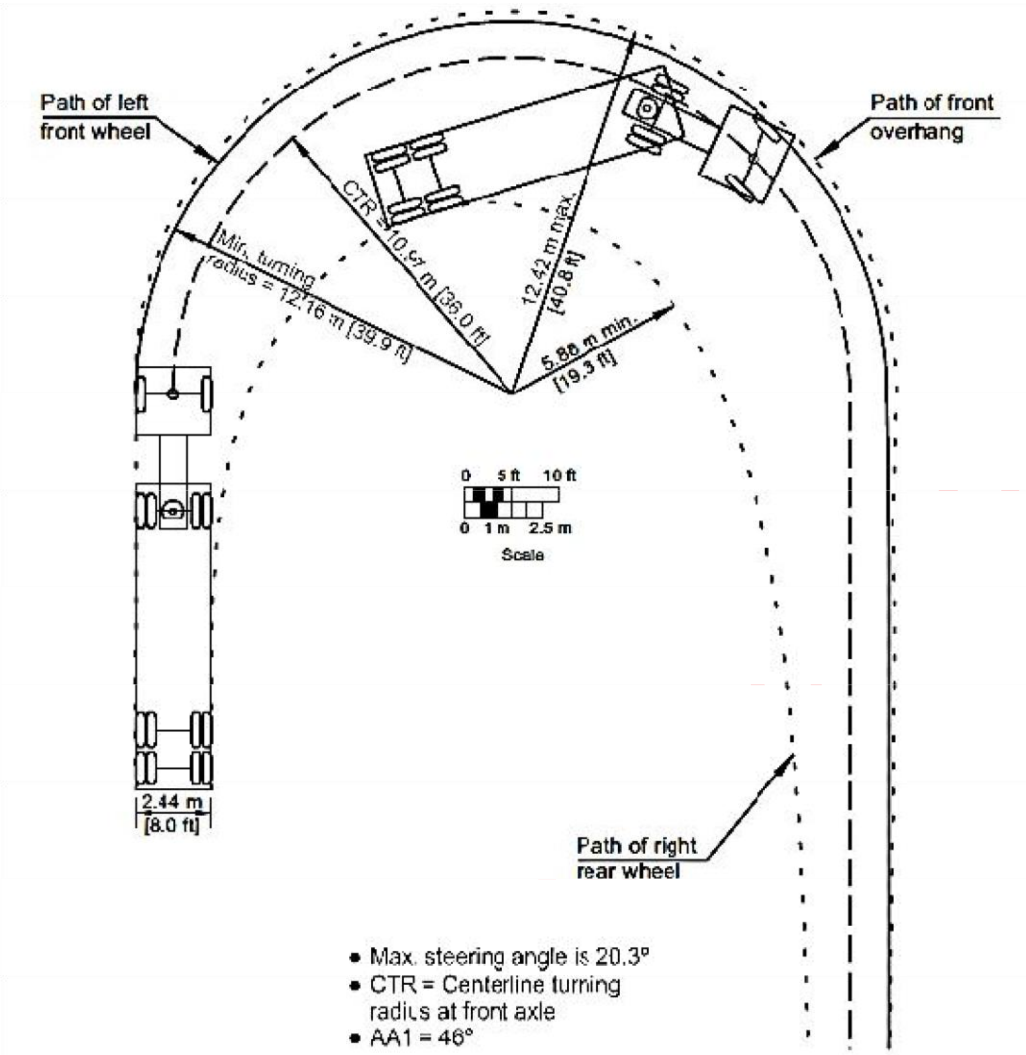


Figure 1b — Minimum turning path for intermediate semi-trailer

Figure 1 — Geometry of the design vehicle and lateral clearance on curve

5.1.7.4 For the design of feeder roads, the WB-12 (SI) - WB-40 (imperial) should be used. DV5 should be the minimum design vehicle for those types of vehicles travelling feeder roads. Furthermore, for design purpose, the width of the truck shall be assumed to be 2.6 m minimum.

5.1.8 Passenger Car equivalent Unit (PCU)

The number of PCUs associated with a single vehicle type is a measure of impedance that it offers to the passenger cars in the traffic stream. The recommended PCUs are presented in table 3.

Table 3 — Passenger Car Equivalent Unit

S/N	Vehicle type	Terrain		
		Flat	Rolling	Mountainous
		PCU		
i.	Passenger cars	1.0	1.0	1.5
ii.	Light goods vehicles	1.0	1.5	3.0
iii.	Medium goods vehicle	2.5	5.0	10.0
iv.	Heavy goods vehicles	3.5	8.0	20.0
v.	Buses	2.0	4.0	6.0
vi.	Motor cycles, scooters	0.5	1.0	1.5
vii.	Pedal cycles	0.5	0.5	0.5

5.1.9 Design hourly volume

The design hourly volume represents the 30th highest hourly volume during the year. Field data should be gathered to estimate the K factor. In the absence of these data, values of K of 0.15 for rural roads and 0.10 for urban roads should be used. Then DHV=0.15x ADT or 0.10 x ADT respectively.

5.1.10 Design speeds

Design speeds corresponding to feeder roads and respond to the traffic volume criteria as a function of the four terrains classifications typical to Rwanda are indicated in table 4.

Table 4 — Design speeds for feeder roadsas a function of the terrain type

Road class		Design speed (km/hr)			
		Flat terrain	Rolling terrain	Mountainous terrain	Steep terrain
Feeder roads	District class 1	80	60	40	40
	District class 2	60	40	30	30

5.1.11 Brake reaction time

The brake reaction time commonly considered as adequate for complex conditions as those of laboratory test should be 2.5 sec. The need for greater reaction time can be encountered in most complex situations such as those found at multiphase at grade intersections.

5.1.12 Brake distance

5.1.12.1 The approximate braking distance of a vehicle level roadway travelling at a design speed of the roadway may be determined from the following equation:

$$d_B = 0.039\frac{V^2}{a}$$

where

d_B is braking distance, m;

V is design speed, km/h;

a is deceleration rate, m/s^2.

5.1.12.2 The braking distance shall be computed on base of the applicable design speed using a deceleration rate of 3.4 m/s^2 and a reaction time of 2.5 sec. The corresponding stopping sight distances as a function of the design speed likely to been countered on majority of the feeder roads network. For those segments of the feeder road network pertaining to higher class roads, corresponding values referred to are given in table 5. The lowest design speed should be 30 km/h.

5.1.12.3 The stopping sight distance (SSD) is given by the formula below:

$$SSD = 0.278Vt + 0.039\frac{V^2}{a}$$

where

SSD is Stopping Sight Distance

V is Design speed, km/h

t is Brake reaction time, 2.5 sec

a is Deceleration rate, m/s^2

Table 5 — Stopping sight distance for feeder roads

Design speed (km/h)	Brake reaction distance (m)	Brake reaction distance on level (m)	Stopping sight distance	
			Calculated (m)	Design (m)
20	13.9	4.6	18.5	20
30	20.9	10.3	31.2	35
40	27.8	18.4	46.2	50
50	34.8	28.7	63.5	65
60	41.7	41.3	83.0	85
70	48.7	56.2	104.9	105
80	55.6	73.4	129.0	130

5.1.13 Effect of grade on stopping

For road way segment on a grade, the values of table 6 shall be used to take into consideration the grade G from the following relationship:

$$d_B = \frac{V^2}{254\left[\left(\frac{a}{9.81}\right) + G\right]}$$

where

d_B is braking distance on grade, m;

V is design speed, km/h;

a is deceleration, m/s^2;

G is grade, rise/run, m/m.

Table 6 — Stopping sight distance for feeder roads with effect of grade

Design speed (km/h)	Stopping sight distance					
	Downgrades (%)			Upgrades (%)		
	3	6	9	3	6	9
20	20	20	20	19	18	18
30	32	35	35	31	30	29
40	50	50	53	45	44	43
50	66	70	74	61	59	58
60	87	92	97	80	77	75
70	110	116	124	100	97	93
80	136	144	154	123	118	114

5.1.14 Decision Sight Distance (DSD)

Decision sight distance shall offer drivers additional margin for error, afford them sufficient length to manoeuvre their vehicles at the same reduced speed, other than to just stop, its values are substantially greater than stopping sight distances (See Table 7).

Table 7 — Decision Sight Distance

Design sight distance (km/h)	Decision Sight Distance (m)				
	Avoidance manoeuvre				
	A	B	C	D	E
50	70	155	145	170	195
60	95	195	170	205	235
70	115	325	200	235	275
80	140	280	230	270	315

NOTE 1 Avoidance manoeuvre A: Stop on rural road –t = 3.0 s; ;

NOTE 2 Avoidance manoeuvre B: Stop on urban road –t = 9.1 s; ;

NOTE 3 Avoidance manoeuvre C: Speed/path/direction change on rural road 10.2 s < t < 11.2 s ;

NOTE 4 Avoidance manoeuvre D: Speed/path/direction change on rural road 12.1 s < t < 12.9 s

NOTE 5 Avoidance manoeuvre E: Speed/path/direction change on rural road 14.0 s < t < 14.5 s

NOTE 6 Avoidance manoeuvres A and B are given by the following relationship:

$$DSD = 0.278Vt + 0.039\frac{V^2}{a}$$

where

DSD is Decision Sight Distance, m

t is pre-manoeuvre time, sec

V is design speed, km/h

a is driver deceleration, m/s^2

NOTE 7 Avoidance manoeuvres C, D and E are given by the following relationship:

$$DSD = 0.278Vt$$

where

DSD is Decision Sight Distance, m

t is total pre-manoeuvre and manoeuvre time, sec

V is design speed, km/h

5.1.15 Object height design value

The object height values shall be the ones indicated in Table 8 for the purpose of stopping sight distance, decision sight distance and passing sight distance computation.

Table 8 — Object height (m) for use in the computation of SSD, DSD and PSD

Object height (m)		
Stopping sight distance	**Decision sight distance**	**Passing sight distance**
0.60	0.60	1.08

5.1.16 Passing Sight Distance

5.1.16.1 Passing Sight Distance shall be the minimum sight distance on two-way single roadway roads that shall be available to enable the driver of one vehicle to pass another vehicle safely without interfering with the speed of an oncoming vehicle travelling at the design speed.

5.1.16.2 Within the sight area, the terrain should be the same level or a level lower than the roadway. Otherwise, for horizontal curves, it may be necessary to remove obstructions and widen cuttings on the insides of curves to obtain the required sight distance.

5.1.16.3 Care shall be taken in specifying passing/no-passing zones in areas where the sight distance may be obscured in the future due to vegetative growth.

5.1.16.4 Passing sight distance shall be measured between an eye height of 1.08 m and an object height of 1.08 m. The sight line near the centre of the area inside the curve should be approximately 0.24 m higher than the stopping sight distance. In cut sections, the resultant lateral dimension for normal highway cross sections (1V:2H to 1V:6H back slopes) between the centreline of the inside lane and the midpoint of the sight line is from 0.5 m to 1.5 m greater than that for stopping sight distance.

5.1.16.5 The passing sight distance should be calculated on the basis of a distance required for a successful overtaking manoeuvre and makes adequate provision for an aborted manoeuvre in the case of a truck attempting to pass another truck. The minimum passing sight distance should be the total of four components: d1 + d2 + d3 + d4 where

d1 is the distance travelled during the perception-reaction time and during initial acceleration to the point where the passing vehicle just enters the right lane;

d2 is the distance travelled during the time passing vehicle is travelling in the right lane;

d3- distance between the passing vehicle and the opposing vehicle at the end of the passing manoeuvre;

d4 is the distance moved by the opposing vehicle during two thirds of the time the passing vehicle is the left lane (usually taken to be 2/3 d2).

5.1.16.6 The recommended minimum passing sight distance for two lane-roads are given in Table 9.

Table 9 — Passing Sight Distance in two-lane roads

Design speed (km/h)	Assumed speeds	Passing sight distance (m)

	Passed vehicle	Passing vehicle	Total passing sight distance	Rounded for design[1]
30	29	44	200	200
40	36	51	266	270
50	44	59	341	345
60	51	66	407	410
70	59	74	482	485
80	65	80	538	540

[1]The rounded values in Table 9 shall be used for Passing Sight Distance calculations

5.2 Horizontal alignment

5.2.1 Alignment between control points

Alignment between control points should be designed to be as favourable as practical, consistent with the environmental impact, topography, terrain, design traffic volume, and the amount of reasonably obtainable right-of-way. Sudden changes between curves of widely different radii or between tangents and sharp curves should be avoided. Where crest vertical curves and horizontal curves occur together, greater than minimum sight distance should be provided so that the horizontal curves are visible to approaching drivers. The following basic curve formula for moving mass on a curve features the relationship between the side friction, the rate of roadway superelevation, the radius of curve and the design.

$$\frac{0.01e+f}{1-0.01ef}=\frac{v^2}{g^R}=\frac{0.0079V^2}{R}=\frac{V^2}{127R}$$

where

e is rate of roadway superelevation, per cent;

f is side friction (demand) factor;

v is vehicle speed, m/s;

g is gravitational constant, 9.81 m/s^2;

V is vehicle speed, km/h;

R is radius of curve, measured to a vehicle's centre of gravity, m.

5.2.2 Side friction factor ‘f’

The value of (0.01 *ef*) being so small, the previous equation is re-arranged to give:

$$f = \frac{V^2}{127R} - 0.01e$$

The relationship of the side friction and speed for low speed roads is given in figure 2 which can be simplified for design purposes.

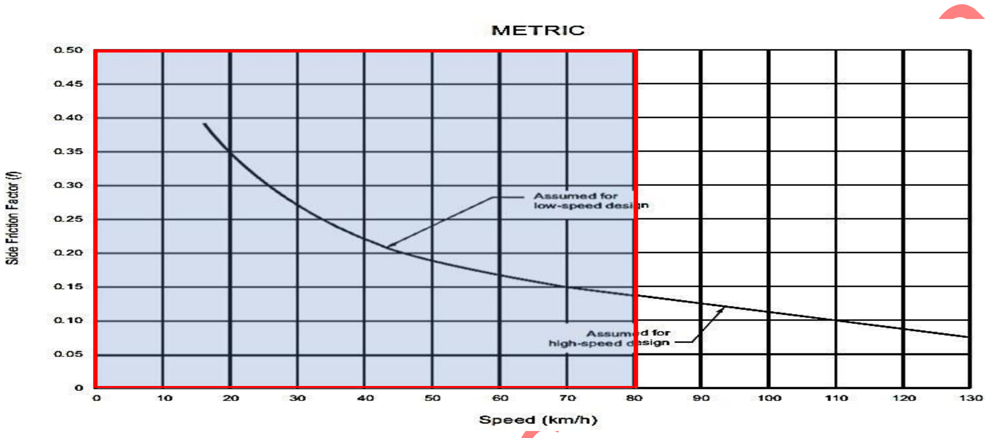


Figure 2 — Relationship between side friction and design speed on curve

NOTE It can be seen that the side friction decreases as the speed increases. For the case of feeder roads, the first portion of the graph corresponding to speeds of 20 km/h to 70 km/h. For these same speeds, the side friction decreases from 0.35 (at 20 km/h) to 0.15 (at 70 km/h).

