Transportation Engineering

Course Code –CE-422

Contact Hours -3+3

Dr Hassan Mujtaba

Highway Materials

- Soils
- Aggregates
- Bituminous materials

Chemical Stability of Aggregates

- Certain aggregates may be unsuitable for particular highway construction because of the chemical composition of the aggregate particles.
- In asphalt mixes, certain aggregates that have an excessive affinity for water may contribute to what is known as film stripping, leading to disintegration of asphalt concrete.

Bitumen Adhesion Property

- The bitumen in a bituminous mixture may be assumed to be present in the form of thin films surrounding the aggregate particles and filling, or partially filling, the void spaces between adjacent particles.
- These thin films of bitumen adhere to the surface of normal aggregates and contribute to the shearing resistance of the mixture, this effect being generally considered as a part of the "cohesion" of the mix.

Bitumen Adhesion Property

- On continued exposure to water, either in the laboratory or in the field, bituminous mixtures containing certain aggregates show a definite tendency to loose shearing resistance or "strength" because of a decrease in cohesion due to primarily replacement of the bituminous films surrounding the aggregate particles with similar films of water.

Hydrophobic and Hydrophilic Aggregates

- An aggregate that is "hydrophobic" in nature is one which exhibits a high degree of resistance to film stripping in the presence of water.
- Aggregates that exhibit least resistance to film stripping in presence of water are termed "hydrophilic" aggregates, hydrophilic meaning "water-loving."

Bitumen Adhesion Property

- The property of the aggregates to resist film stripping depends upon its electrolytic property of bitumen and normally, the available bitumen are anionic.
- It is for this reason limestone which are positively electrolytic are hydrophobic where as quartz, sand stone which are negatively electrolytic are hydrophilic.

Bitumen Adhesion Property

- It is also been found that rough surface of the aggregates and slight porosity increases adhesion and prevent stripping of bitumen while aggregates having weak crumbling surface should be avoided as they encourage stripping.

Immersion Test

- In judging the relative resistance to film stripping of aggregates, various immersion stripping tests have been used. It include
  - Static Immersion Test (ASTM D1664)
  - Immersion-Compression Test (ASTM D 1075)

    (This is also known as Immersion mechanical tests)

Other Properties of Aggregates

- Specifications for aggregates used in highway construction commonly have requirements related to the particle shape, surface texture, and cleanliness of the aggregate.
- Specifications for aggregates used in bituminous mixes usually require that the aggregates be clean, tough, durable in nature, and free of excess amounts of flat or elongated particles, dust, clay balls, and other objectionable material.

Other Properties of Aggregates

- Sand Equivalent is used to determine their relative proportions of plastic fines and dust in fine aggregates.

Evaluation of Mineral Aggregates (Particle Shape)

Table 5.3 Descriptive evaluations of mineral aggregates

(a) Particle shape

Classification	Description	Examples
Rounded	Fully water-worn or completely shaped by attrition	River or seashore gravel; desert, seashore and wind-blown sand
Irregular	Naturally irregular, or partly shaped by attrition and having rounded edges	Other gravels; land or dug flint
Flaky	The thickness is small relative to the other two dimensions	Laminated rock
Angular	Possessing well-defined edges formed at the intersection of roughly planar faces	Crushed rock of all types; talus; crushed slag
Elongated	Usually angular, in which the length is considerably larger than the other two dimensions	–
Flaky and elongated	The length considerably larger than the thickness	–

Evaluation of Mineral Aggregates (Surface Texture)

(b) Surface texture

Surface texture	Characteristics	Examples
Glassy	Conchoidal fracture	Black flint, vitreous slag
Smooth	Water-worn, or smooth due to fracture of laminated or fine-grained rock	Gravels, chert, slate, marble, some rhyolites
Granular	Fracture showing more or less uniform round grains	Sandstone, oolite
Rough	Rough fracture of fine- or medium-grained rock containing no easily visible crystalline constituents	Basalt, felsite, porphyry, limestone
Crystalline	Containing easily visible crystalline constituents	Granite, gabbro, gneiss
Honeycombed and porous	With visible pores and cavities	Brick, pumice, foamed slag, clinker, expanded clay

