

Chapter III

Geometric design of Highways

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Lecture Overview

- Introduction
- Appropriate Geometric Standards
- Design Controls and Criteria
 - Design Speed and Design Class
 - Sight Distance
 - Traffic Volume
 - Design Vehicle
- Geometric Design Elements
 - Horizontal Alignment
 - Straights (Tangents)
 - Circular Curves
 - Super elevation
 - Transition Curves
 - Widening of Curves
 - Vertical Alignment
 - Vertical Curves
 - Length Of Vertical Curves
 - Sight Distances At Underpass Structures:
 - Grades and Grade Control
 - Cross-Section

Introduction

- Highway geometric design involves the design of geometric elements of a highway and fixation of standards with respect to various components
- Its dictated within economic limitations to satisfy the requirements of traffic in designing elements such as
 - Cross-section
 - Horizontal alignment
 - Vertical alignment
 - Sight distances
 - Lateral and vertical clearances
 - Intersection,
 - Etc.

Introduction Cont...

- The *safety, efficiency, and economic* operation of a highway is governed to a large extent by the care with which the geometric design is worked out
- The engineer has to consider the following points when selecting design standards
 - Volume and composition of traffic in the design year should be the basis of design
 - Faulty geometries are costly to rectify at a later date
 - The design should be consistent and the standards used for the different elements should be compatible with one another
 - The design should embrace all aspects of design including signs, markings, lighting, etc.
 - The road should be considered as an element of the total environment and its location and design should enhance rather than degrade the environment
 - The design should minimize the total transportation cost
 - Safety should be built in the design
 - The design should be enable all road users to use the facility

Design controls and criteria

- The elements of design are influenced by a wide variety of design controls, engineering criteria, and project specific objectives which include
 - Functional classification of the road
 - Design traffic volume and composition
 - Nature of terrain
 - Traffic capacity
 - Design speed
 - Density and character of adjoining land use
 - Economic & Environmental Considerations
 - Road users characteristics
 - Vehicle size and performance
 - Level service to be provided
 - Available fund
 - Safety, etc.

Road Functional Classification

(or Road Hierarchy)

Roads generally serve a multitude of purposes:

- As through route - *for long distance traffic*
- As local route – *for local traffic*
- In urban and rural areas –urban roads/rural roads
- For fast and slow vehicles – 2 wheels to 10+ wheels
- As servicing/access roads
- For use by pedestrians
- For parking areas
- For Street Vendors, etc

Road Functional Classification (or Road Hierarchy)

Such a mix of uses *Reduces* SAFETY,
EFFICIENCY, and CAPACITY

Hence a hierarchical road system is necessary

Roads are therefore classified according to their respective functions in terms of the character of the services they are providing

Road Functional Classification

(or Road Hierarchy)

- *Functional classification* is the process by which streets and highways are grouped into classes, or systems, according to the character of service they are intended to provide.
- Basic to this process is the recognition that individual roads and streets do not serve travel independently in any major way.
- Rather, most travel involves movement through a network of roads. It becomes necessary then to determine how this travel can be channelized within the network in a logical and efficient manner.
- Functional classification defines the nature of this channelization process by defining the part that any particular road or street should play in serving the flow of trips through a highway network.
- To offer network users a choice for how to travel

Road Functional Classification

(or Road Hierarchy)