5.2.3 Relationship between the design speed and the running speed

Values in table 10 for running speeds as a function of the design speed should be used.

Table 10 — Relationship between design speed and running speed (km/h)

Design speed (km/h)	Average running speed (km/h)
20	20
30	30
40	40
50	47
60	55
70	63
80	70

5.2.4 Normal cross slope

5.2.4.1 Consistent with the type of road and amount of rainfall, normal cross slope vary between 3 % - 4 % for unpaved roads , 3% - 3.5 % for paved roads with chip seal and 2.5% for paved roads with asphalt concrete shall be adopted with due consideration of the drainage system . Steeper slopes may be needed where curbs are needed to avoid ponding of water on the outside trough lane.

NOTE: For unpaved roads, the range depends on the type of terrain

5.2.5 5.2.4.2 Maximum superelevation rates

5.2.5.1 Maximum superelevation rates shall be controlled by four factors such as climate conditions (frequency and amount of rain); terrain conditions (flat, rolling or mountainous); type of area (rural, urban); and frequency of slow-moving vehicles whose operation might be affected by high superelevation rates.

5.2.6 5.2.5.2 For feeder roads, super-elevation should be limited to a maximum of 8%. Where terrain conditions are favourable, only the normal crown shall be provided. Minimum radius

5.2.6.1 For a given speed, minimum curve radius is limited by maximum allowable side friction, which is usually based on comfort required, maximum super- elevation rate for the curve, and the necessity to maintain stopping sight distance. The minimum radius can be calculated directly from the simplified curve equation as:

$$R_{min} = \frac{V^2}{127(0.01e_{max} + f_{max})}$$

5.2.6.2 The limiting values of the side friction are shown in table11.

Table 11 — Limiting values of the side friction

Design speed (km/h)	Limiting value of 'f'
30	0.17
40	0.17
50	0.16
60	0.15
70	0.14
80	0.14

5.2.6.3

5.2.7 The straights

Straight sections provide better visibility and more passing opportunities and hence enhance safety. The length of straight sections should not be greater than 20 x V where V is the design speed (km/h) to reduce the danger of glare and excessive speeding. A minimum of 6 x V should be also adopted between circular curves following the same direction.

5.2.8 Minimum and maximum length of curves

For small deflection angles, curves should be long enough to avoid the appearance of a kink. The length of a curve should be at minimum 300 m, but should not exceed 1000 m.

5.2.9 Turning roadways

5.2.9.1 Compound curves

Curves that are compounded should not be too short or their effect in enabling a change in speed from the tangent or flat curve to the sharp curve is lost. In a series of curves with decreasing radii, each curve should be long enough to enable the driver to decelerate at a reasonable rate. The recommended deceleration rate in gear alone represents 1.5 km/h - 2.5 km/h. The minimum compound curves lengths computed on base of these criteria should be developed on the premise that travel is in the direction of sharper curvature. Table 12 gives values of acceptable and recommended minimum length of circular arcs based on the compound curve radii.

Table 12 — Length of circular arcs for different compound curve radii

Radius (m)	Minimum length of circular arc (m)	
	Acceptable	Recommended
30	12	20
50	15	20
60	20	30
75	25	35
100	30	45
125	35	55
150 or more	45	60

5.2.10 Turning design control

For appearance and comfort, the length of superelevation runoff should be based on a maximum acceptable difference between longitudinal grades of the axis of rotation and the edge of pavement. Current practice is to limit the grade difference referred to as the relative gradient, to a maximum value of 0.5 % or a longitudinal slope of 1:200 at 80 km/h. A comfortable and aesthetically pleasing runoff design can be attained through the exclusive use of the maximum relative gradient criterion (See Table 13).

Table 13 — Maximum relative slope as a function of the relative gradient and the design speed

Design speed (km/h)	Maximum relative gradient (%)	Equivalent maximum relative slope
30	0.75	1.133
40	0.70	1.143
50	0.65	1.154
60	0.60	1.167
70	0.55	1.182
80	0.50	1.200

5.2.11 The minimum length of super-elevation runoff

5.2.11.1 The minimum length of super-elevation runoff should be determined as follows:

$$L_r = \frac{(wn_1)e_d(b_w)}{\Delta}$$

where

L_r is minimum length of superelevation runoff, m

w is width of one traffic lane, m (3.5m for district roads class 1 and 3.0 m for district road class 2);

n_1 is number of lane rotated;

e_d is design superelevation rate, %;

b_w is adjustment factor for number of lanes rotated;

Δ is maximum relative gradient, %.

5.2.11.2 Table 14 gives adjustment factor for the number of lanes rotated. From the Figure 3, the Rwandan feeder road network should be equal to unity. Therefore, the minimum length for super-elevation runoff should be calculated from the equation given above with the value of b_w = 1 and w = 3.0m.

Table 14— Adjustment factor for the number of lanes rotated

Number of lanes rotated, n1	Adjustment factor,* bw	Length increase relative to one- lane rotated (= n1bw)
1	1.00	1.0
1.5	0.83	1.25
2	0.75	1.5
2.5	0.70	1.75
3	0.67	2.0
3.5	0.64	2.25

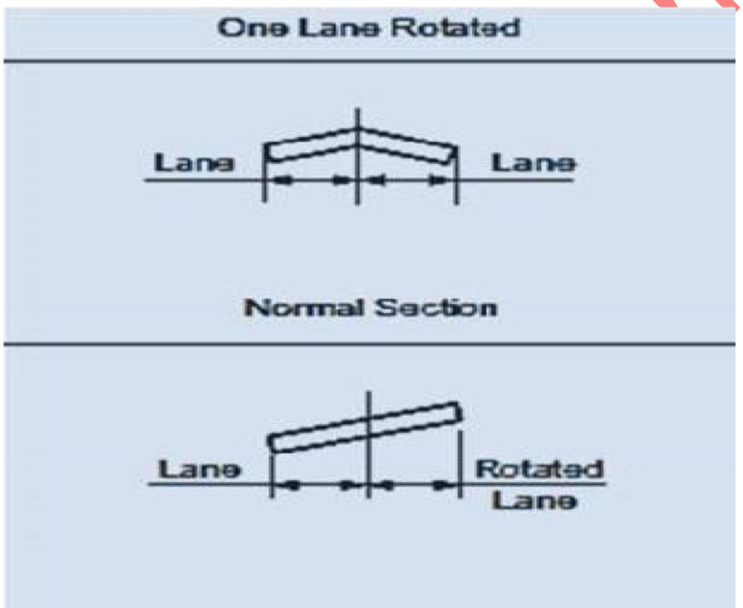


Figure 3 — Lane rotations and determination of the adjustment factor

5.2.12 Minimum length of tangent run-out

5.2.12.1 The length of tangent run-out is determined by the amount of adverse cross slope to be removed and the rate at which it is removed. To achieve a smooth edge of pavement profile, the rate of removal should equal the relative gradient used to define the super-elevation runoff length. Based on this rationale, the following equation is used to compute the minimum tangent runout length:

$$L_t = \frac{e_{NC}}{e_d} L_r$$

where

L_t minimum length of tangent runout, m;

e_{NC} nominal cross slope rate, %;

e_d design superlevation rate, %;

L_r minimum length of superelevation runoff, m.

5.2.12.2 The minimum length of tangent run-out shall be computed using the adopted values of cross slope rates, the design super- elevation rates and the minimum length of super elevation length by means of the equation in 5.2.11.

5.2.13 Location of the superelevation runoff length with respect to the point of curvature

To achieve the balance in lateral acceleration, it is recommended to locate the runoff length on the tangent prior to the curve. The portion of the runoff length placed on the tangent should be 0.8 as shown on Table 15.

Table 15 — Runoff locations that minimize the vehicle's lateral motion

Design speed (km/h)	Portion of runoff located prior to the curve
	Number of lanes rotated
	1.0
20-70	0.80
80-130	0.70

5.2.14 Minimum length of spiral transition curve

5.2.14.1 The minimum length of spiral transition curve shall be calculated using the following equation:

$$L = \frac{0.0214V^3}{RC}$$

where

L is minimum length of spiral, m;

V is speed, km/h;

R is curve radius, m;

C is rate of increase of lateral acceleration, m/s^3.

5.2.14.2 The factor C is an empirical value representing the comfort and safety levels provided by the spiral curve. The minimum length of the spiral transition curve should be equal to the length needed for superelevation runoff.

5.2.15 Maximum radius for use of a spiral

The maximum radius for use of a spiral should be based on a minimum lateral acceleration rate of 1.3 m/s^2.Table 16 gives the maximum radius for use of a spiral curve transition.

Table 16 — Maximum radius for use of a spiral curve transition

Design speed	Maximum radius
20	24
30	54
40	95
50	148
60	213
70	290
80	379

5.2.16 Maximum length of spiral

5.2.16.1 Two criteria shall be used, the first being based on the driver's comfort is intended to provide a spiral length that allows for a comfortable increase in lateral acceleration as a vehicle enters a curve, the second is based on lateral shift and is intended to provide a spiral curve that is sufficiently long to result in a shift in a vehicle's lateral position within its lane that is consistent with that produced by the vehicle's natural spiral path. The minimum spiral; length is thus computed as:

$L_{s,min}$ should be the larger of:

$$L_{S,min} = \sqrt{24(p_{min})R}$$

or

$$L_{S,min} = 0.0214\frac{V^2}{RC}$$

where

$L_{s,min}$ is minimum length of spiral, m;

p_{min} is minimum lateral offset between the tangent and circular curve (0.20 m);

R is radius of circular curves, m;

V is design speed, km/h;

C is maximum rate of change in lateral acceleration (1.2 m/s[2]).

5.2.16.2 A value of 1.0 m is recommended for p_{max}. This value is consistent with the maximum lateral shift that occurs as a result of the natural steering behaviour of most drivers. It also provides a reasonable balance between spiral length and curve radius.

5.2.16.3 The recommended minimum value of the length of the spiral shall be given by the highest value obtained from the two equations for $L_{s,min}$ as provided in 5.2.15 but shall not exceed the recommended length of spiral as given in Table 17. Widening of the travelled way shall be envisaged to minimize the potential for encroachments into the adjacent lanes wherever lower values than those given in Table 17 or the preceding formulas are used.

5.2.17 Recommended length of a spiral

The most recommended operating conditions are when the spiral curve length is approximately equal to the length of the natural spiral path adopted by drivers. Differences between these two lengths resulted in operational problems associated with large lateral velocities or shifts in lateral position at the end of the transition curve. Table 17 gives recommended length of spiral curve transition. If these values are higher than those given by equations in the preceding section, the minimum value shall be used.

Table 17 — Recommended length of a spiral

Design speed (km/h)	Spiral length (m)
20	11
30	17
40	22
50	28
60	33
70	39
80	44

5.2.18 Limiting superelevation rates

Table 18 gives superelevation rates associated with large relative gradients. The values of superelevation to be used in the design should not exceed those given in table18 so as to avoid an increase in the maximum relative gradient allowed for a tangent–to-curve design. Column 1 in Table18 shall be used in this standard.

Table 18 — Limiting superelevation rates

Design speed (km/h)	Number of lane rotated
	1
20	3.7

30	5.2
40	6.5
50	7.5
60	8.3
70	8.9
80	9.3

5.2.19 Length of tangent runout

5.2.19.1 The tangent runout length for a spiral curve transition design is based on the same approach used for the tangent-to-curve transition design. A smooth edge of pavement design is desired so that the common edge slope gradient is maintained throughout the superelevation runout and runoff sections. Table 19 gives the values of tangent runout length for spiral curve transition design for superelevation rates from 2 % - 10%.

5.2.19.2 The length of tangent runout is given by the following formula:

$$L_t = \frac{e_{NC}}{e_d} L_S$$

where

L_t is length of tangent runout, m;

L_s is length of spiral, m;

e_d is design superelevation rate, %;

e_{NC} is normal cross slope rate, %.

Table 19 — Tangent runout length for spiral curve transition design

Design speed(km/h)	Tangent rounout length (m)				
	Superlevation rate				
	2	4	6	8	10
20	11	-	-	-	-
30	17	8	-	-	-
40	22	11	7	-	-

50	28	14	9	-	-
60	33	17	11	8	-
70	39	19	13	10	-
80	44	22	15	11	-

5.2.20 Widths outside travelled way

The width of the shoulders should be dictated by the established law on Right - Of - Way (ROW). Table 20 gives a range of usable shoulder widths or equivalent lateral clearances outside of turning roadways not on structures. Where roadway barriers are provided, the width indicated should be measured to the face of the barrier, and the graded width should be about 0.6 m greater.

Table 20 — Range of usable shoulder widths or equivalent lateral clearances outside of turning roadways not on structures

Turning roadway condition	shoulder width or lateral clearance outside of travelled-way edge (m)	
	Left	Right
Short length, usually within channelized intersection	0.6 - 1.5	0.6 - 1.5
Intermediate to long length or in cut or in fill	1.2 - 3.0	1.2 - 3.0

5.2.21 Horizontal sight distance

As illustrated on Figure 4, the sight line for general use in design of horizontal curve is a chord of the curve, and the stopping sight distance is measured along the centreline of the inside lane around the curve. Figure 5 is a design chart showing the horizontal sight line offsets needed for clear sight areas that satisfy stopping sight distance criteria for horizontal curves of various radii on flat grades. Figure 5 includes radii for all superelevation rates to a maximum of 12 %.