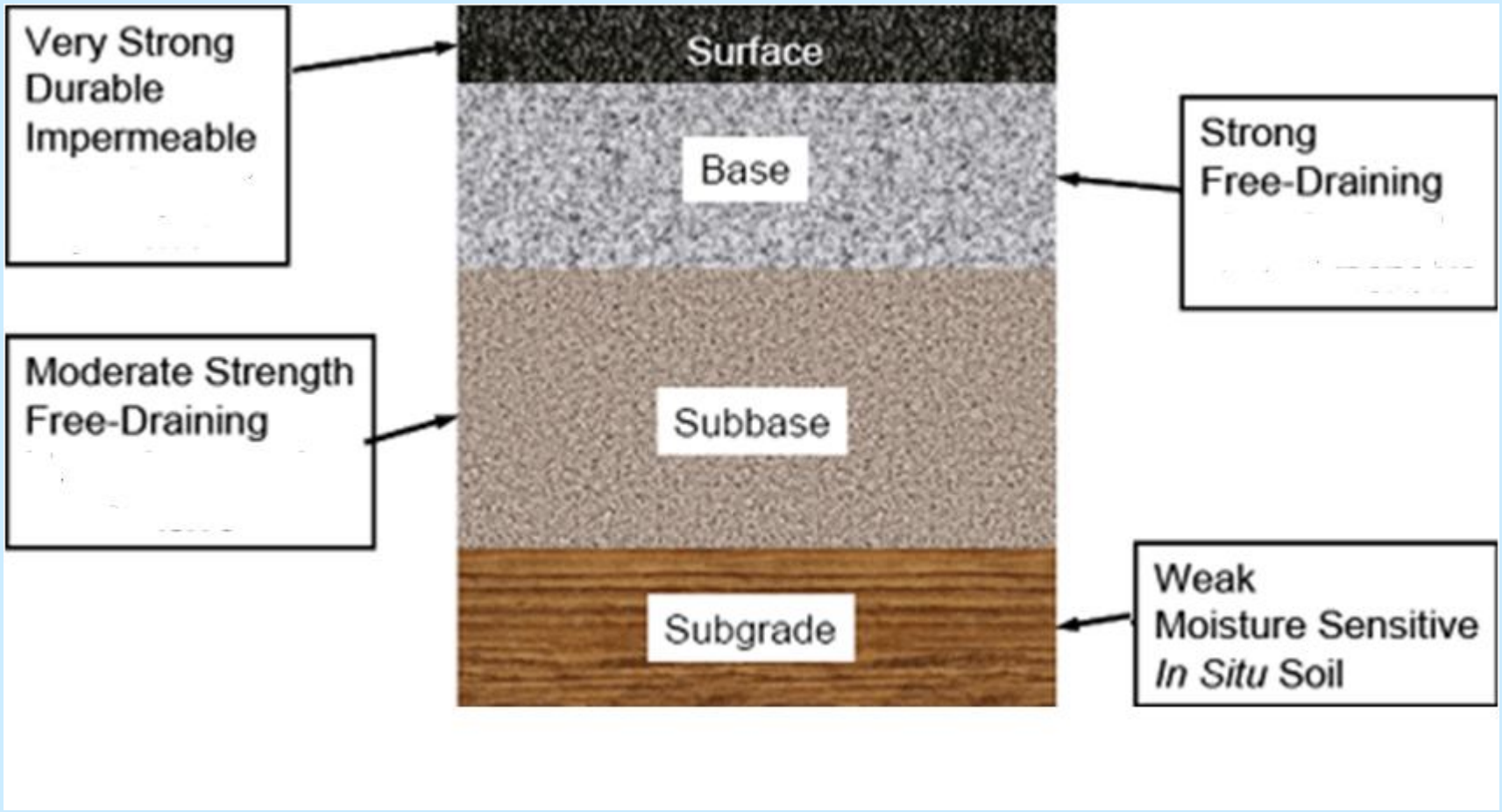
Deleterious Material and Friable Particles

- To test for clay lumps or friable particles, a sample is first washed and dried to remove material passing the No. 200 sieve (0.075-mm).
- The remaining sample is separated into different sizes and each size is weighed and soaked in water for 24 hours. Particles that can be broken down into fines with fingers are classified as clay lumps or friable material.
- The amount of this material is calculated by percentage of total sample weight.

Deleterious Material and Friable Particles

- Specifications usually limit clay and friable particles to a maximum of one percent.
- The standard test procedure is described in :
  - AASHTO T 112 and ASTM C 142: (Clay Lumps and Friable Particles in Aggregate)

Granular Sub-Base



Material Requirements Granular Sub-Base

- This item shall consist of furnishing, spreading in one or more layers and compacting granular sub-base according to the Specifications and the Drawings and/or as directed by the Engineer.