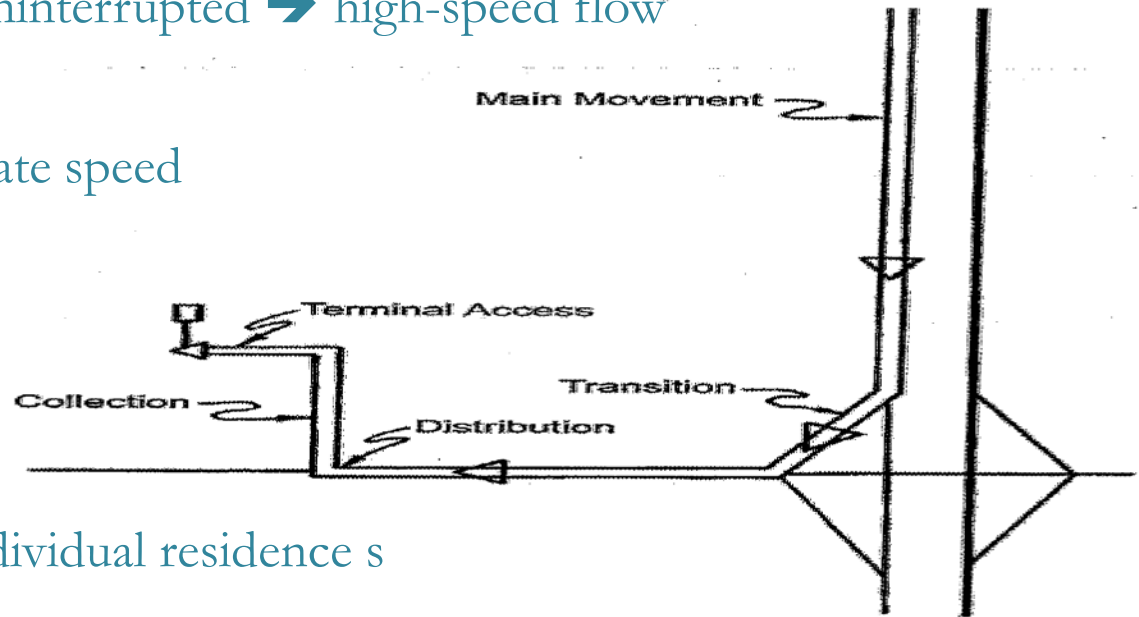
Objectives in setting a hierarchy

- To obtain best use of an existing network
- To ensure that each type of traffic is using the most appropriate route
- To minimize the risk to users and to the natural built environment
- To ensure better management, maintenance regimes and design policies
- To ensure funding for routes is targeted appropriately
- To offer network users a choice for how to travel

Road Functional Classification (or Road Hierarchy)

A complete functional design system provides a series of distinct travel movements. The six recognizable stages in most trips include :

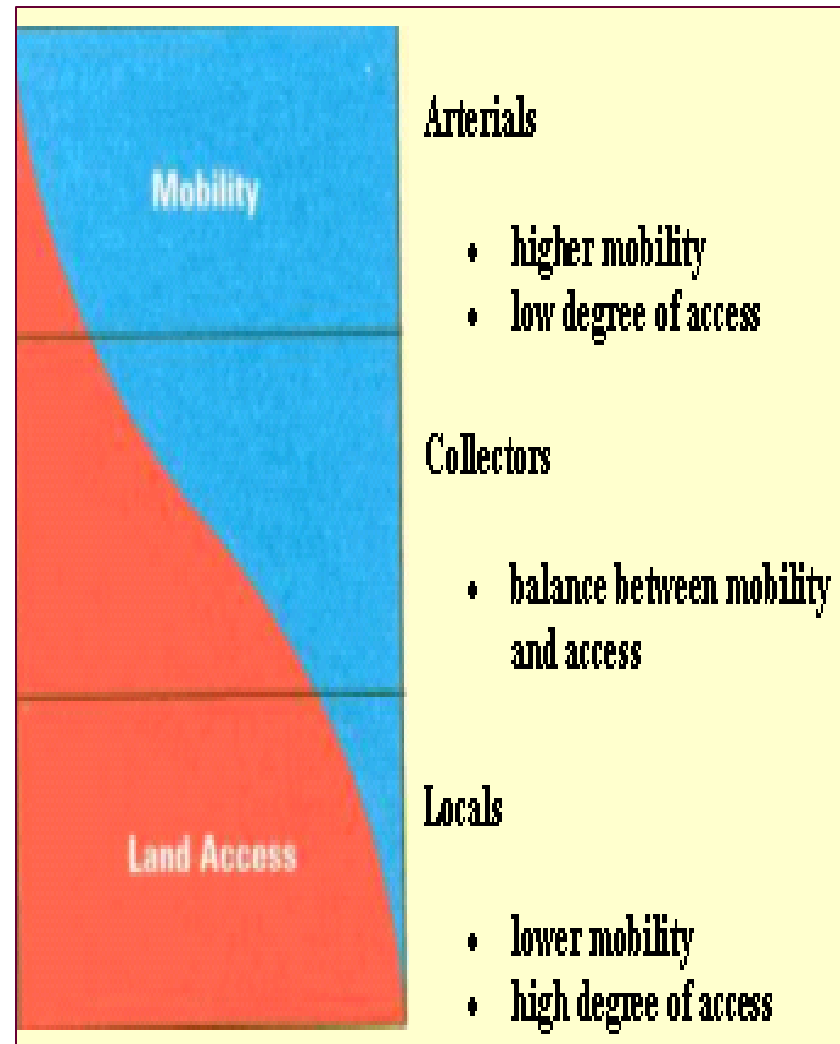
- *Main movement* → freeway → uninterrupted → high-speed flow
- *Transition* → freeway ramps
- *Distribution (arterials)* → moderate speed
- *Collection* → brings them nearer to the vicinity of their destination neighborhoods
- *Access* → direct approach to individual residence s
- *Termination*