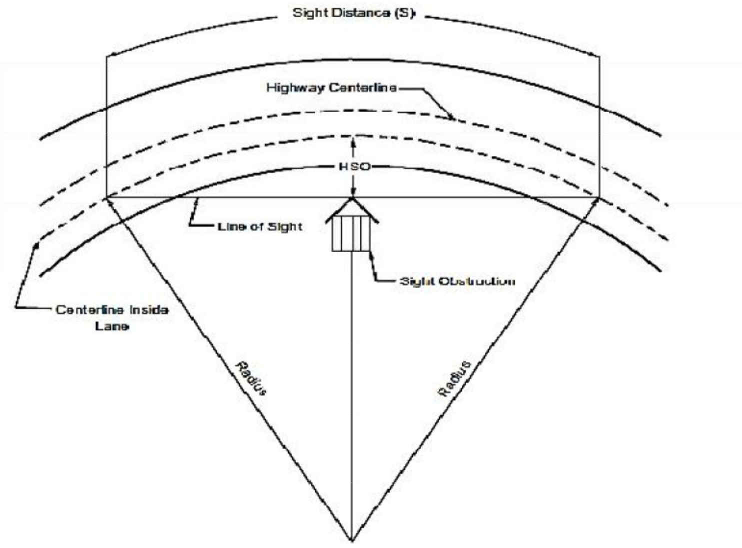


Figure 4 — Diagram illustrating components for determining horizontal sight distance

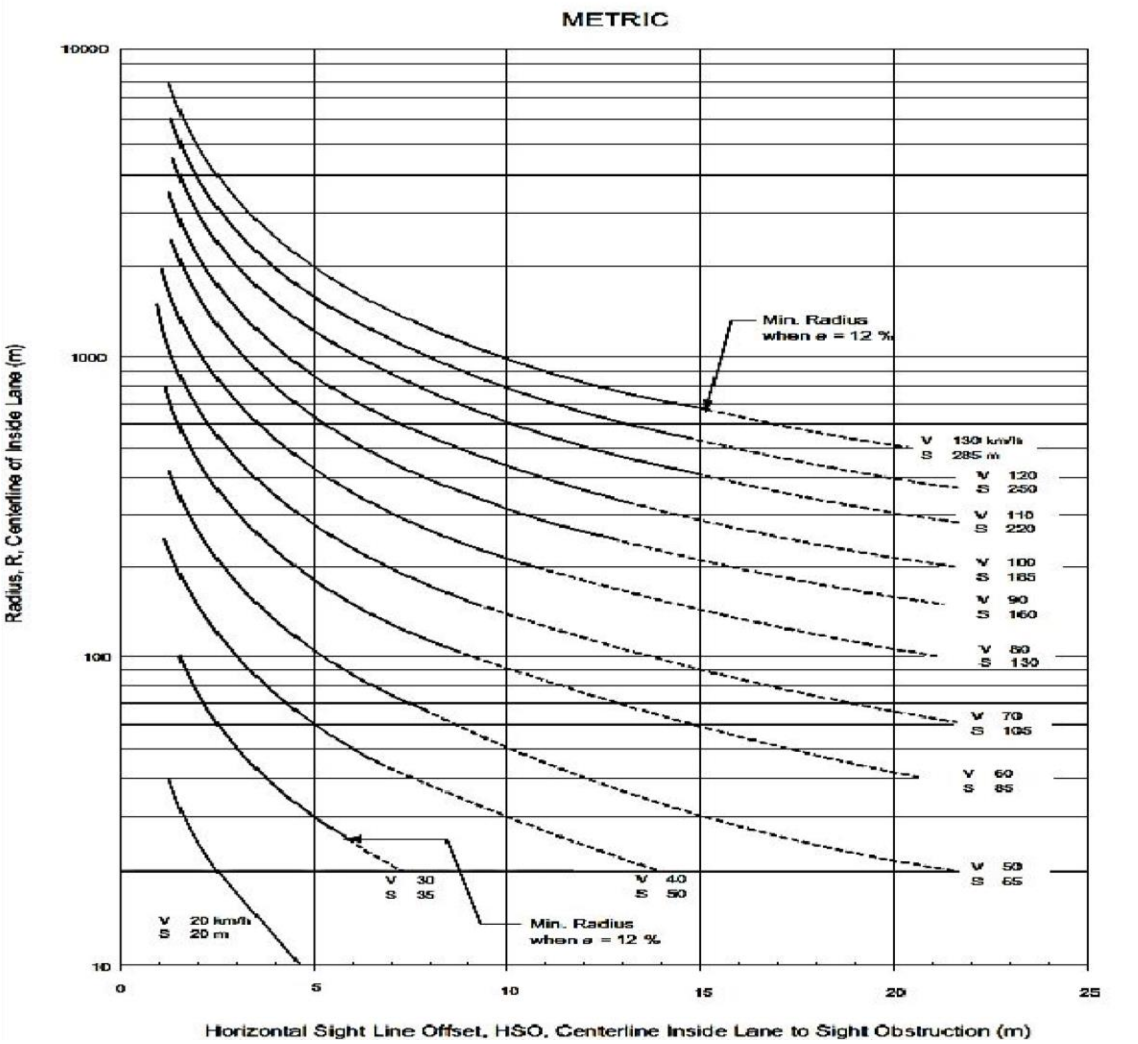


Figure 5 — Design Controls for Stopping Sight Distance on Horizontal Curves

The horizontal sightline offset is calculated using the following equation:

$$HSO = R[1 - Cos(\frac{28.65S}{R})]$$

where

HSO is horizontal sight line offset, m;

S is stopping sight distance, m;

R is radius of curve, m.

The chart from Figure 5 shall be used for corresponding applicable to design speeds and superelvations as identified in previous sections.

5.3 Vertical alignment

5.3.1 Crest vertical curve

5.3.1.1 Parameters illustrated in Figure 6 shall be used in determining the length of a parabolic vertical curve needed to provide a specified value of sight distance. The basic equation of a crest vertical curve in terms of algebraic difference in grade and sight distance is given below:

When *S* is less than *L*,

$$L = \frac{AS^2}{100\left(\sqrt{2h_1 + \sqrt{2h_2}}\right)^2}$$

When *S* is greater than *L*,

$$L = 2S - \frac{200\left(\sqrt{h_1 + \sqrt{h_2}}\right)^2}{A}$$

where

L is length of vertical curve, m;

A is algebraic difference in grades, %;

S is sight distance, m;

h_1 height of eye above roadway surface, m;

h_2 height of object above roadway surface, m.

5.3.1.2 When the height of the eye and of the object are respectively 1.08 m and 0.6 m as used for stopping sight distance; equation should be simplified to the following:

When S is less than L,

$$L = \frac{AS^2}{658}$$

When S is greater than L,

$$L = 2S - \frac{658}{A}$$

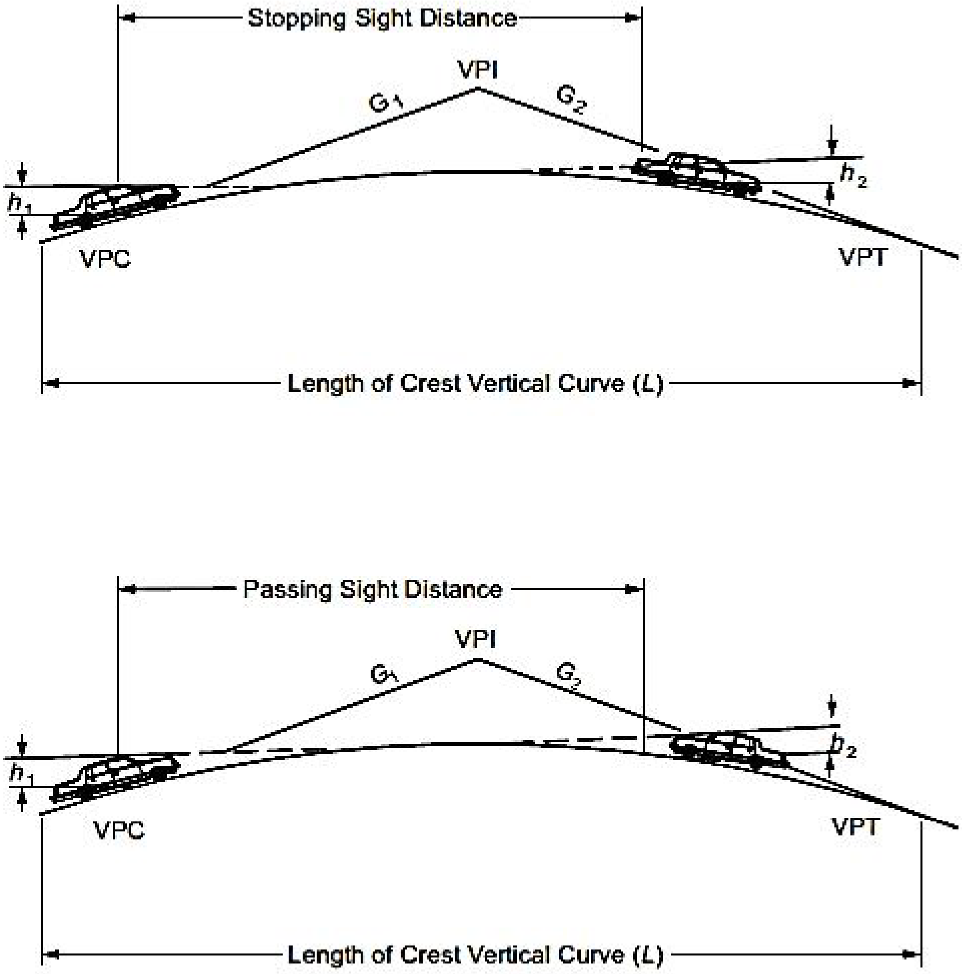


Figure 6 — Parameters considered in determining the length of the crest vertical curve to provide sight distance

5.3.2 Sag vertical curve

5.3.2.1 Four different criteria for establishing lengths of sag vertical curves should be recognized to some extent. These are:

A. headlight sight distance;

B. passenger comfort;

C. drainage control; and

D. general appearance.

5.3.2.2 A headlight height of 0.6 m and a one-degree upward divergence of the light beam from the longitudinal axis of the vehicle is commonly assumed. The following relationship between S, L and A, using S as a distance between the vehicle and the point where one-degree upward angle of the light beam intercepts the surface of the roadway:

When *S* is less than *L*,

$$L = \frac{AS^2}{200[0.6 + S(\tan 1^*)]}$$

Or,

$$L = \frac{AS^2}{120 + 3.5S}$$

When S is greater than L,

$$L = 2S\frac{200[0.6 + S(tan1^*)]}{A}$$

Or,

$$L = -\frac{120 + 3.5S}{A}$$

where

L is length of sag vertical curve;

A is algebraic difference in grades, %;

S is light beam distance, m.

5.3.2.3 For drivers to see the roadway ahead, a sag vertical curve should be long enough that the light beam distance is approximately the same at the stopping sight distance. Accordingly, it is appropriate to use stopping sight distances for different design speeds as the value of *S* in the above equations. The resulting lengths of the sag vertical curves for the recommended stopping sight distances for each design speed are shown in Figure 7 with solid lines using rounded values of *K* as was done for crest vertical curves.

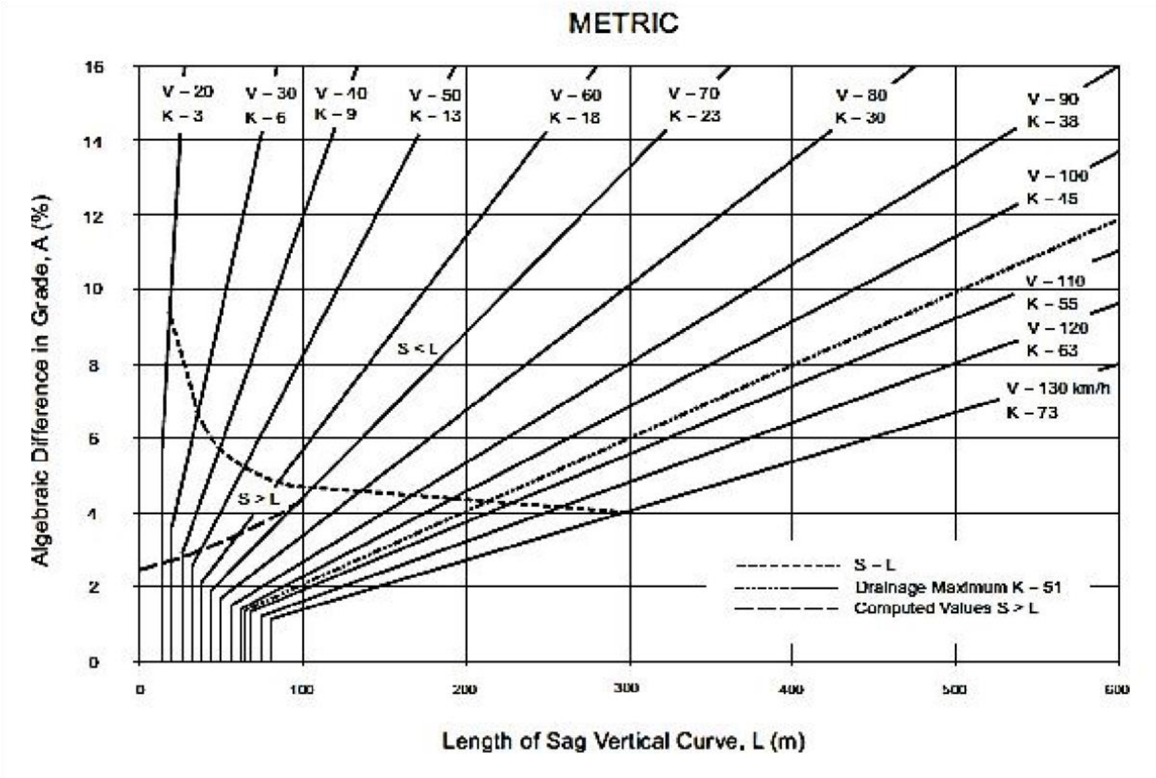


Figure 7 — Length of sag vertical curve as a function of algebraic difference in grade A (%)

Table 21 — Stopping sight distance and rate of vertical curvature as a function of the design Speed

Design speed (Km/h)	Stopping site distance (m)	Rate of vertical curvature k[a]	
		Calculated	Design
20	20	2.1	3
30	35	5.1	6
40	50	8.5	9
50	65	12.2	13
60	85	17.3	18
70	105	22.6	23
80	130	29.4	30

a

Rate of vertical curvature, *k*, is the length of curve (m)percent difference intersecting grades *(A),k=UA*

5.3.2.4 Same lengths of sag vertical curves as that of the stopping sight distance should be used and the rate of vertical curves should be determined accordingly.

5.3.3 Sight distances at undercrossing

5.3.3.1 In some conditions, it is recommended to check the available sight distance at undercrossing such as at an undercrossing without ramp where passing sight distance need to be provided (Figure 8).