Material Requirements Granular Sub-Base

- Granular sub-base material shall consist of natural or processed aggregates such as gravel, sand or stone fragment and shall be clean and free from dirt, organic matter and other deleterious substances and shall be of such nature that it can be compacted readily under watering and rolling to form a firm, stable sub-base.
- The material shall comply with the following grading and quality requirements:

Material Requirements Granular Sub-Base (cont'd)

Grading Requirements for Subbase Material

Sieve Designation		Percent Passing by Weight	
(mm)	(in)	A	B
60.6	2 ½	100	-
50.0	2	90~100	100
25.0	1	50~80	55~85
9.5	3/8	--	40~70
4.75	No. 4	35~70	30~60
2.0	No. 10	-	20~50
0.425	No. 40	-	10~30
0.075	No. 200	2~8	5~15

Coefficient of Uniformity D_{60} / D_{10} shall be not less than 3

Material Requirements Granular Sub-Base

- The sub-base material shall have a gradation curve within the limits for grading B. However, grading A may be allowed by the Engineer in special circumstances.
- The Material shall have a CBR value of at least 50%, determined according to AASHTO T 193.
- The CBR value shall be obtained at a density corresponding to ninety-eight (98) % of the maximum dry density determined according to AASHTO T 180.

Material Requirements Granular Sub-Base (cont'd)

- The coarse aggregate material retained on sieve No. 4 shall have a percentage of wear by the Los Angeles Abrasion (AASHTO T 96) of not more than fifty (50) %.
- In order to avoid intrusion of silty and clayey material from the subgrade in the sub-base, the ratio D_{15} (Subbase) / D_{85} (Subgrade) should be less than five (5).

Material Requirements Granular Sub-Base (cont'd)

- Where D_{85} and D_{15} are the particle diameters corresponding to eighty-five (85) % and fifteen (15) %, respectively, passing (by weight) in a grain size analysis curve.
- The fraction passing the 0.075 mm (No. 200 sieve) shall not be greater than two third of the fraction passing the 0.425 mm (No. 40) sieve.
- The fraction passing the 0.425 mm (No. 40 sieve) shall have a liquid limit of not greater than twenty-five (25) and plasticity index of six (6) or less.

Material Requirements Granular Sub-Base (cont'd)

- If oversize is encountered, screening of material at source, shall invariably be done, no hand picking shall be allowed, however hand picking may be allowed by the Engineer, if over-size quantity is less than five (5) % of the total mass.
- Sand equivalent for all classes shall be twenty-five (25) minimum.

Crushed Aggregate Base Course

- This item shall consist of furnishing, spreading and compacting one or more layers of Crushed Aggregate Base Course on a prepared subgrade, subbase, or existing road surface (overlay), in accordance with the Specifications and the Drawings and/or as directed by the Engineer.

Crushed Aggregate Base Course

- Material for crushed aggregate base course shall consist of crushed hard durable gravel, rock or stone fragments.
- It shall be clean and free from organic matters, lumps of clay and other deleterious substances. The material shall be of such a nature that it can be compacted readily under watering and rolling to form a firm, stable base for both flexible and rigid pavements. The crushed aggregate base course shall comply with the following grading and quality requirements:

Crushed Aggregate Base Course

Grading Requirements for Aggregate Base Material

Sieve Designation		Percent Passing by Weight	
mm	Inch	A	B
50.0	2	100	100
25.0	1	70~95	75~95
9.5	3/8	30~65	40~75
4.75	No. 4	25~55	30~60
2.0	No. 10	15~40	20~50
0.425	No. 40	8~20	12~25
0.075	No. 200	2~8	5~10

Coefficient of Uniformity D_{60} / D_{10} shall be greater than 4 and material is well graded

Crushed Aggregate Base Course

- The gradation curve of the material shall be smooth and within the limits for Grading A or B.
- Crushed Aggregate (material retained on sieve No. 4) shall consist of material of which at least ninety (90) % by weight shall be crushed particles, having a minimum of two (2) fractured faces.
- The Coarse aggregate shall have a percentage of wear by the Loss Angeles Abrasion test (AASHTO T 96) of not more than forty (40).