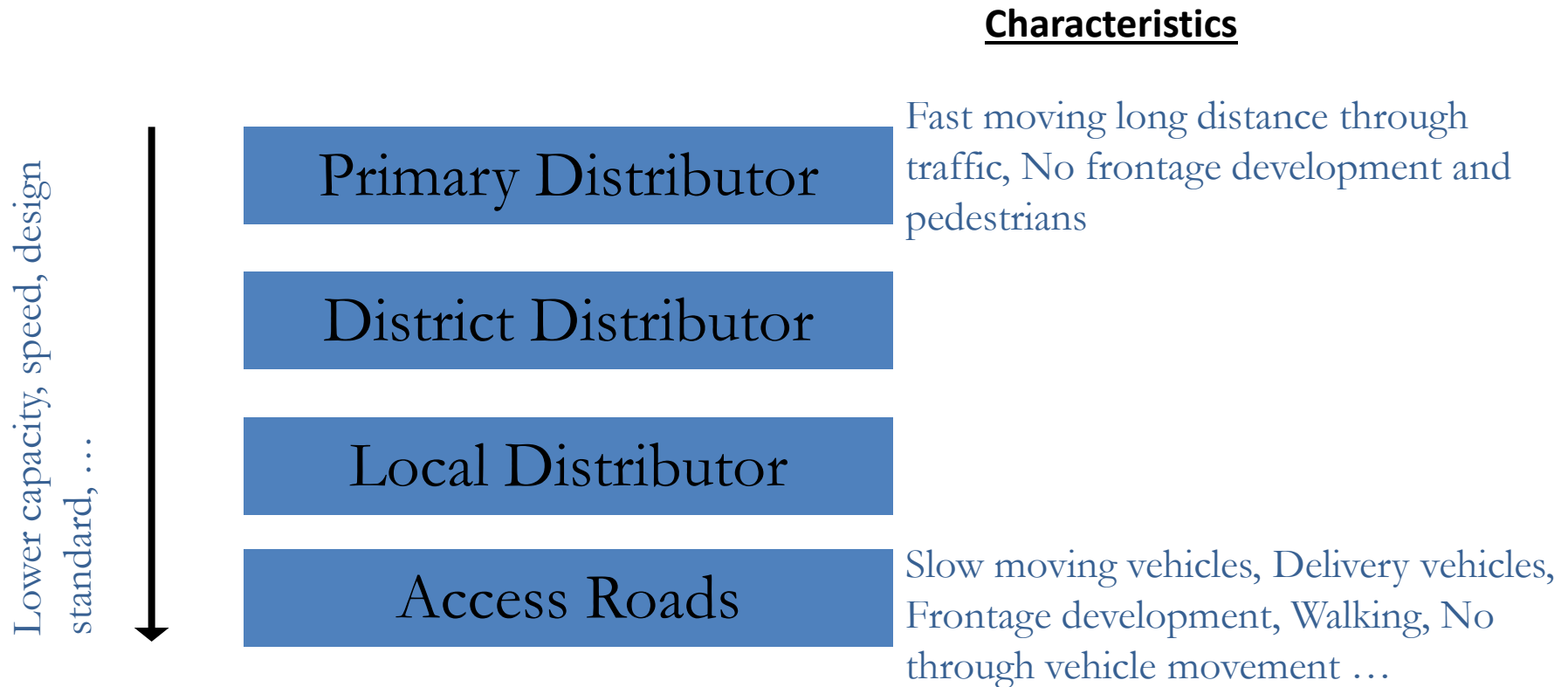
Road Functional Classification

(or Road Hierarchy)

- Allied to the idea of traffic channelization is the dual role the highway network plays in providing: access to property, and travel mobility.
- Access is a fixed requirement, necessary at both ends of any trip.
- Mobility, along the path of such trips, can be provided at varying levels, usually referred to as "level of service." It can incorporate a wide range