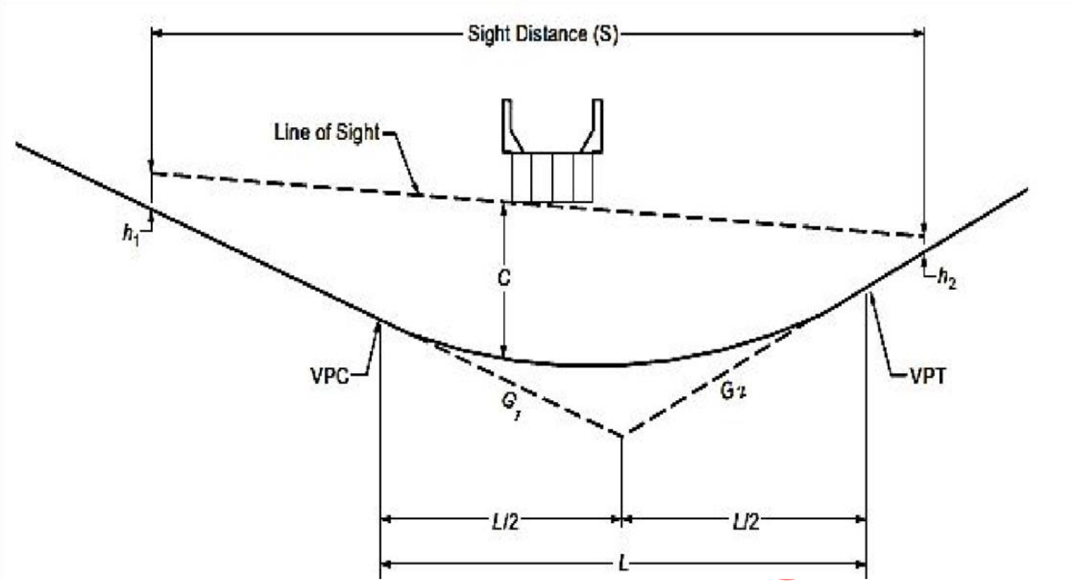


Figure 8 — Schematic view of sight distance at undercrossing

5.3.3.2 General equations should be developed for two cases as follows:

A. Case 1 Sight distance greater than length of vertical curve ($S > L$)

$$L = 2S - \frac{800\left[C - \left(\frac{h_1+h_2}{2}\right)\right]}{A}$$

where

L is length of vertical curve, m;

S is sight distance, m;

C is vertical clearance, m;

h_1 is height of eye, m;

h_2 is height of object, m;

A is algebraic difference in grades, %.

B. Case 2 Sight distance less than length of vertical curve ($S < L$)

$$L = \frac{AS^2}{800\left[C - \left(\frac{h_1 + h_2}{2}\right)\right]}$$

where

L length of vertical curve, m;

A is algebraic difference in grades, %;

S is sight distance, m;

h_1 is height of eye, m;

h_2 is height of object, m.

5.3.3.3 Using an eye height of 2.4 m for truck driver and an object of height of 0.6 m for the taillights of a vehicle, the following equations can be derived:

A. Case 1 Sight distance greater than length of vertical curve (*S* > *L*)

$$L = 2S - \frac{800(C - 1.5)}{A}$$

B. Case 2 Sight distance less than length of vertical curve (*S*< *L*)

$$L = \frac{AS^2}{800(C - 1.5)}$$

5.3.3.4 The sight distance undercrossing shall be determined for two cases where:

A. is the sight distance is greater than the vertical curve;

B. is the sight distance is less than the vertical curve.

5.3.3.5 The cases of a truck driver's eye from 2.4 m staring an object of 0.6 m height for the taillights of a vehicle shall as well be considered.

5.3.4 Gradients

5.3.4.1 To avoid stagnant water, the minimum gradient should be of at least 0.5 %and the maxima shall not exceed the values given in Table 22 according to terrain categories.

NOTE: The desirable maximum gradient should be less than 6% for unpaved roads to avoid the erosion of materials. Where gradient is higher than the recommended, other alternative of paving the section should be proposed,

Table 22 — Maximum gradient according to terrain categories

Terrain	Maximum road gradient (%)
Flat	4
Rolling	4 - 6
Mountainous	7 - 11
Steep	12 - 18

5.3.4.2 These gradients shall be used for feeder roads with due consideration of other factors like the drainage system.

5.3.5 Climbing lanes

Climbing lanes shall not be required for conditions of traffic flow on feeder roads except when safety considerations may require such addition of climbing lane, in which case it shall be done regardless of grade or traffic volumes.

5.3.6 Other features affecting geometric design

5.3.6.1 Erosion control and landscape development

Erosion control and maintenance should be minimized largely by using specific design features such as flat side slopes, drainage channels designed with due regards to width, depth, slopes, alignment, and protective treatment, inlets located and spaced with erosion control in mind; prevention of erosion at culvert outlets; proper facilities for groundwater interception; dikes berms, and other protective devices to trap sediment at strategic locations; and protective ground coverage and planting. To the practical extent, these features should be designed and located to minimize the potential crash severity for motorists who unintentionally run of the roadway.

5.3.6.2 Utilities

5.3.6.2.1 Depending on the location of a project, the utilities involved should include the following:

a) sanitary sewers;

b) water supply lines;

c) oil, gas, and petroleum product pipelines; overhead and underground power and communications lines including fibre optic cable;

d) cable television;

e) wireless communication towers;

f) drainage and irrigation lines; and

g) special tunnels for building connections.

5.3.6.2.2 All utility installation on, over or under road or street right-of-way and attached structures should be of durable materials designed for long service-life expectancy, relatively free from routine servicing and maintenance, and meet or exceed the applicable industry codes or specifications.

5.3.6.2.3 For the design and installation of utilities, the designer shall refer to the instructions/regulations issued by the relevant authority.

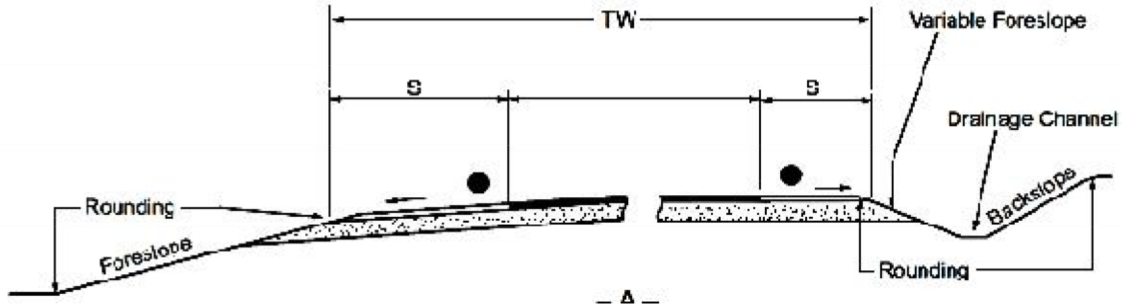
5.4 Cross section elements

5.4.1 Travelled way

5.4.1.1 A typical cross section showing different configurations of a normal crown road way is shown on Figure 9. The rate of cross slope shall be an important element in cross-section design. Cross slope or crown on tangents or on long radius curves are complicated by two contradictory controls. On the one hand, a reasonably steep lateral slope is recommended to minimize ponding of water on pavements with flat profile grades as a result of pavement imperfections or unequal settlement. Horizontal and vertical alignment should also be coordinated to avoid creating flat spots where crest vertical curves and super-elevation transition coincide. On the other hand, steep cross slopes are not recommended on tangents because of the tendency of the vehicle to drift towards the low edge of the travelled way.

5.4.1.2 In areas of intense rainfall, a steeper cross slope may be needed to facilitate roadway drainage.

5.4.1.3 Because of the nature of the surfacing materials used and surface irregularities, unpaved surfaces as earth, gravel or crushed stone need an even greater cross slope on tangents to prevent the absorption of water into surface.



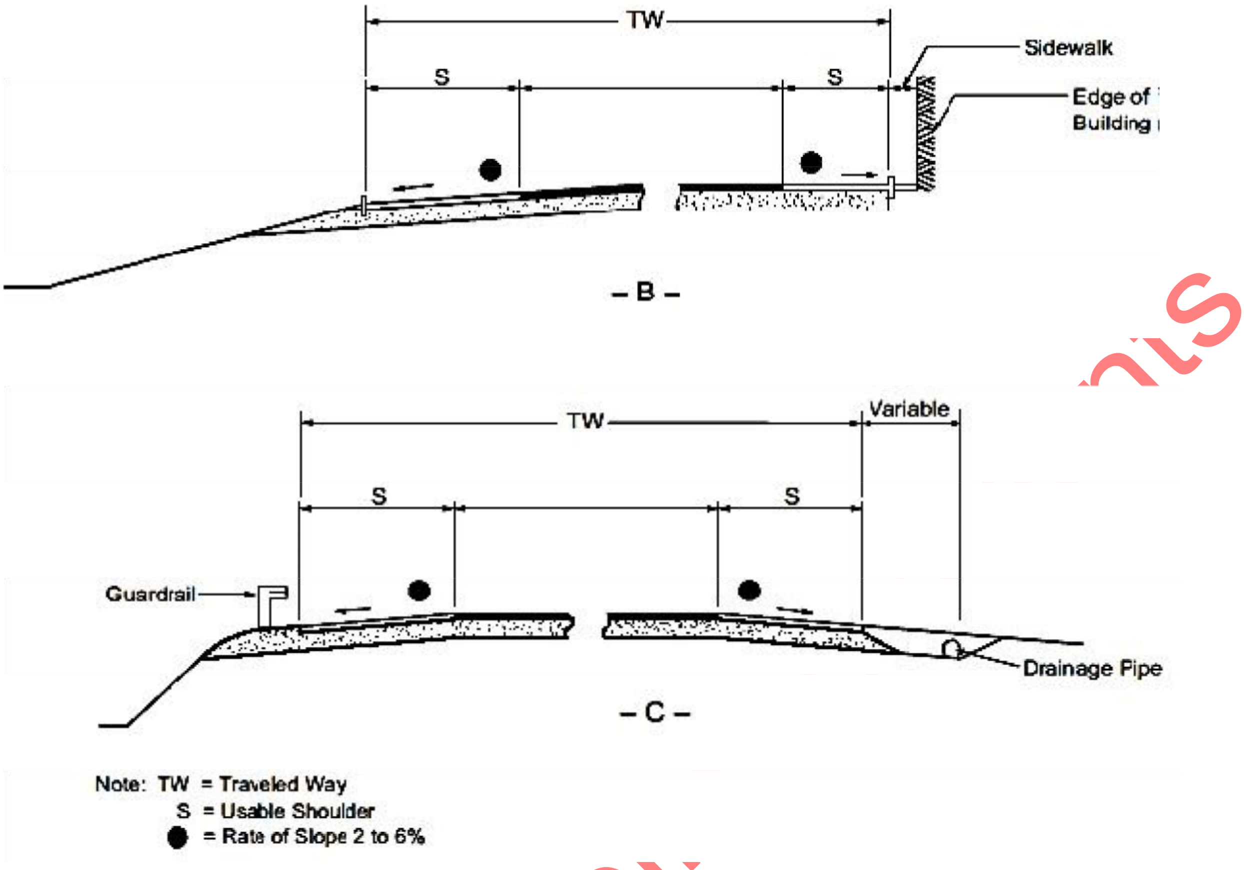


Figure 9— Typical Cross-Section, Normal Crown

5.4.2 Lane width

The lane width of the roadway influences the comfort of driving, operational characteristics, and in some situations, the likelihood of crashes. The lane width of carriageway for feeder roads shall be 3 m to 3.5m. However, where the feeder road falls under the classification in the Law Governing Roads in Rwanda, the recommended width shall prevail.

NOTE In very difficult terrain where cut and fill operations might require substantial amount of earthwork, demarcation from the standard lane width might be considered. The same is done for need of enlargement especially in curves. However, the lanes width remains in the range of 3 m - 3.5 m for feeder roads. In some circumstances, it may be advisable to consider the construction of a single lane road, with periodic turn-outs to allow opposing vehicles to pass. Such circumstances are largely confined to existing 4 m - 5 m wide roads in side hill cuts in mountainous terrain. In such locations, earthwork cost can be prohibitive to construct a two-lane width, and slope stability can be affected. Engineering judgment should be employed in making the decision to use a single lane facility in low traffic volume areas.

5.4.3 Curve widening

The pavement should be widened at sharp curves to accommodate off-tracking, whereby the rear wheels, particularly of larger vehicles, do not follow precisely the same path as the front wheels when the vehicle negotiates a horizontal curve or makes a turn. The amount of off-tracking, and therefore the amount of widening needed on a curve shall depend on the characteristics of the design vehicle and the radius of curvature negotiated.

5.4.4 shoulder widths

5.4.4.1 A hard shoulder width should be in the range of 0.6 m -1.5 m where judged necessary to better accommodate pedestrian and bicycle traffic, and parked vehicles, in built-up areas.

5.4.4.2 When roadside barriers, walls, or other vertical elements are present, it is recommended to provide a graded shoulder wide enough that the vertical elements should be offset a minimum of 0.6 m from the outer edge of the usable shoulder. On low-volume roads, roadside barriers may be placed at the outer edge of the shoulder however, a minimum clearance of 1.2 m should be provided from the travelled way to the barrier.