Crushed Aggregate Base Course

- The material shall have a loss of less than twelve (12) % when subjected to five cycles of the Sodium Sulphate Soundness test according to AASHTO T 104.
- The sand equivalent determined according to AASHTO T 176 shall not be less than forty-five (45).
- The portion of filler, including any blended material, passing No. 40 sieve shall have a liquid limit not more than 25 and a plasticity index not more than 4 when tested in accordance with AASHTO T 89 & T 90.

Crushed Aggregate Base Course

- The material passing the 19 mm sieve shall have a CBR value of minimum eighty (80) %, tested according to the AASHTO T 193. The CBR value shall be obtained at the maximum dry density determined according to AASHTO T 180.
- Laminated material shall not exceed fifteen (15) % of total volume of crushed aggregate base course.

Filler for Blending

- The material for such purpose shall be obtained from sources approved by the Engineer. The material shall be free from organic matter, dirt, shale, clay and clay lump or other deleterious matter.
- If filler, in addition to that naturally present in the crushed aggregate base course material is necessary for meeting the grading requirement or for satisfactory bonding of the material, it shall be uniformly blended with the base course material at the crushing plant or in a pugmill unless otherwise approved.

Filler for Blending

- The filler material shall conform to the following requirement

AASHTO sieve	Percent Passing by Weight
3/8 in	100
4	85~100
100	10~30
Plasticity Index (AASHTO T 90)	6 maximum
Sand Equivalent (AASHTO T 176)	30 minimum

However, the combined aggregates prepared by mixing the coarse material and filler shall satisfy the requirements as mentioned above.

Bituminous Materials

- Bituminous materials are used extensively for roadway construction, primarily because of their excellent binding or cementing power and their waterproofing properties, as well as their relatively low cost.
- Bituminous materials consist primarily of bitumen, which, according to ASTM D8, is a class of black or dark-colored solid or viscous cementitious substances composed chiefly of high-molecular-weight hydrocarbons;
- By definition, Bitumen is soluble in carbon disulphide.

Bituminous Materials

- The term Asphalt is used in the American Technical Literature where as Bitumen is used in UK. In UK the term asphalt is reserved for the materials containing a mixture of bitumen and mineral matter.
- Bitumen that are produced artificially from petroleum crudes are known as refinery bitumen where as bitumen from natural resources are native asphalt.

Bituminous Materials (cont'd)

- Bituminous materials are divided into two broad categories:
  - Asphalt
  - Tars

Asphalt and Tars

- Asphalts are the residues of the petroleum oils. A great majority of asphalts used nowadays are the residues from the refinery of crude oils, although there are natural deposits called "native asphalt."
- Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum. Tars obtained from the destructive distillation are crude tars, which must undergo further refinement to become road tars.

Comparison between Asphalt and Tars

- Asphalts have no odor, are more resistant to weathering, and less susceptible to temperature than tars, which have a pungent odor and react to weathering and temperature.
- Asphalt will be dissolved in petroleum oils whereas tars will not. Therefore, tars have been used to seat asphalt concrete surfaces, such as fog seals, to improve the oil resistance of asphalt surfaces. Asphalts are black in color, whereas tars are usually brown-black in color.
- Today, tars are not used extensively as binders for highway pavements.

Sources of obtaining Asphalts

- Petroleum Asphalts or Penetration-grade refinery bitumen
  - Bitumen that are produced artificially from petroleum crudes (usually napthenic-and asphaltic-base crudes) are known as Refinery Bitumen.
- Natural Asphalt
  - Lake Asphalt
  - Rock Asphalt

Lake Asphalt

- The largest natural deposit of *lake asphalt* occurs on the Island of Trinidad off the north-west coast of South America.
- The main lake of asphalt covers an area of roughly 35 ha, has a depth of about 90 m, and is estimated to contain 10 to 15 million tonnes of material.
- Following excavation, the asphalt is heated to 160°C to drive out gases and moisture, and then run through strainers to remove vegetable debris before being poured into wooden barrels for export under the name 'Trinidad Epure' or 'Refined Trinidad Lake Asphalt'.

Lake Asphalt

- The refined lake asphalt product typically contains about 55 per cent bitumen, 35 per cent mineral matter, and 10 per cent organic matter.
- Following the first commercial shipment to England (in 1840), it was widely used in road construction until the introduction of pitch-bitumen in the 1960s, i.e. a blend of 70-80 per cent bitumen with 20-25 per cent coal-tar pitch, which had similar qualities.