of elements (e.g., riding comfort and freedom from speed changes) but the most basic is operating speed or trip travel time.
- Local facilities emphasize the land access function. Arterials emphasize a high level of mobility for through movement. Collectors offer a compromise between both functions.



Road Hierarchy (most frequently)

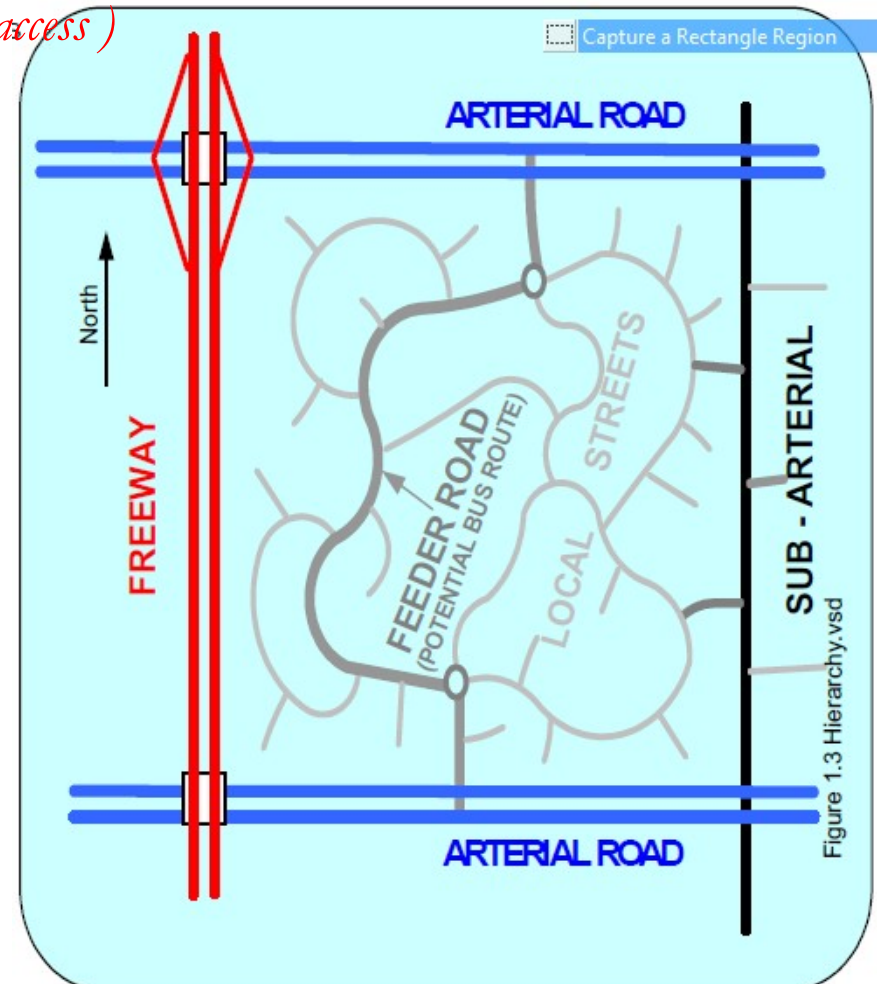


Movement is up/down the hierarchy

Road Functional Classification (AACRA)