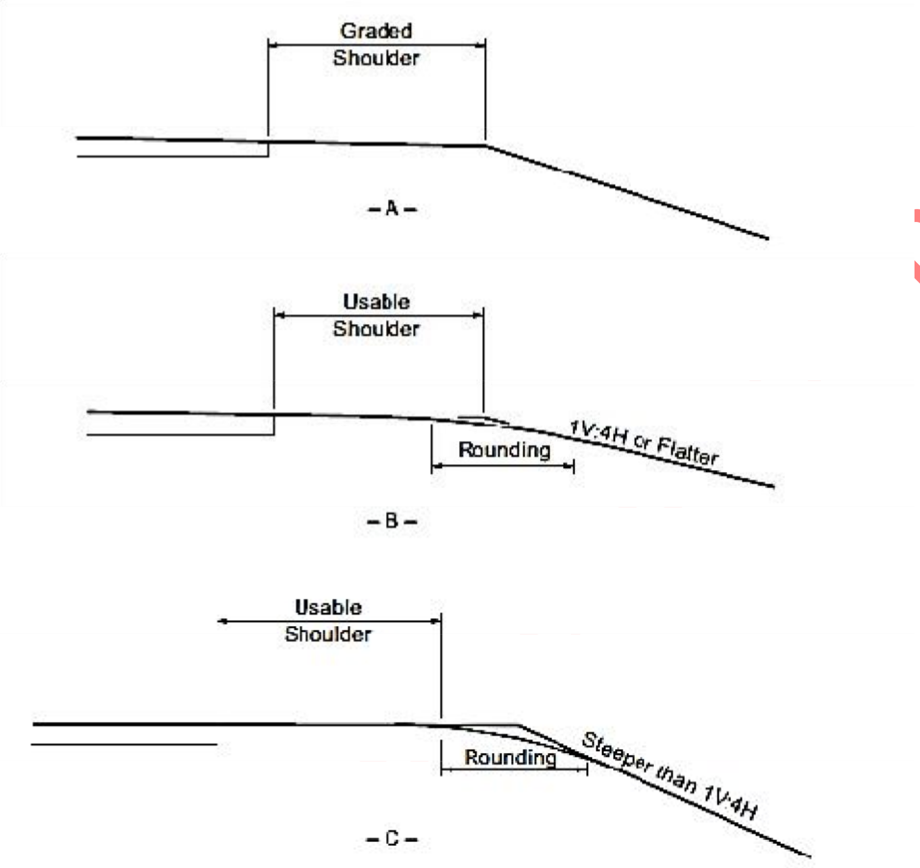


Figure 10 — Graded and usable shoulders

5.4.5 shoulders cross sections

Shoulders for roads class 1 shall be 1.0 m -1.5 m wide while for road class 2, shoulders shall be 0.6 m - 1.0 m wide.

5.4.6 Normal cross fall

A cross slope is used on traffic lanes to promote drainage of surface water. For the Rwandan terrain, a cross slope indicated in 5.2.4 .1 shall be considered.

5.4.7 Slopes in shoulders

Shoulders should be flush with the roadway surface and abut the edge of the travelled way. Any type of shoulder construction has a bearing on the cross slope and the two should be determined jointly. Therefore, the shoulder should have the same slope as the carriageway.

5.4.8 Side slope and back slope

5.4.8.1 Side slopes and back slopes shall be designed to ensure roadway stability and provide reasonable opportunity for recovery for an out-of-control vehicle. Three main regions (Figure 11) of the side slopes are important to safety: the top of the slope (hinge point), the fore slope and the toe of the slope. Slope and soil data should be used in combination to approximate the stability of the slopes and the erosion potential. Effective erosion control, low-cost maintenance, and adequate drainage of the subgrade are largely dependent upon proper shaping of the side slopes. Overall economy depends not only on initial construction cost but also on the cost of maintenance, which is dependent on slope stability.

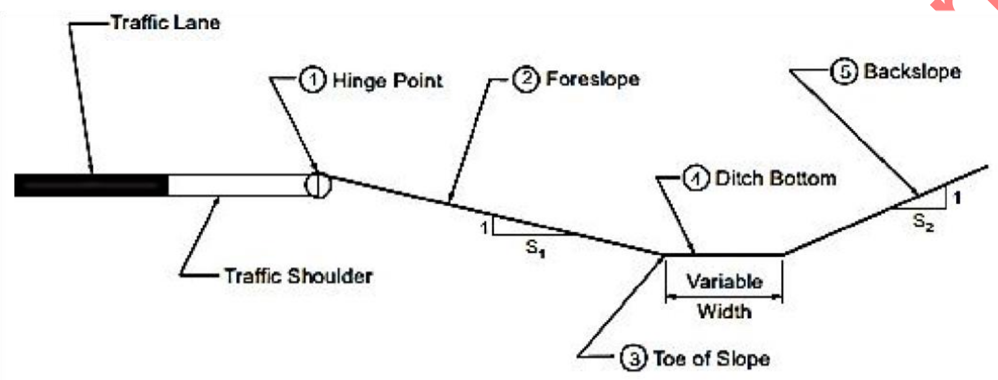


Figure 11 — Designation of roadside regions

5.4.8.2 Slopes of 1V: 3H to 1V:4H should be used, and for slopes less than 1V: 3H, road side barriers should be provided and slope stability as well as traffic safety should be evaluated. In such cases, fill slope should not be steeper than 1V:1H and cut slopes not steeper than 1V:1.5H with additional safety provisions (retaining walls, barriers etc…).

5.4.9 Right-of-Way

Right of way dimensions shall comply with the provisions of the Law Governing Roads in Rwanda.

5.4.10 Clear zones

Clear zone area shall be provided beyond the edge of the roadway for the recovery of errant vehicles. It may include any shoulders or auxiliary lanes and is related to speed, volume, embankment slope and horizontal geometry. The need for clear zone increases with speed and curvature.

Table 23 — Clear zones

Speed limit	Desired (m)	Minimum (m)
70	5	3

80	6	4

5.4.11 Safety barriers

5.4.11.1 The safety barriers are designated to redirect errant vehicles with a specified performance level and provide guidance for pedestrians or other road users.

5.4.11.2 Safety barriers should be provided to protect vehicles from hitting dangerous obstacles that cannot be removed and also to protect vehicles from falling off the road down embankments

5.4.11.3 Safety barriers such as concrete, guardrails, gabion walls, etc should be selected considering the road category, surfacing type and terrain conditions.

5.4.12 Headroom and lateral clearance

A minimum of 5.5 m headroom under a bridge structure, 7.0 m headroom under a high-power cables and 6.0 m headroom under low-power cables shall be provided; The minimum lateral clearance width of 0.6 m on each side of a bridge for traffic volume of less than 400 VPD, 1.0 m -1.2 m on each side of a bridge for traffic volume of 400 VPD - 2000 VPD and increase the value by 1 m for bridges of more than 30 m span.

5.5 Drainage design

Proper drainage design shall be an essential feature of overall design and planning. In drawing up a drainage plan information concerning the following factors shall apply:

a) hydrological consideration such as maximum rainfall and intensity rate of runoff and nature and amount of stream flow;

b) characteristics of the drainage basin (area to be drained) such as size, shape, general slope, nature and type of vegetation and land use (existing and future; and

c) nature and type of basin soils including their permeability and tendency to erode.

5.5.1 Longitudinal drainage

Water should be drained from the carriageway and shoulders by virtue of the cross-fall or transverse slope and longitudinal grade. Such water should either be allowed to flow down the face of the side slope (for small embankments) or collected at the edge of the shoulder by the use of kerbs, dykes or paved ditches and carried longitudinally for disposal at a convenient place. The water from the roadway and surrounding areas should be drained away by use of roadside ditches, mitre drains or cut-off drains. These usually carry the water for disposal at a convenient place or to a bridge or culvert inlets.

5.5.2 Roadside ditches

5.5.2.1 Drainage ditches shall be constructed along the edge of the roadway to receive the runoff from the pavement surfaces and water from subsurface drains. Where the surrounding area is sloping toward the roadway, these ditches shall also serve to intercept and carry away water which would otherwise reach the roadbed.

5.5.2.2 With open drains, the slope next to the road should not be steeper than 1:4, so as to avoid the risk of severe damage and injury when errant vehicles fall into the drain.

5.5.2.3 Generally trapezoidal shape ditches with side slope of 1 in 1 to 1 in 4 (depending upon soil type) and variable bottom width are used. In rolling to hilly terrain where space is limited, V-shaped drains can be used. The capacity of drainage ditch can be increased by widening or deepening the channel. Widening is preferred to limit potential scouring.

5.5.2.4 The minimum depth of ditches should be 0.5 m measured from the bottom of the ditch to the formation level.

5.5.2.5 Maximum velocity of the water in the ditch, which can cause erosion or scour depends on the material of the ditch. An average value of 1 m/sec for loam or fine sand and 2 m/sec for coarse gravel cannot cause erosion. However, in cases when velocities are expected to exceed 2 m/ sec a lining shall be used.

5.5.2.6 To assure flow, ditches should have minimum longitudinal slope of 0.5 % if unpaved and 0.3 % if paved. Key points to consider in the design of safe side drains shall be:

a) there should be sufficient discharge points and culverts to ensure that the drain never gets very deep;

b) with open drains, the slope next to the road should, as much as possible, be flat enough to reduce the risk of errant vehicles overturning;

c) in built-up areas channel drains deeper than 500 mm should be covered or under-drain system be used for the safety and convenience of both pedestrians and vehicles;

d) the drain should terminate or discharge in a satisfactory manner without risk of causing erosion or other problems; and

e) the drain should be capable of being cleaned and maintained easily.

5.5.3 Median drains

Median drains not only drain the median, but also, in the case of a horizontal curve, prevent water from the higher carriageway flowing in a sheet across the lower carriageway. The transverse slopes should be in the range of 1:4 to 1:10. Unlike side drains, median drains, should be generally constructed with a shallow V-profile with the bottom gently rounded.

5.5.4 Chutes drains

5.5.4.1 Chutes are intended to convey a concentration of water down a slope which, without such protection, would be subject to scour. They may vary in size from large structures to half-round precast concrete product, but they are all open channels. Flow velocities are high, so that stilling basins are required if down-stream erosion is to be avoided. An example of the application of chutes is the discharge of water down a fill slope from an edge drain. The entrances to chutes require attention to ensure that water is deflected from the edge drain into the chute, particularly where the road is on a steep grade.

5.5.4.2 The chutes and stilling basins should be such that these drainage elements do not present an excessive risk to errant vehicles. Generally, they should be as shallow as is compatible with their function.

5.5.4.3 Depths in excess of 150 mm should be viewed with caution.

5.5.5 Mitre drains

5.5.5.1 The water collected on side drains shall be disposed of by diverting the drains away from the road before it has become too long and collected too much water. If there is no stream or river into which it can be diverted, mitre drains with small check bends should be constructed pointing away from the road and running downhill. Thus, putting up large size, culverts should be avoided. If it is not possible to construct mitre drains because the surrounding ground is sloping towards the road, then a culvert to take the water across the road away on the other side shall be provided.

5.5.5.2 Where the terrain conditions permit the collected water should be drained freely, however when the conditions for free drain do not permit the mitre drains should be provided with the frequency of 20m.

5.5.6 Catch-water drains

5.5.6.1 Where the surrounding area consists of higher ground, as in a cut or where the highway runs along the side of a hill, additional drains known as catch water cut-off or interceptor drains should be provided. These are effective in preventing erosion of the slope and consequent blocking of the side drain.

5.5.6.2 Catch-water drains shall be constructed at the back of the top of the cut or on benches in the cut slope. The practice of providing catch-water drains along the top of the cutting may sometimes cause a slope failure. Therefore, when it is necessary, it should be provided between 3m-6m away from the top of the cut with the draining slope/incline of 2% (Figure 12).

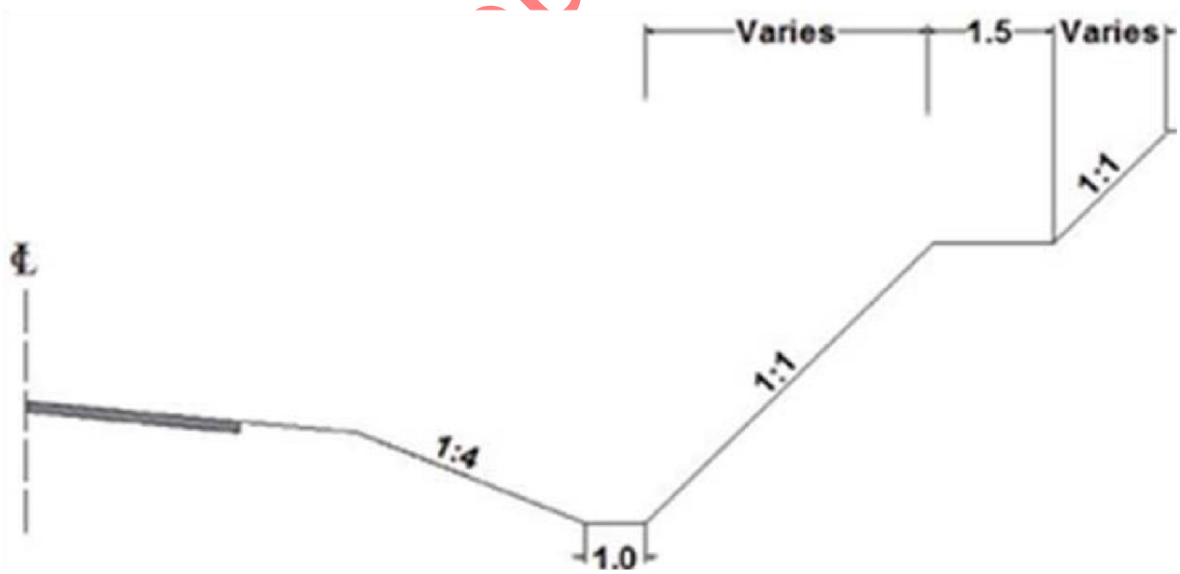


Figure 12 — Catch-water drains

5.5.7 Subsurface drainage

The road base shall be designed either to exclude water completely or alternatively to permit egress of water which has entered. When impermeable bases such as stabilized soils or densely graded bituminous concrete are used, drainage of base shall not be necessary. When permeable and porous base materials are used, particular attention shall be paid to the drainage of the base layer. The base and sub-base should extend the full width across the roadway and the surface of the sub-base layer given adequate cross fall to assist drainage.

5.5.8 Capillary cut -off

Capillary cut off shall collect and lead to drains any water which may pass through the road surface (from top) or rising into the pavement from below by capillary action as shown in figure 13.Capillary cut-off can either be a layer of porous materials such as sand or gravel, or an impervious membrane such as layer of primer, tar felt or polythene. The cut-off should be located at least 0.6 m below top of subgrade. It should also be at least 0.15 m above the general ground level or stagnant water level.

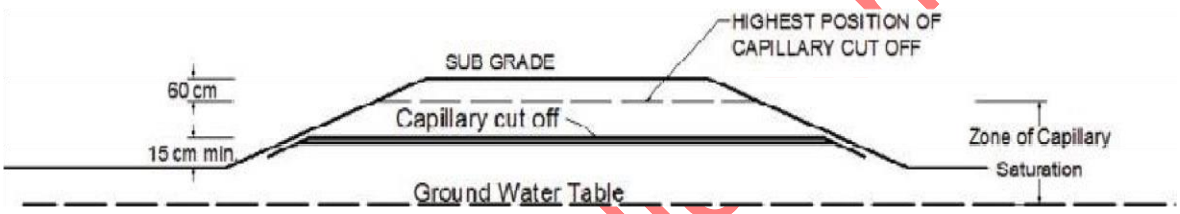


Figure 13 — Capillary cut – off

5.5.9 Control of seepage flow

5.5.9.1 There are two methods of dealing with condition of seepage flow. If the seepage zone is narrow and within 0.6 m to 1.0 m from the surface then the procedure shall be to install an intercepting drain in the impermeable strata underlying the seepage zone as shown in figure 14.