Lake Asphalt

Trinidad Lake Asphalt

Natural rock asphalts

- *Natural rock asphalts* are mainly limestones and sandstones that are impregnated with, typically, 5-15 per cent of natural bitumen. Historically, the natural rock asphalt used in the UK was imported from Switzerland and France.
- Natural rock asphalts are rarely employed in road construction in the UK today.

Natural rock asphalts

Production of Asphalt

- A wide variety of refinery processes, such as the straight distillation process, solvent de-asphalting process, and solvent extraction process, may be used to produce asphalt of different consistency and other desirable properties.
- Depending on the sources and characteristics of the crude oils and on the properties of asphalt required, more than one processing method may be employed.

Cutback Asphalt

- Asphalt cement produced from the vacuum-steam distillation exists as a semi-solid at room temperature, and usually proper workability can be attained by heating the asphalt cement to a temperature of 120 to 165°C (250°F to 330°F) to liquefy it.

Cutback Asphalt

- In order for asphalt products to attain workability at room temperature, they must be rendered liquid at room temperature. There are two ways to liquefy asphalt without resorting to heat:
  - Dissolve asphalt in solvent
  - Emulsify asphalt in water

Cutback Asphalt

- When volatile solvents are mixed with asphalt cement to make a liquid product, the mixture is called "cutback asphalt."
- After a cutback asphalt is exposed to air, the volatile solvent evaporates, and the asphalt in the mixture regains its original characteristics (cured).
- Depending on the volatility of the solvent used, the rate of curing of cutback asphalt can vary from a few minutes to several days.
-

Cutback Asphalt

Following are three types of cutback asphalt and the solvent used.

- Rapid-curing (RC): gasoline or naphtha
- Medium-curing (MC): kerosene
- Slow-curing (SC): road oils

Cutback Asphalt (cont'd)

- The suffix numbers, for example MC-70, represent the minimum kinematic viscosity in centistokes at 60°C (140°F) for the particular grade.
- Spec-ifications for RC, MC, and SC are given in ASTM D2026, D2027, and D2028, respectively.
- Cutback asphalt is increasingly being replaced by emulsified asphalt in commercial use.

Emulsified Asphalt

- Emulsified asphalt is a mixture of asphalt cement, water and an emulsifying agent.
- These three constituents are fed simultaneously into a colloid mill to produce extremely small globules (5-10 μ) of asphalt cement, which are suspended in the water.
- The emulsified agent imparts the electric charges (cationic or anionic) to the surface of the asphalt particles, which causes them to repel one another; thus the asphalt particles do not coalesce.

Emulsified Asphalt

- The emulsified asphalt thus produced is quite stable and could have a shelf life of several months.
- When an emulsified asphalt is exposed to the air, alone or mixed with an aggregate, it "sets" or "breaks," because the asphalt globules react with the surface they are in contact with and coalesce, squeezing out the water between them.

Emulsified Asphalt

- The evaporation of water is the primary mechanism that finally causes the anionic emulsified asphalt to "break."
- Electrochemical processes are the primary mechanisms that cause the cationic emulsified asphalt to break.

Emulsified Asphalt

- Emulsified asphalt offers certain advantages in construction, particularly when used with moist aggregates or in wet weather.
- An emulsified asphalt does not require a solvent to make it liquid and thus is relatively pollution-free.
- Emulsified asphalt has low viscosity at the ambient temperature, it generally can be used without additional heat.
- These factors tend to make emulsified asphalt more energy-efficient and less costly than cutback asphalt

Penetration Grades of Bitumen

Table 5.1 Penetration-grade bitumens commonly used for road purposes[1]

Property	Grade of bitumen: 15 pen	40 pen HD	50 pen	100 pen	200 pen
Penetration at 25°C	15 ± 5	40 ± 10	50 ± 10	100 ± 20	200 ± 30
Softening point (°C)					
minimum	63	58	47	41	33
maximum	76	68	58	51	42
Loss on heating for 5 h at 163°C (%, maximum)					
loss by mass	0.1	0.2	0.2	0.5	0.5
drop in penetration	20	20	20	20	20
Solubility in trichloroethylene (% by mass, minimum)	99.5	99.5	99.5	99.5	99.5
Relative permitivity at 25°C and 1592 Hz	–	2.650	2.650	–	–

40 pen HD- Heavy duty penetration bitumen

Penetration Grades of Bitumen

- Harder Grades (15-25 pen) – Mastic Asphalt
- Medium Grades (35-70 pen)- hot rolled asphalt
- Softer Grades (100-450 pen) – Macadams
- 40 pen heavy duty (HD 40) is blown by passing air through it (oxidation process); this makes is less susceptible to temperature changes than other bitumen. Also, provide a stiffer asphalt which deform less under traffic.