Roads generally serve a multitude of purposes:

- Arterial roads including freeways
(traffic movement function with Controlled access)
- Sub-arterial roads
(largely traffic movement function)
- Feeder roads
(traffic, transition and access function)
- Local roads
(largely property access function)



Road Hierarchy (The Ethiopian way)

Trunk roads

Roads linking centers of international importance and roads terminating at international boundaries and have a present AADT ≥ 1000 and as low as 100.

Link roads

Roads linking centers of national or international importance and have over 400 - 1000 first year AADT, although values can range between 50-10,000 AADT.

Access roads

Roads linking centers of provincial importance and their first year AADTs between 30-1,000 .

Collector roads

Roads linking locally important centers to each other, to a more important center, or to higher class roads and their first year AADTs between 25-400 .

Feeder roads

Any road link to a minor center such as market and local locations with first year AADT between 0-100.

Traffic Volume and Composition

- Traffic data indicates the service for which the road is being planned and directly affects the geometric elements such as width, alignment, etc,
 - *Traffic volume* – AADT, ADT, PHV, DHV
 - *Directional distribution* – the percentage of traffic volume flowing in each direction
 - *Traffic composition* – the percentage of different types of vehicles in the traffic stream – different types of vehicles are converted into passenger car unit to design a road width
 - *Traffic projection* – using the design period of a road (5-20 years) a reliable traffic projection should be made considering the following elements

Traffic Volume and Composition

– Traffic projection (cont'd.):–

- *Current traffic* – currently using the existing road
- *Normal traffic growth* – anticipated growth due to population growth or change in land use
- *Diverted traffic* – traffic that switches to a new facility from near by roads
- *Converted traffic* – traffic resulting from changes of mode
- *Change of destination traffic* – traffic that has changed to different destination due to new or improved transport and not changes in land use
- *Development traffic* – traffic due to improvement on adjacent land development that would have taken place had the new or improved road not been constructed
- *Induced traffic* – traffic that did not previously exist in a any form but results when new or improved transport facilities are provided

Design Standards vs. Road Classification and AADT

Road Functional Classification	Design Standard No.	Design Traffic Flow (AADT)
<div> <div>FEEDE</div> <div>COLLECTOR</div> <div>MAIN ACCESS</div> <div>LINK</div> <div>TRUNK</div> </div>	DS1	10,000 – 15,000
	DS2	5,000 – 10,000
	DS3	1,000 – 5,000
	DS4	200 – 1,000
	DS5	100 – 200
	DS6	50 – 100
	DS7	30 – 75
	DS8	25 – 50
	DS9	0 – 25
	DS10	0 – 15