5.5.9.2 If the seepage zone is wider or the impermeable strata are at a considerable depth below the surface, it is generally impracticable to construct the drainage trench sufficiently deep to intercept all the seepage water. In this case, the intercepting drain shall be well above the impervious strata, leading to a partial interception of seepage zone.

5.5.9.3 Where a road is on sloping ground, longitudinal drains may not be capable of intercepting all the seepage water. In such cases it may be necessary to install transverse intercepting drains too.

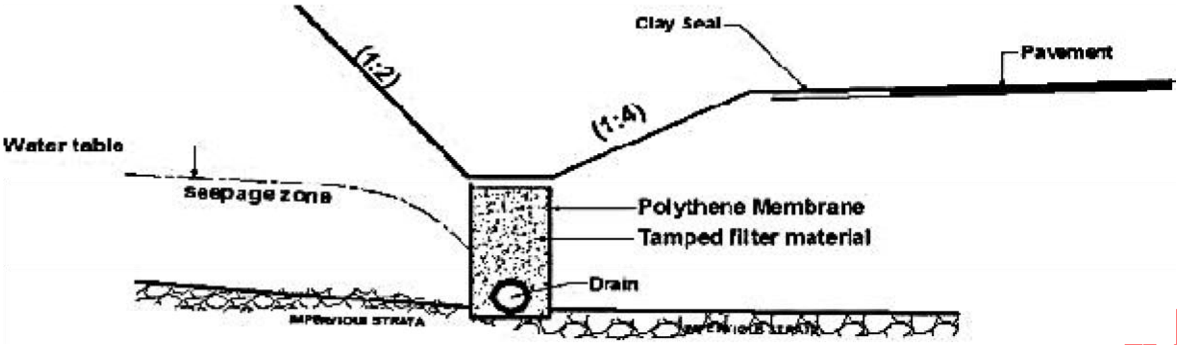


Figure 14— Interception drain for the Seepage Zone

5.5.10 Control of high water table

A high water table can be lowered by the installation of a drainage system similar to the system displayed in Figure 14, above. It is recommended that the water table should be maintained at a depth not less than 1.2 m below the formation level. The actual spacing and depth of drains to achieve this requirement shall depend on the soil conditions and the width of the road formation. In the case of dual carriageway, drains may be necessary under the median as well as under the edges of the formation.

5.5.11 Cross drainage structures

5.5.11.1 Cross drainage structures comprise a wide range of measures from major bridges to drifts and minor culverts. The major structures that are most commonly used for passing water from one side of a road to the other should be pipes, slabs, bridges, beams & walls, , box girders, box culverts, trusses, frames, arches and cable bridges.

5.5.11.2 Collection of water from the roadway should be properly channelled to the bridges to avoid erosion of abutments. Culverts in various shapes and materials are used to convey water from streams below the road and to carry water from one side ditch to the other. Culverts should have inlet headwalls on the upstream side and outlet headwalls on the downstream side. Wing walls on the upstream are intended to direct the flow into the culvert and provide transition from the culvert to normal or regular channel on the downstream. Both help to protect the embankment from flood water. An example is shown in figure 15 below.

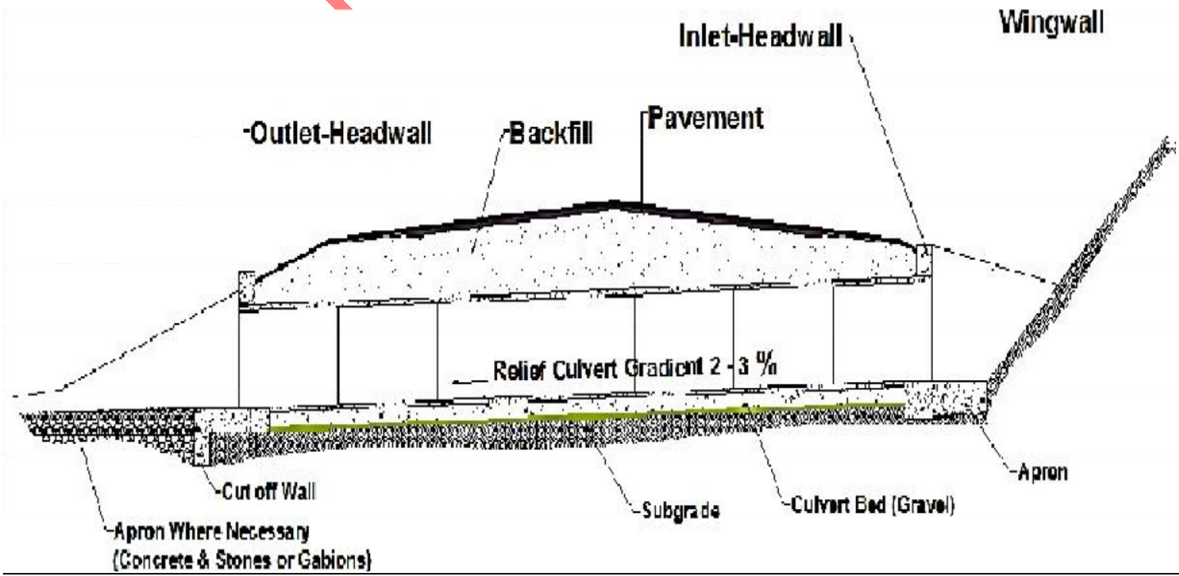


Figure 15 — Example of a pipe culvert

5.5.12 Drainage design

5.5.12.1 The rational method

Runoff calculations shall be undertaken using the rational method. The rational method is usually confined to smaller catchment areas, and other methods, such as unit hydrographs and stream gauges are used to determine peak flows for larger catchment areas. However, as such data, with one exception, is not available for larger streams; the rational method shall be used for all catchment areas. Usually, this can result in flood values above the actual values, as peak rainfall intensities can vary locally within the larger catchment area.

5.5.12.2 Design frequency

The design flood value chosen varies depending on the type of a structure constructed. Recommended design storm frequencies shall be as follows:

a) longitudinal ditches: 1 in 2 years;

b) pipe culverts :1 in 10 years;

c) box culverts :1 in 25 years; and

d) bridges: 1 in 50 years

5.5.12.3 Rational formula

The Rational formula is:

$Q + 0.00278CIA$ (Formula 1)

where

Q is peak runoff in cubic meters per second (m^3/s);

C is runoff coefficient representing a ratio of runoff to rainfall;

I is rainfall Intensity in mm/hr; and

A is catchment area in hectares.

NOTE 1 The formula is modified through multiplication by a factor Cf, when design frequencies of greater than 10 years are specified. For a 25-year frequency, Cf, = 1.1; for 50-year, Cf, = 1.2.

NOTE 2 Most drainage areas will be found to be too small to be measured using a Geographic Information System 1:20000 scale map series. For such areas, a pipe culvert of 100mm Ø should suffice to discharge the flood flow.

5.5.12.4 Catchment area

Catchment areas can be determined by application of the appropriate scale factor to the areas from the Geographic Information System 1:20000 Scale Maps, which include contours at 25 m increments. As most catchment areas are too small to be discernible at this map scale, only the larger catchments shall be shown.

5.5.12.5 Catchment slope

The first step should be to determine the change in elevation, ΔH, by subtracting the elevation at the structure, H1, from the highest elevation of the catchment, H2. This is then divided by the length of the path of the runoff, L. For instance, when the elevation for a catchment drops from 973 m - 720 m (= 253 m) over a length of 2860 m, this gives a slope of 253/2860 or 8.8 %.

5.5.12.6 Hydrological soil group

Soil properties influence the relationship between runoff and rainfall since soils have differing rates of infiltration. Permeability and infiltration shall be the principal data required to classify soils into Hydrologic Soils Groups (HSG). Based on infiltration rates, soils should be divided into four hydrologic soil groups as shown in Table 24.

Hydrologic soil group D shall be used for clay soils, which are the most prevalent Hydrological Soil Group. This soil group also gives the highest runoff rates, and shall be therefore the safest group to use to ensure that the runoff can be conveyed by the selected structure.

Table 24 — Hydrological soil groups

Group	Description
Group A	Sand, loamy sand or sandy loam. Soils having a low runoff potential due to high infiltration rates. These soils primarily consist of deep, well-drained sands and gravels.
Group B	Silt loam, or loam. Soils having a moderately low runoff potential due to moderate infiltration rates. These soils primarily consist of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
Group C	Sandy clay loam. Soils having a moderately high runoff potential due to slow infiltration rates. These soils primarily consist of soils in which a layer exists near the surface that impedes the downward movement of water or soils with moderately fine to fine texture.
Group D	Clay loam, silty clay loam, sandy clay, silty clay or clay. Soils having a high runoff potential due to very slow infiltration rates. These soils primarily consist of clays with high swelling potential, soils with permanently-high water tables, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious parent material.

5.5.12.7 Runoff coefficient

This recommended Runoff Coefficient C for Pervious Surfaces by Selected Hydrologic Soil Groupings and Slope Ranges," is shown in table 24. For instance, if terrain is mountainous (6 % – 15 %), and the Hydrologic Soil Group is Group D (see above), a clay loam soil, and this table gives a "C" of between 0.28 and 0.38. A value between these extremes can be determined through interpolation using the actual cross terrain slope of the catchment area. For the example at 8.8 % mentioned in the above text, C= 0.31.

Table 25 — Recommended runoff coefficient C for pervious surfaces by selected hydrologic soil groupings and slope ranges

Terrain types for hydrological design	Soil type			
	A	B	C	D
Flat < 2 %	0.04 - 0.09	0.07 - 0.12	0.11 - 0.16	0.15 - 0.20
Rolling 2 % – 6 %	0.09 - 0.014	0.12 - 0.17	0.16 - 0.21	0.20 - 0.25
Mountainous 6 % – 15 %	0.14 - 0.18	0.18 - 0.24	0.23 - 0.31	0.28 - 0.38
Steep > 15 %	0.18 - 0.22	0.24 - 0.30	0.24 - 0.30	0.38 - 0.48

5.5.12.8 Time of Concentration (TC)

The determination of rainfall intensity first requires a determination of the Time of Concentration, TC.

$$L_C = \left(0.87 \times \frac{L_3}{H}\right)^{0.385}$$

where

Tc is time of concentration (hr);

L is length of catchment area (km);

H is height of catchment (m).

NOTE In the above example, a catchment area measuring 2860 m long with a drop of 253 m would result in *Tc* = 0.38 hrs or 23 min

5.5.12.9 Rainfall intensity, I.

The rainfall intensity data shall be determined by using local references (National meteorological service).The rainfall station closest to the road project should be chosen for hydrological design for that project to determine peak runoff Q.

5.5.12.10 Minor runoff areas

If the catchment area is too small to be measured on a 1:50000 scale map, then it will have a runoff in ten years (Q10) flow of less than 3 m^3/s, which means that a single barrelled 1000 mm Ø pipe culvert can handle the flow. Often such small catchments are already addressed by more than one cross drain, which further divides the flow into smaller areas, especially at intervals down a gradient.

5.5.12.11 Spacing of cross drains on steep gradients

For long steep road gradient segments, i.e. those of over 7 % gradient, it is recommended to transport the runoff out of the longitudinal side ditch, through cross drains, at regular intervals. This shall prevent the side drains from overflowing, which otherwise would result in a diversion of a portion of the flow onto the gravel surfacing, and a loss of the surfacing. The side ditch does not only carry runoff flow from the roadway, but from the adjacent hillside. Rather than performing very tedious calculations to determine this flow, spacing can be selected at which the ditch flow is channelled through a cross drain culvert pipe (relief culvert). The spacing should be located at every 100 m of distance.

5.5.12.12 Verification of Stream Channel Peak Flow Using Manning's Equation

5.5.12.12.1 Major catchment areas should be analysed to check the flood flow values obtained through the use of the Rational Method against flood flow values obtained from historic flood height observations. These are obtained through interviews with local residents. The claimed flood height is then checked against a topographic survey to determine the required parameters such as flow area and petted perimeter, and used in the Manning's Equation to obtain flood flows.This double check is especially valid given the uncertainty mentioned above in extending the intensity-duration-frequency curves beyond the range of available data. Manning's Equation to obtain flood flows, is described below.

5.5.12.12.2 ***Manning's Equation*** – For a given depth of flow in a channel with a steady, uniform flow, the mean velocity, V, can be computed with Manning's equation:

$$V = (1/n)R^{2/3}S^{1/2}$$

where

V is velocity, m/s;

n is Manning's roughness coefficient;

R is hydraulic radius;

S is slope of the energy gradeline, m/m (note: for steady uniform flow, S = channel slope, m/m).

Manning's Equation can also be written as:

$Q = (1/n)R^{2/3}S^{1/2}$

where

Q is discharge, m^3/s;

A is cross-sectional area of flow,

m^2;

NOTE The selection of Manning's 'n' is generally based on observation.

5.5.12.13 Pipe culvert design

5.5.12.13.1 A pipe culvert shall comply with the requirements of RS 265.

5.5.12.13.2 A pipe culvert should have a minimum cover from the top of the culvert to the finish grade line of 600 mm, inclusive of embankment and wearing course.

5.5.12.14 Side ditches (longitudinal drains)

5.5.12.14.1 Side ditch flow should be accommodated through a various range of ditch configurations, including rectangular U-ditches, trapezoidal ditches, and triangular v-ditches.

5.5.12.14.2 Rectangular ditches are not recommended as they can be unsafe for vehicles. If an errant vehicle leaves the roadway and enters the ditch, damage may be done to the undercarriage of the vehicle that may likely render it inoperable. Because of this, drivers tend to stay away from the ditch or drive more towards the centreline of the road, creating an unsafe condition for oncoming traffic. A vehicle entering the ditch can be "unrecoverable," which means that it cannot be able to get out of the ditch and resume operations.

NOTE Rectangular ditches are unsafe for animals and pedestrians. The vertical drop of more than 0.5 m would cause serious injuries. Rectangular ditches are disease vectors. Water and mud that collect in the flat bottom are a breeding ground for mosquitoes.

5.5.12.14.3 At places where a hard shoulder exists, drivers may tend not to use the hard shoulder for its intended purposes of accommodation of stopped vehicles and emergency use, fearing that they may misjudge the distance to the ditch. Hence they may remain partially in the travel lane, creating further safety issues.