Classification of Bituminous Material

- Bituminous materials are commonly classified based on consistency.
  - Penetration Grades
  - Viscosity Grades
  - Rolling Thin-Film Oven Test

Penetration Grades

Asphalt Cement Grade	Penetration Range (100 gm, 5 sec)
AC 40-50	40-50
AC 60-70	60-70
AC 80-100	80-100
AC 120-150	120-150
AC 200-300	200-300

Viscosity Grades

Asphalt Cement Grade	Viscosity, 60º C (140 º F), (poise)
AC 2.5	250 ± 50
AC 5	500 ± 100
AC 10	1000 ± 200
AC 20	2000 ± 400
AC 30	3000 ± 600
AC 40	4000 ± 800

Rolling thin-film Oven Test Grades

Asphalt Cement Grade	Viscosity, 60º C (140 º F), (poise)
AR 10	1000 ± 250
AR 20	2000 ± 500
AR 40	4000 ± 1000
AR 80	8000 ± 2000
AR 160	16000 ± 4000

Design of Highways

Geometric Design of Highways

Structural Design of Highways

Highway Classification

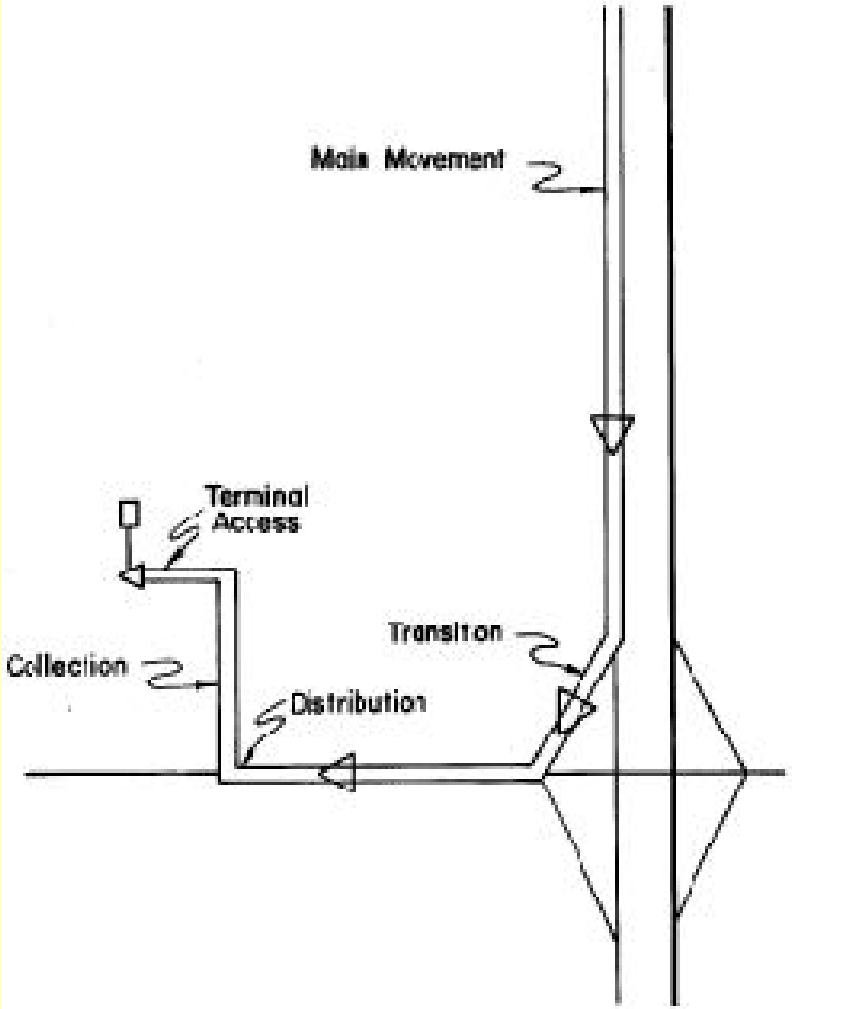
- The classification of highway into different operational systems, functional classes, or geometric type is necessary for communication among engineers, administrators, and the general public.
- Different classification schemes have been applied for different purposes in different rural and urban regions.