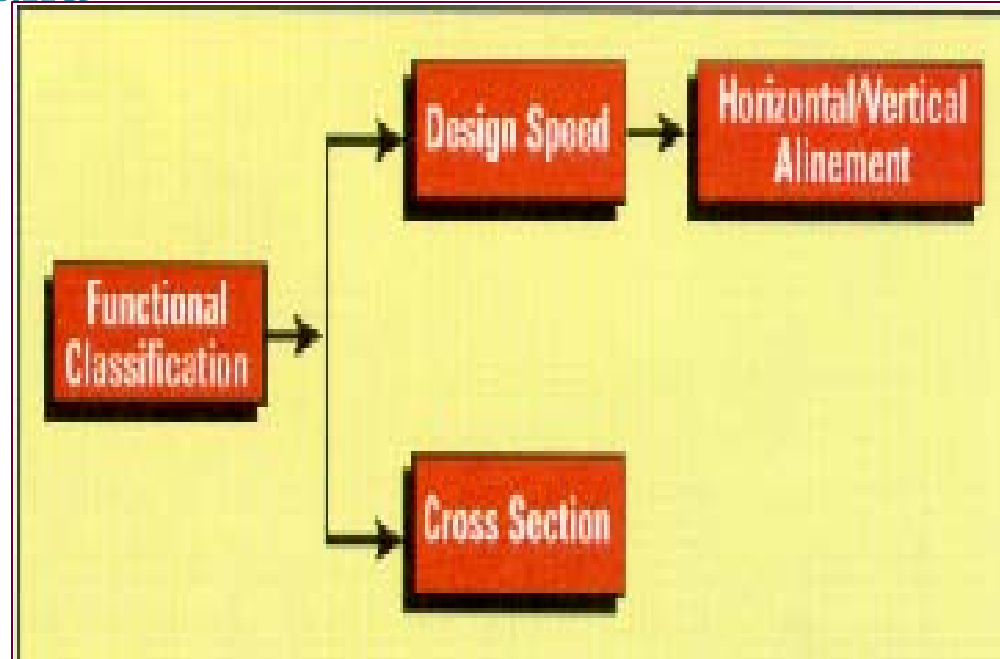
As per ERA Geometric Design Manual

As per TRL:

Road Function	Design class	Traffic flow
Arterial	A	5,000-15,000
	B	1,000-5,000
	C	400 - 1000
Collector	C	400-100
	D	100-400
Access	D	100-400
	E	20-100
	F	< 20

Design Standards vs. Road Classification and AADT

Once the functional classification of a particular roadway has been established, so has the allowable range of *design speed*. With the allowable range of *horizontal and vertical alignment* are also defined. Similarly, a determination of functional classification establishes the basic *roadway cross section* in terms of lane width, shoulder width, type and width of median area, and other major design features.



Design Speed

- The speed that a driver adopts on a road depends on:
 - » Physical characteristics of the road and its surroundings
 - » Weather conditions in the area
 - » Presence of other vehicles and the nature of these vehicles, and
 - » Speed limitations placed upon the vehicles either by law or by mechanical devices fitted in vehicles
- Design speed is the max safe speed selected for designing specific section of road considering the terrain, land use, classification of the road, etc.

Design Standards vs. Road Classification and terrain

Design Element	Unit	Flat	Rolling	Mountainous	Escarpment	Urban/Peri-Urban
Design Speed	km/h	70	60	50	40	50
Min. Stopping Sight Distance	m	110	85	55	45	55
Min. Passing Sight Distance	m	275	225	175	125	175
% Passing Opportunity	%	25	25	15	0	20
Min. Horizontal Curve Radius	m	175	125	85	50	85
Transition Curves Required		No	No	No	No	No
Max. Gradient (desirable)	%	4	5	7	7	7
Max. Gradient (absolute)	%	6	7	9	9	9
Minimum Gradient	%	0.5	0.5	0.5	0.5	0.5
Maximum Superelevation	%	8	8	8	8	4
Crest Vertical Curve	k	31	18	10	5	10
Sag Vertical Curve	k	25	18	12	8	12
Normal Crossfall (Paved)	%	2.5	2.5	2.5	2.5	2.5
Shoulder Crossfall (Paved)	%	4	4	4	4	4
Normal and Shoulder Crossfall (Unpaved)	%	4	4	4	4	4
Right of Way	m	50	50	50	50	50

Nature of Terrain

- The location and geometric design elements such as gradients, sight distance, cross-sections, radius of curvature, speeds, etc. of a highway are affected by topography, physical features, and land use.
- Transverse terrain properties are categorized into four classes as follows:
 - *FLAT*: Flat or gently rolling country, which offers few obstacles to the construction of a road, having continuously unrestricted horizontal and vertical alignment (transverse terrain slope up to 5 percent).