5.5.12.14.4 It is recommended to provide V-ditch configuration whereby the front ditch slope, i.e. the one facing the traffic lane, has a slope of 1.5:1 H:V. This should allow vehicles and pedestrians to resume travel if they enter the ditch. The ditch back slope should be made steeper in the interests of reducing the right-of-way take, and is set at a slope of 0.67:1 H:V. The ditch shall have a depth of 0.6 m. Ditches on gradients steeper than 7 % shall be lined (mortared) ditches.**5.5.12.14.5** The drainage on the conglomeration of houses should be lined and covered

NOTE Debris and waste that collects in the flat bottom pose adverse health effects for someone who falls into the ditch. V-ditches, lacking a flat bottom, do not have the same magnitude of health issues.

5.6 Site and materials investigation

5.6.1 General

5.6.1.1 Site investigation and surveys are a vital and integral part of selecting the road alignment and undertaking the design and construction of the road. Surveys provide essential information on the characteristics of the soils along the possible alignments.

5.6.1.2 Materials investigation provides the background for the general understanding of the approach to selecting and using materials for the construction of feeder roads in an economic and sustainable manner, and to ensure that satisfactory levels of quality are attained.

5.6.2 Subgrade strength

5.6.2.1 The design of a road pavement dictates that the layer(s) of pavement and the sub-grade foundation should be capable of sustaining the stresses applied to them by repeated vehicle loading without suffering damaging permanent deformation. When a vehicle wheel load is applied to a road surface, the resulting stresses are distributed through the pavement layers to the ground and the load is spread over an increasing area as it is transmitted downwards. The pavement structure shall be sufficiently thick over the subgrade soil to ensure that the soil is not overstressed. The greater the strength of the soil, the thinner the pavement layers need to be. Hence, the load carrying capacity of the subgrade is a principal factor in determining the required pavement thickness.**5.6.2.2** To complete the design process, material investigations of the existing and new road surface should be undertaken to better determine the properties of the existing and new pavement and subgrade. A Dynamic Cone Penetrometer (DCP) complying with the requirements of RS ISO 22476-2 shall be performed at least every 200m to rapidly obtain an insitu measurement of the structural properties of the gravel layers, and sub-grades after an excavation is made through the surface layers.

NOTE The DCP is a simple apparatus that can characterize the ground conditions in and beneath an unsealed road quickly and with accuracy appropriate to the requirements of the design. In its use, a steel cone (20 mm diameter with a 60º angle) is driven into the ground under a fixed energy (an 8 kg mass falling through 575 mm).

5.6.2.3 The rate of penetration into the gravel or soil material (DN mm/blow) should be a reasonably good predictor of the California Bearing Ratio (CBR) at the prevailing insitu moisture and density conditions as shown in table 25.

5.6.2.4 The penetration should be measured up to a depth of 800 mm. On un-compacted soils (e.g., investigations for new alignments, lane additions, or lane widening), do not do DCP measurements immediately after rainfall or if the ground surface appears wet as this will influence the rate of penetration and may result in weaker than actual soil strengths.

Table 26 — Tabulated Correlation of California Bearing Ratio vs Dynamic Cone Penetrometer

Dynamic Cone Penetrometer (DCP) Index Mm/blow	California Bearing Ratio (CBR) %
< 3	100
3	80

4	60
5	50
6	40
7	35
8	30
9	25
10 - 11	20
12	18
13	16
14	15
15	14
16	13
17	12
18 - 19	11
20 - 21	10
22 - 23	9
24 - 26	8
27 - 29	7
30 - 34	6
35 - 38	5
39	4.8
40	4.7
41	4.6
42	4.4
42	4.3
43	4.2
44	4.1
45	4.0
46	3.9
47	3.8
48	3.7
49 - 50	3.6
51 - 52	3.5
53 - 54	3.4
55	3.3

56 - 57	3.2
58	3.1
59 - 60	3.0
61 - 62	2.9

Table 26 — Tabulated Correlation of California Bearing Ratio vs Dynamic Cone Penetrometer (Cont)

Dynamic Cone Penetrometer (DCP) Index Mm/blow	California Bearing Ratio (CBR) %
63 - 64	2.8
65-66	2.7
67-68	2.6
69-71	2.5
72-74	2.4
75-77	2.3
78-80	2.2
81-83	2.1
84-87	2.0
88-91	1.9
92-96	1.8
97-101	1.7
102-107	1.6
108-114	1.5
115-121	1.4
122-130	1.3
131-140	1.2
141-152	1.1
153-166	1.0
166-183	0.9
184-205	0.8
208-233	0.7
234-271	0.6
272-324	0.5
>324	<0.5

5.6.3 Laterite wearing course

5.6.3.1 Borrow pits should contain laterite materials (murram). Nearly all laterites are rusty-red because of iron oxides. They develop by intensive and long-lasting weathering of the underlying parent rock.

5.6.3.2 Laterite should vary in gradation. It ranges from hard gravel to a softer earth embedded with small stones. Not all laterite roads are therefore strictly gravel roads.

5.6.3.3 Laterite which contains a significant portion of clay can become very slippery when wet and in the rainy season, it may be difficult even for four-wheel drive vehicles to avoid slipping off highly cambered roads. As it dries out, laterite can become very hard.

5.6.3.4 From 5.6.3.1 to 5.6.3.4 dictate that laterite should conform to an approved specification which addresses gradation and other performance indicators such as plasticity index, liquid limit, and CBRs.

5.6.4 Material stabilization

5.6.4.1 Stabilisation in a pavement construction (either as material delivered to site having been mixed in a pug mill plant or in-situ stabilised) or in the rehabilitation of an existing pavement (ie in-situ stabilisation) should be undertaken with the following purposes:

a) To correct any mechanical deficiencies (particles size distribution and/or plasticity) in unbound granular materials and sub-grades;

b) Increase the strength or bearing capacity of pavement;

c) Reduce the permeability and or moisture sensitivity, which can result in a loss of strength of the material or seasonal volume change;

d) In-situ stabilisation in particular provides a means by which existing pavements can be recycled;

e) Improve the strength of sub-grades so they are capable of accepting construction traffic as well as provide the support for more economical pavement configurations; and,

f) Enhance the compaction in unbound granular materials and in silty and clayey subgrades.

5.6.4.2 The mechanical stabilisation consists of blending two or more materials to produce one with suitable grading and/or plasticity. Mechanical can be possible by undertaking the following;

a) Mixing of materials from various parts of a deposit at the source of supply.

b) Mixing of selected, imported material with in-situ materials.

c) Mixing two or more selected imported natural gravels, soils and/or quarry products on-site or in a mixing plant, and

d) The use of excessive compaction to consolidate a material.

5.6.4.3 Chemical stabilization consists of treating materials with sufficient amount of stabiliser complying with relevant standards requirements to increase the engineering parameters of materials to be used in the pavement design. A chemical stabiliser can be added to the sub-grade, sub-base and/or base layers to impart a necessary change to the engineering parameters of that layer. Base stabilization should not be considered as a wearing course however replacement to a bituminous seal.

NOTE: Common types of chemical stabilization materials include hydraulic stabilizing agents such as cement, lime and/or blended hydraulic materials and bitumen.

5.6.4.4 Where mechanical stabilisation methods cannot be applied or where naturally occurring materials that meet the specified requirements cannot be located within economical haul distance from the project site, chemical stabilisation should be considered.

5.6.4.5 Selection of the correct stabiliser requires an in-depth understanding of several input variables. The following shall be taken into consideration:

a) Climate

b) Existing pavement conditions, such as variability of material, thickness of layers, etc.

c) Traffic data, especially loading

d) Engineering parameters of the material to be stabilised

e) Capacity and experience

f) Distance to and quality of borrow pit materials

g) Availability and type of binder in terms of quantity required and transportation distance

h) Ease of application of binder in consideration of plant and equipment on site

5.7 Pavement

5.7.1 Pavement design

5.7.1.1 The gravel road design process generally does not focus on cumulative axle loads, fatigue or a target life expectancy. This is because the gravel road seldom fails as a result of punching into the subgrade (*i.e.* shear failure of either the wearing course or the subgrade material). Failure is typically either the result of continued slippage of the vehicle tires against the soil (gravel) when a high moisture content prevails (lack of frictional resistance leading to plastic failure) resulting in settlement of the tire into the material, or shear failure of the upper portion of the wearing course with lateral displacement. Unlike paved roads, motorcycles can cause stress to a gravel road due to kick-out of gravel, and loss of fines."

5.7.1.2 A road pavement structure is usually composed of several layers of different materials overlying the (subgrade). Materials selection forpavement layers shall consider two major variables:

a) the bearing capacity and stiffness of foundation soil (subgrade) beneath the pavement, which may be variable, changing with soil type, dry density and ground water conditions; and

b) The climate of the region;

5.7.2 Traffic volume and axle loads

5.7.2.1 Design life of pavements

5.7.2.1.1 The “design life” does not mean that at the end of the period the pavement will be completely worn out and in need of reconstruction; it means that towards the end of the period, the pavement shall need to be strengthened through the placement of additional surfacing materials so that it can continue to carry traffic satisfactorily for a longer period.

5.7.2.1.2 Design life provided in 5.1.5 for both paved and unpaved should be considered

5.7.2.2 Estimation of traffic

A traffic count study should be conducted on feeder roads to provide an indication of what future counts and traffic composition may be anticipated as the road develops over time.

5.7.2.3 Traffic /Load Equivalence Factors (LEF/TEF)

5.7.2.3.1 The commonly used equivalent load should be 80 kN equivalent single axle load, normally designated Equivalent Single Axel Load (ESAL).

5.7.2.3.2 Traffic Equivalence Factors (TEFs) shall be used for various sizes of trucks and buses to relate the fleet to the equivalent loads. Load assumptions are presented Table 27.

Table 27 — Traffic Equivalence Factors (TEFs)

Vehicle type	TEFs
Light Vehicles	0.01
Buses	0.50
Heavy trucks	1.00

5.7.2.3.3 As a rule-of-thumb, the damage caused by a particular load is roughly related to the load by a power of four (for reasonably strong pavement surfaces).For example:

— for a 80 kN single axle, LEF =1.0

— what is the TEF for a 133 kN single axle?

— using the fourth power rule-of-thumb:

$$\left(\frac{133}{80}\right) = 7.7$$

5.7.2.3.4 Axle loads shall be estimated by taking an average of the present ADT and the future ADT by vehicle class, dividing by two to account for the traffic volumes per direction or lane, and multiplying by the equivalence factor. An assumption is that the ratio of buses to trucks is 50/50.

5.7.2.3.5 Feeder roads with light traffic and a low number of commercial vehicles shall be designed for gravel surfacing." A gravel wearing course shall be placed at 150 mm thickness on a prepared subgrade where the subgrade CBR value is greater than 7 %. Where the CBR is between 4 and 7, the gravel wearing course shall be increased to 200 mm in thickness. Instances where the CBR is less than 4 shall be considered special cases which may require an additional layer of 50mm of sub base material.

5.7.2.3.6 Recommended thickness of gravel layers to the placed wearing coarse on the subgrade of the gravel is shown in Table 27.

Table 28 — Recommended thickness of gravel layers to the placed wearing coarse on the subgrade of the gravel

Traffic (AADT) in both directions	Subgrade soil	Recommended total minimum thickness of gravel
< 200	CBR > 7	150 mm
	3< CBR < 7	200 mm
> 200	CBR > 7	200 mm
	3 < CBR < 7	250 mm

5.7.2.4 Subgrades

5.7.2.4.1 Design depth

The subgrade depths of feeder roads varying from 0.3 m - 0.6 m shall be considered depending on the CBR. Soils with CBRs less or equal to 3 shall be improved or replaced.

5.7.2.4.2 Centreline soil surveys

Following the DCP tests, a minimum of 2 CBR strength testing shall be conducted at each uniform section but the spacing should not be more than 2 km..

5.7.2.4.3 Characterization of the subgrade strength design value

The statistical approach of estimating subgrade CBR design value for a section which takes the 90 %ie CBR test value for a homogeneous section shall be used as the CBR design value.

5.7.2.4.4 Subgrade classes and CBR design values

5.7.2.4.4.1 The following classification for classes of subgrades shall apply:

a) S3 is natural gravel/soil with nominal CBR value of minimum 3;

b) S7 is natural gravel/soil with nominal CBR value of minimum 7; and

c) S15 is natural gravel/soil with nominal CBR value of minimum 15.

5.7.2.4.4.2 Improvement should be done on subgrades with strength values S3 and S7 only.

5.7.2.4.4.3 For gravel roads, the materials for improved subgrade layers should meet the requirements for class G15 and G7.

5.7.2.4.4.4 Subgrades with CBR value less than 7 shall be used with care and good engineering judgment. Use of extra thickness shall be balanced against the option of upgrading to higher material strength.

5.7.2.5 Gravel Wearing Course (GWC)

5.7.2.5.1 The following requirements shall be met by materials for gravel wearing course:

a) the need for a sufficient cohesion to bind the particles and prevent the surface from travelling and becoming corrugated in dry seasons; and

b) limiting the amount of fines and the plasticity so as to avoid the occurrence of a slippery surface in wet weather.

5.7.2.5.2 The main material properties for fully engineered gravel wearing course should be CBR, gradation, shrinkage product, grading coefficient, and field density and the gravel wearing course should also meet the requirements for the same properties.