Highway Classification (cont'd)

- Functional Classification – The grouping of highways by the character of service they provide. Developed for transportation planning purposes.
- Administrative Classification is used to denote the level of government responsibility, and the method of financing, highway facilities. (for allocation of). funds and to define authority for planning, design, construction and maintenance)

Movements and Components

- Freeway – main movement is uninterrupted
- Freeway Ramps – acts as transition roadways
- Arterials – Moderate speed distributor facility
- Collector Roads – to penetrate neighborhood.
- Local Access Road – to individual residence.



Functional Categories

- Access Roads
  - Single lane
    - provided where there is a small probability of vehicles meeting (AADT < 20).
    - Very few passing maneuvers can be undertaken at very reduced speed using shoulders.
    - Vehicle flow from access roads will be aggregated in the collector road network.
  - Two lanes – Provided for higher traffic flows (AADT 20 – 100). Safe overtaking insured. Provide access to rural agriculture and cities.

Access Roads

Single Lane Access Road

Double Lane Access Road

Collector Roads

- Collectors link access roads to Arteries.
- For medium volume of traffic (100 to 1000 vehicles/day)
- Width may be 5 to 5.5 m (when heavy vehicles are less)
- Width may be 5.5 to 6.0 m (when heavy vehicles are >40%)

Principal arteries (for main movement)

- For high traffic flows (> 1000 vehicles/day).
- Minimum width required is 6.5 m
- Width of vehicle is 2.5 m
- Heavy vehicles can pass safely without moving laterally or slowing down.

Express ways

- Divided Arterial highways for through traffic with full or partial control of access and generally with grade separator at major intersections.
- Full control of access means that authority to control access is exercised to give preference to through traffic by providing access connections with selected public roads only and by prohibiting cross section at grade or direct private driving connection.

Express ways (cont'd)

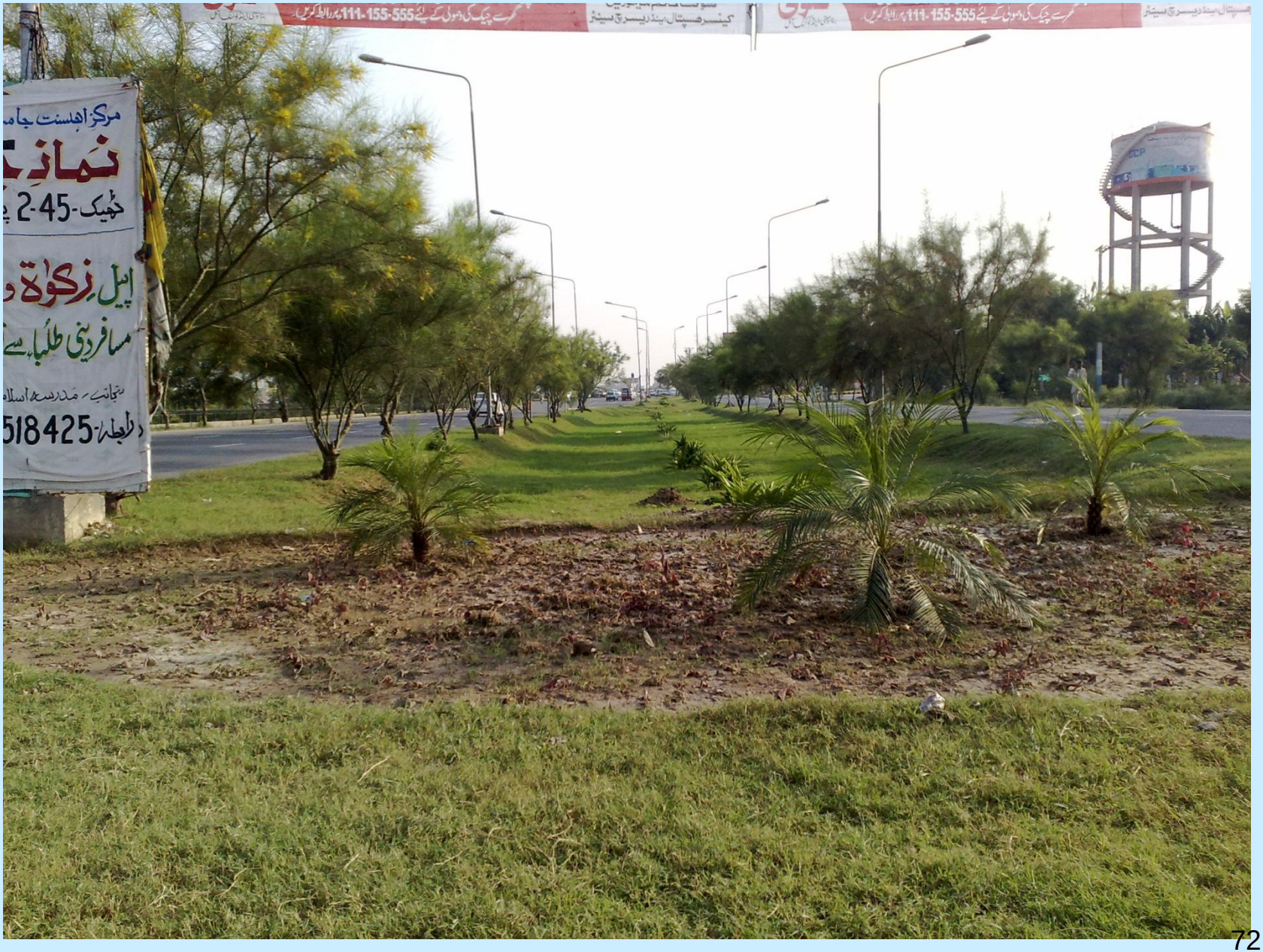
- Partial control of access means that authority to control access is exercised to give preference to through traffic to a degree that is added to access connections with selected public roads, there may be some crossing at grade and some private driving connection.