Nature of Terrain

ROLLING: Rolling, hilly or foothill country where the slopes generally rise and fall moderately and where occasional steep slopes are encountered, resulting in some restrictions in alignment (transverse terrain slope from 5 percent to 25 percent).



Nature of Terrain

MOUNTAINOUS: Rugged, hilly and mountainous country and river gorges. This class of terrain imposes definite restrictions on the standard of alignment obtainable and often involves long steep grades and limited sight distance (transverse terrain slope from 25 percent to 50 percent).



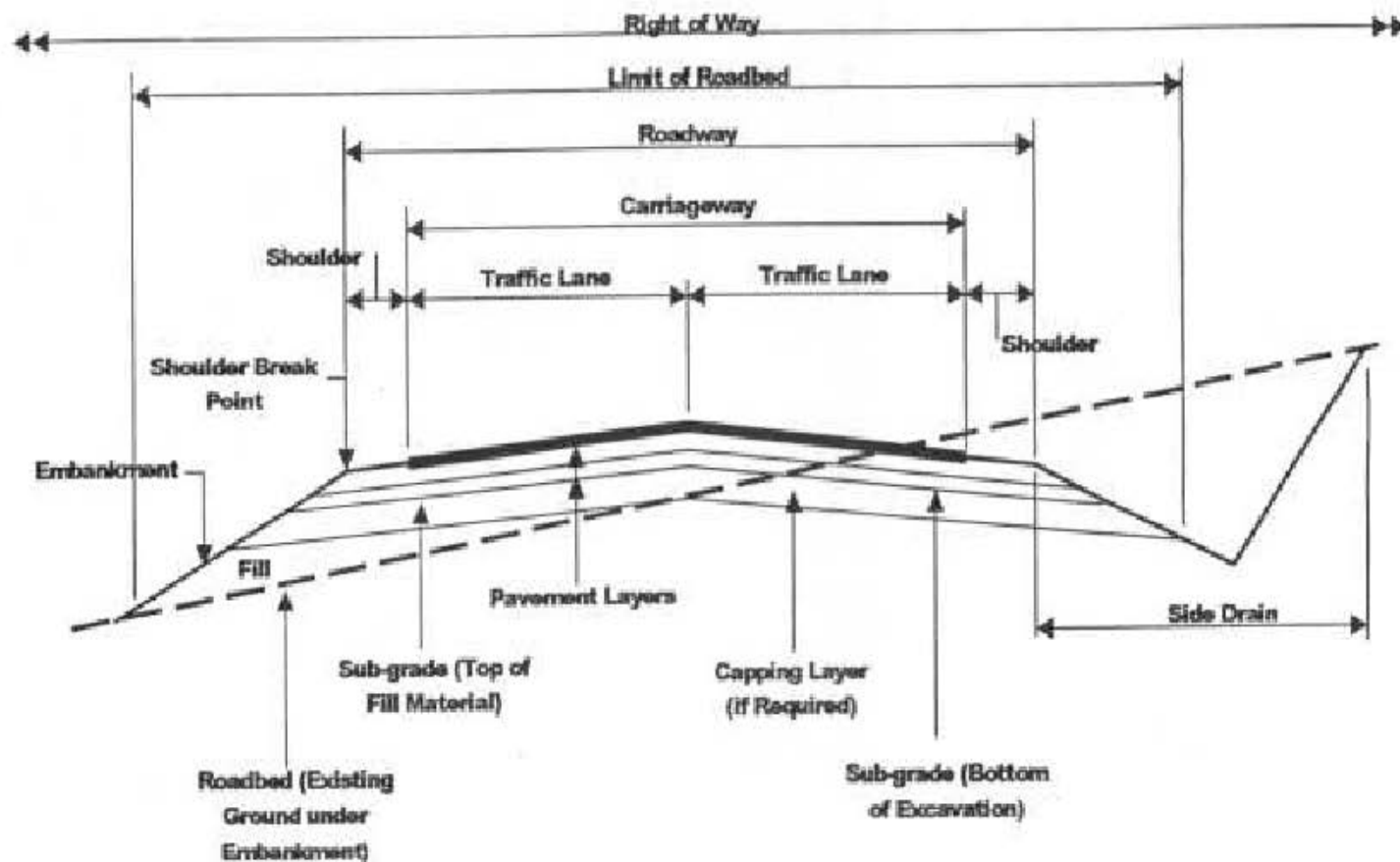
Nature of Terrain

ESCARPMENT: Escarpment include situations where switchback roadway sections are used or side hill transverse sections which cause considerable earthwork quantities, with transverse terrain slope in excess of 50 percent.