5.7.2.6 Earthworks compaction requirements

5.7.2.6.1 Requirements for earthwork compaction are shown in the Table 29.

Table 29 — Compaction requirements for earthwork

Layer and typical material type specified	Minimum dry density (Nominal value)

Hard material, soft material-waterlogged, and swampy material	95 % MDD, 100 % MDD for 300 mm I cuttings, embarkments
Upper improved subgrade layer, nominally G 15 material or better, for layers less than150 mm below the formation level	95 % of BS Heavy
Lower improved subgrade layer, nominally G 7 material or better, for layers from 150mm to 300mm below the formation level	93 % of BS Heavy
Fill, nominally G3 material or better, for layers more than 300mm below the formation level	90 % of BS Heavy
Fill or improved subgrade layers using rock fill(DR)	Compaction method specification shall apply
Roadbed compaction to 150 mm depth after clearing, grubbing and removal of topsoil or other unsuitable material, where the roadbed level is:	
Less than 150 mm below the formation level	97 % of BS Heavy
150 mm – 300 mm below the formation level	95 % of BS Heavy
300 mm – 600 mm below the formation level	93 % of BS Heavy
More than 600 mm below the formation level	100 % of BS Light

5.7.2.6.2 The recommended requirements for fill and improved layers for earthwork are indicated in Table 30.

Table 30 — Requirements for fill and improved subgrade layers

Material type	**Requirements**				
	CBR(%)	**CBR Swell (%)**	**PI (%)**	**Maximum particle size**	**Maximum layer thickness**
G 15	Minimum 15 after 4 days soaking	1.5, max.	25	½ of	250 mm

G 7	Minimum 7 after 4 days soaking	Max. 2	30	compacted layer thickness but not > 50 mm	compacted layer thickness placed in one operation
G 3	3 after 4 days soaking, measured at 90 % of MDD of BS –Heavy compaction	Max. 2	-		
DR	-	-	-	Two third of compacted layer	1 m placed in one operation

5.7.2.7 Unbound materials

5.7.2.7.1 Code designation for unbound materials is shown in Table 31

Table 31— Code designation for unbound materials

GW	Gravel wearing coarse for gravel roads or unpaved shoulders
G 25	CBR minimum 25 %
G 45	CBR minimum 45 %
G 60	CBR minimum 60 %
G 80	CBR minimum 80 % and include crushed materials with less than 50 % by mass of particles retained on the 5 mm sieve has a crushed face
CRR	Crushed rock made by crushing and screening of fresh quarried rock or clean, unweathered boulders of minimum 0.3 m diameter. All particles should be crushed, no soil fines allowed
CRS	Crushed stone made by crushing and screening of blasted rock, stones, boulders and oversize from natural gravel. Min 50 % by mass of particles larger than 5 mm shall have at least one crushed face. Max 30 % of material passing 5 mm can be soil fines.

5.7.2.7.2 For pavement layers of natural gravel materials, materials requirements for gravel wearing course, base and sub-base layers are indicated in Table 32.

Table 32— Requirements for fill and improved subgrade layers

Material type	Requirements									
	Compaction	**CBR**	**CBR swell (%)**	**Maximum LL**	**Passing 37.5 mm sieve (%)**	**Shrinkage product (SP)**	**Gradient coefficient (GCO)**	**Max. PI**	**Max. LS**	**TFV**
GW	95 % of BS Heavy	Min 25[d]			Min 95	120-400	16-34			
G 80[a2]	98 % of BS Heavy	Min 80[d]	0.5	30[3]/35[4]				8[3]/10[4]	4[3]/5[4]	80kN[5]
G 60[a2]	98 % of BS Heavy	Min 60[d]	1.0	35[3]/40[4]				10[3]/12[4]	5[3]/6[4]	60%[6]
G 45[b2]	95 % of BS Heavy	Min 45[d]	0.5	40[3]/45[4]				14[3]/16[4]	7[3]/8[4]	50kN[5]
G 30[d2]	95 % of BS Heavy	Min 30[d]	1.0	45[3]/45[4]				16[3]/18[4]	8[3]/9[4]	60 %[6]

[a2] dmax is ½ of compacted layer thickness but not > 50mm and GM is 2.2

[b2] GM is 1.5

[c2] GM is 1.2

[d] After 4 days of soaking

[3] General requirements;

[4] Calcrete or other pedogenic materials

[5] Minimum TFV dry;

[6] Raio soaked to dry value of TFV

5.7.2.7.3 The grading requirements for G 80 and G 60 materials shown in Table 33 shall apply.

Table 33 — Grading requirements for G80 and G60 materials

Sieve size (mm)	G 80 grading limits (% passing sieve)	G 60 grading limits (% passing sieve)
63	100	100
37.5	80 - 100	80 - 100

20	60 - 95	60 - 95
5	30 - 65	30 - 65
2	20 - 50	20 - 50
0.425	10 - 30	10 - 30
0.075	5 - 15	5 - 15

5.7.2.8 Crushed aggregate base course

For a crushed rock to be viable as a pavement material, it shall be available, workable and give satisfactory field performance at the lowest possible cost. The final in-place cost should take into account supply and cartage costs, cost of repair to road during cartage, spreading and compaction costs and preparation of surface costs. Table 34 gives requirements for crushed aggregate base course materials.

Table 34 — Crushed aggregate base course requirements

Material type	Requirements					
	Compaction	Max PI	Max. LS	TFV	Ratio TFV soaked to dry	Max. Flakiness index
CRS	98 % of BS-Heavy	6	4	110kN	60 %	35 %
CRR	102 % of BS-Heavy	Non plastic	3	110kN	75 %	35 %

Sieve size (mm)	Grading limits (% passing sieve)			
	CRS		CRR	
	Coarse type	Fine type	Coarse type	Fine type
50	100			
37.5	90 - 100	100	100	
28	75 - 95	90 - 100	87 - 97	100
20	60 - 90	65 - 95	75 - 90	87 - 97

10	40 - 75	40 - 70	52 - 68	62 - 77
5	29 - 65	29 - 52	38 - 55	44 - 62
2	20 - 45	20 - 40	23 - 40	27 - 45
1.18	17 - 40	15 - 33	18 - 33	22 - 38
0.425	12 - 31	10 - 24	11 - 24	13 - 27
0.075	5 - 12	4 - 12	4 - 12	5 - 12

5.7.2.9 Design method

5.7.2.9.1 The design process should include computation of the traffic volume, and conversion into Equivalent Single Axle Loads (ESALs) using a traffic growth rate. The design subgrade CBR values are determined based on estimated 90th percentile CBR values, and conversion into the Effective Modulus of Subgrade Reaction (K-value) as shown in Table 35.

Table 35 — Recommended aggregate thickness Vs. roadbed soil quality and traffic

Relative quality of roadbed soil	Traffic level*	Aggregate thickness
Very good (K-value > 550 pci)	High Medium Low	200 mm 150 mm 100 mm
Good (K-value 400 - 550)	High Medium Low	275 mm 200 mm 100 mm
Fair (K-value 250 - 400)	High Medium Low	325 275 150 mm

Poor (K-value 150 - 250)	High Medium Low	** ** 225 mm
Very poor (K-value < 150pci)	High Medium Low	** ** 275 mm
*High = 60 – 80000 ESLs; medium = 30 – 60000 ESLs; low = 10 – 30000 ESLs **higher type of pavement design recommended.		

5.7.2.9.2 The soil quality is fair as the traffic volume in ESALs is low (100000 ESALs/year), a thickness of 150 mm is recommended. For any higher traffic volumes, the table indicates that "a higher type of pavement design is recommended."

5.7.2.10 Design for annual gravel loss

Regravelling should be considered whenever a gravel loss of 30 mm /year is encountered. This means that, an addition of 75 mm should be required (1/2 x 30 mm/yr x 5 yr) is regravelling is planned in five years. Rather than having to add such thickness, methods of stabilizing the wearing course should be investigated.

5.8 Design for climate resilience

5.8.1 The projected climate change is likely to have several significant effects on the road infrastructure. To reduce this impact, new roads must be designed incorporating the necessary climate adaptation measures.

5.8.2 To implement the necessary adaptations to make roads more climate resilient and assist with the prioritisation, it is necessary to carry out visual assessments of existing roads with particular attention being paid to the expected changing climatic conditions along those roads.

5.8.3 To take account of future changes in climate, either in the design of new roads and structures or in improving the resilience of existing roads, the following should be considered;

1. In the design of storm water drains and the downspout, the hydraulic design should include the design of water catch basins / check dams/detention basins where possible after analysing the topography of the project area. This can reduce the frequency and extent of downstream flooding, erosion, sedimentation and water pollution.
2. In the design of the bridges and culverts, the rate of sedimentation should be analysed
3. The design of high slopes in rural areas should consider the sealing options to avoid erosion and slipperiness
4. The bioengineering which is the use of grasses on cuts and embankment slopes, should be applied for protection against erosion. Grasses with long roots contribute to the stability of slopes
5. The choice of the alignment of a new road, the section of the project prone to flooding, landsliding, erosion and scouring should be identified and analysed in particular. If found to be at high risk, an

alternative alignment should be identified. With the topography conditions, the geology and rainfall conditions, the proposition of relocation or change of the alignment can be supported.

6. Clear indication of the height of the embankment against the level of water. It is recommended that the height of the road structure be at a minimum 0.5 m from the highest estimated flooding level.
7. Where there are underground water the analysis to determine the moisture level should be conducted to provide the underground soil drainage.
8. Provision of catch water drain at regular intervals in the road side drain to avoid the erosion of unpaved drainage. This is necessary for high gradient roads.
9. Shape the earthen drain to allow water to run in the channel. If they are constructed, mitre drain should be provided at regular intervals and not distant (i.e. where possible at every 100 m) to avoid much water in the drain and then erosion.
10. Provision should be made to discharge the runoff across the road at regular intervals to avoid such a concentration of runoff at the low point and to maintain a balance of runoff. These intervals depend upon the locality and type of road and could be in excess of 500m in flat terrain.

5.9 Seismic considerations

Rwanda is located in an earthquake intensity zone identified as “Degree VII” on the Modified Mercalli and Ritchter Scales. Given Rwanda is relatively high rating on both scales, practioners shall be required to include seismic considerations in the project’s bridges and those locations where slope stability issues warrant close examination.

5.10 Demographics

Appropriate design approaches shall be introduced in populous areas to mitigate the effects of dust and improve the safety of road users, that is, additional road widths, seal surfacing, parking, bus lay-bys, etc. and appropriate drainage systems.

5.11 All-Weather Access

5.11.1 General

An essential consideration in the design of LVRs shall be to ensure all-weather access most of the time. This requirement places particular emphasis on the need for sufficient bearing capacity of the pavement layer’s structure and the providing of drainage and sufficient earthworks protection in flood or problem soil areas.

5.11.2 Surface Performance

5.11.2.1 The performance of the LVR’s surface material primarily depends on its physical properties and qualities, location, and the volume of traffic. LVRs passing through populated areas in particular require materials that do not generate excessive dust in dry weather. Steep gradients place particular demands on LVR pavement layer materials, which shall not become slippery in wet weather or erode easily. Consideration should therefore be given to the type of LVR pavement layer materials to be used in particular locations such as towns or steep sections. Annual LVR surface loss rates of approximately 25-mm thickness per year per 300 VPD is expected, depending on rainfall and materials properties, particularly its plasticity.

5.11.2.2 Roughness should be maintained between 3.5 mm/m and 8.5 mm/m to satisfy road users and keep the vehicle operating costs low at a maximum vehicle speed of 50 km/h on LVR pavement surface as shown below.

5.11.2.3 In addition to the foregoing parameters, the LVR's design engineering shall focus on eliminating the following deficiencies:

a) slick or slippery sections owing to the lack of a gravel layer on the road surface;

b) water-logged or muddy sections due to the lack of adequate drainage;

c) water running down the road account faulty side ditches and the lack of adequate drainage facilities which contributes to the slippery conditions;

d) overly-steep sections that exceed the 12 % to 15 % maximum horizontal gradient, or more occasionally, which makes it difficult for a fully-laden truck to pass Poorly constructed culverts (pipe or box) and/or inadequate numbers of such drainage features per kilometre;

e) existing drainage structures that cause out flow erosion outside of and adjacent to the road reserve;

f) the overly-narrow sections of some existing LVRs that is exacerbated by the failure, that is, slippage of the natural, in situ materials excavated for inside slopes;

g) poor surfacing which slow vehicles or damage them as they pass;

h) failing or inadequately constructed bridges and causeways that traverse streams and wetlands;

i) the overall lack of signage or traffic control devices which adds to wearing issues and traffic safety problems;

j) occasional sections where traffic speed and lateritic surfacing cause air pollution – dust –problems in populated areas; and

k) the overall lack of maintaining LVRs which, in general, exacerbates all of the foregoing.

5.12 Bridge design

5.12.1 General

5.12.1.1 Long bridges should typically not found on LVRs. Hence, for these guidelines, a small bridge or culvert should be a structure having individual or multiple spans of total length no greater than 12 m. Small bridges shall be an essential part of all highway networks and are far more numerous than larger structures.

5.12.1.2 The recommended load consists of 20 tons loading with four wheels, 8 tons in front axle and 12 tons in rear axle in 4.27 m distance in the first type of loading. In the second type of loading, in the same class of loading has 21.2 tons loading consisting of six wheels 4.2 tons in front axle, 8.5 tons in intermediate and rear axles.

5.12.1.3 The distance between the front and intermediate axle should be 3.96 m and the intermediate to the rear axle should be 1.22 m. The spacing between successive vehicles can be assumed to be 30 m.

5.12.2 Bridge planning

5.12.2.1 Thorough planning shall be given to the list of site data to be collected. It is more time consuming to skip the collection of site data until later in the design phase, i.e., having a complete set of data in hand for the planning phase ensures the most economical preliminary design. Having to make additional trips to the site to collect missing data during later stages simply slows down the entire process.

5.12.2.2 Because the design of bridges is more involved than it is for geometrics and drainage, the bridge design engineer should be available to devote time during the planning process in order to advise and assist the planners in this important phase of the project's total design.

5.12.3 Bridge design process

The process of bridge design can be divided into the following phases:

a) Bridge Type Selection and Layout Preparation;

b) Foundation Investigation and Analysis;

c) Detailed Design and Plan Development; and

d) Checking, Reviews, and Approvals.

5.13 Safety

5.13.1 Throughout the process of designing safety elements, the designer shall keep in mind the relationship of vehicles and pedestrians. Neither should lose track of the presence of the other. The designer should consider the possibility that frequent reminders on both sides may be necessary in certain cases. Key Principles for designing safer roads are the following:

a) **Design for all road users:** This includes non-motorized vehicles, pedestrians, etc. and has implications for almost all aspects of road design including carriageway width, hard shoulder design, side slopes, and side drains;

b) **Provide clear and consistent message to the driver:** Roads should be easily "read" and understood by drivers and should not present them with any sudden surprises;

c) **Encourage appropriate speeds and behaviour by design:** Traffic speed can be influenced by altering the "look" of the road, for example, by providing clear visual clues such as changing the hard shoulder treatment or installing prominent signing;

d) **Reduce conflicts:** Conflicts cannot be avoided entirely, but can be reduced by design, i.e., by staggering junctions or by using guard rails to channel pedestrians to safer crossing points; and

e) **Create a forgiving road environment:** This requires the designer to establish an environment that forgives a driver's mistakes or vehicle failure, to the extent possible without significantly increasing costs, which ensures that demands are not placed upon the driver which are beyond his or her ability to manage.

5.12.2 Areas of safety hazards shall be identified, effective solutions shall be evaluated, and programme of available funds shall be made for their most effective safety use.

5.14 Quality control

This work shall consist of planning and implementing a construction quality process to ensure work conforms to the feeder road design guidelines. It should include quality control inspection, documentation, process control, sampling and testing during study and construction/rehabilitation phases.

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