Elements of Road Cross-section

Terms and Definitions for Road Cross Section Elements



Elements of Road Cross-section

- Principal elements
 - Traffic lanes
 - Auxiliary lanes – climbing lanes, acceleration and deceleration lanes, etc
 - Shoulders
 - Median (for divided roads)
- Marginal elements include
 - Median and roadside barrier
 - Curbs
 - Gutters
 - Guard rails
 - sidewalks,
 - Side slopes,
 - Cross slopes

Elements of Road Cross-section

- Width of travel lanes
 - Usually vary from 3 to 3.65 m, but occasionally 2.7 m lane width is used in urban areas where the traffic volume is low and there is extreme right-of-way constraints
 - On two way two lane rural roads, accident rate for large trucks increases as the traveled way decreases from 6.5 m
 - The capacity decrease significantly as the lane width decrease from 3.0 m

Elements of Road Cross-section

- *Shoulders*

- Serves for an emergency stop of vehicles
- Used to laterally support the pavement structure

- Shoulder width

- Recommended shoulder width is in the range of 1.8 to 2.4 m
- for highways serving large number of trucks and on highways with high traffic volumes and high speeds, shoulder width of 3.0 to 3.5 m is preferable
- Minimum shoulder width 0.6 m on the lowest type of roads

- Shoulders should be flush with the edge of the traveled lane and be sloped to facilitate drainage (2-4 % if paved, 4-6 % if not paved)

Elements of Road Cross-section

- *Median* – section of divided road that separates lanes in the opposite directions.
- Functions:
 - Provide recovery area during emergency
 - Provide stopping area for left and U-turning vehicles
 - Provide refuge for pedestrians
 - Reduce headlight glare
- Median can be either raised, flush or depressed
- Median width vary between 0.6 up to 24 m or more depending on the availability of right-of-way

Elements of Road Cross-section

- *Median barrier* – a longitudinal structure used to prevent an errant vehicle from crossing the portion of a divided highway separating the traveled way for traffic in the opposite directions
- *Roadside barrier* – protect vehicles from causing hazards onto roadside and shield pedestrians
- *Curbs* – raised structures used mainly on urban roads to delineate pavement edge and pedestrian walkways. Curbs are also used:
 - To control drainage
 - Improve aesthetic
 - Reduce right-of-way
- Are classified as
 - Barrier curbs – relatively high designed for preventing vehicles from leaving the road
 - Mountable curbs – are designed so that vehicles can cross them

Elements of Road Cross-section

- *Gutters* – drainage ditches located on the pavement side of a curb to provide the principal drainage facility for the highway
- *Guard rails* – longitudinal barriers on the outside of sharp curves at sections with high fills (greater than 2.5 m)
- *Side walks* – provided on urban or rural roads
 - When pedestrian traffic is high along main or high speed roads
 - When shoulders are not provided on arterials even when pedestrian traffic is low
 - In urban areas, sidewalks are provided along both sides of streets to serve pedestrians access to schools, parks, shopping centers, and transit stops.

Elements of Road Cross-section

- *Cross-slopes* – to enhance the flow of surface water
 - High type pavement – 1.5 –2 %
 - Intermediate type of pavement – 1.5- 3%
- *Side slopes* – provided for stability of earthworks; the slope varies depending on the material type
- *Right-of-way* – the total land area required for the construction of the roadway
 - To accommodate all the elements of the road cross-section
 - Planned widening of the road
 - Public utility facilities that will be installed along the highway

Thank You!