Freeway and Motorway

- Free ways/ Motorway – Express way with full control of access.
- Motorway – High volume, high speed highways.
  - At least 4 lanes (3.5 m) divided
  - Physical separators between confronting streams of traffic (median, concrete walls)
  - Access control (complete)
  - Grade separated intersections (interchange/fly over)
  - Fencing , underpasses for pedestrians/ cattle passes

Classification of Roads

- Street – Road in built up area
- By pass road – a road built to by pass congested area
- Ring road – Circumferential road built around an urban area to enable free flow of traffic.
- Boulevard – City road with landscape.
- Ribbon development – Unauthorized development around roads / highways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Frontage Roads

- Serve numerous functions, depending on the type of arterial they serve and the character of the surrounding area.
- They may be used to control access to the arterial, function as a street facility serving adjoining properties, and maintain circulation of traffic on each side of the arterial.
- Frontage roads segregate local traffic from the high speed through traffic and intercept driveways of residences and commercial establishments along the highway. Thus the through character of the highway is preserved.

Pedestrian & Pedestrian Crossing

- Pedestrian – A pedestrian is any person on foot. Involvement of pedestrian is a major consideration in highway planning and design.
- Pedestrian Crossing
  - Level with road – Zebra Crossing
  - Above level of road – foot over bridge (not preferred, 15 to 18 ft. height)
  - Below level of road – subway (convenient 7 to 8 ft. height)

Mass Transit

- Speed change lanes / Auxiliary lanes
  - Lanes other than main driving lanes of roadway such as turning lanes, parking lanes, passing lanes or truck lanes etc are auxiliary lanes
- Mass Transit – Movement of large number of people between small no of locations

Terrain

- Terrain / Topography – Causes speed of heavy vehicles to reduce below cars.
  - Level – heavy vehicles can maintain same speed as a car.
  - Rolling – speed of heavy vehicles reduces considerably than cars.
  - Mountainous - heavy vehicles operate at crawling speed

Administrative Authorities

- NHA (National Highway Authority)
- PWD (Public Works Department)
- Local Government

Commercial Vehicles

- Rigid Chases – SU Trucks (2 to 4 axle cargo and power unit mounted on same frame)
- Articulated – Two or more sections of a vehicle joined together in such a way that it makes it easy to turn corners e.g tractor and trailer combination.
- Combination trucks (18 wheeler is most common). It has three axles on tractor and two on semi trailer. It consists of power unit or tractor and one or more trailers.

Commercial Vehicles

- The trailers are either semi trailers (i.e having one or more axle near its rear but no front axle.) or full trailers i.e having one or more axles at front and rear.

Design Vehicles Dimensions

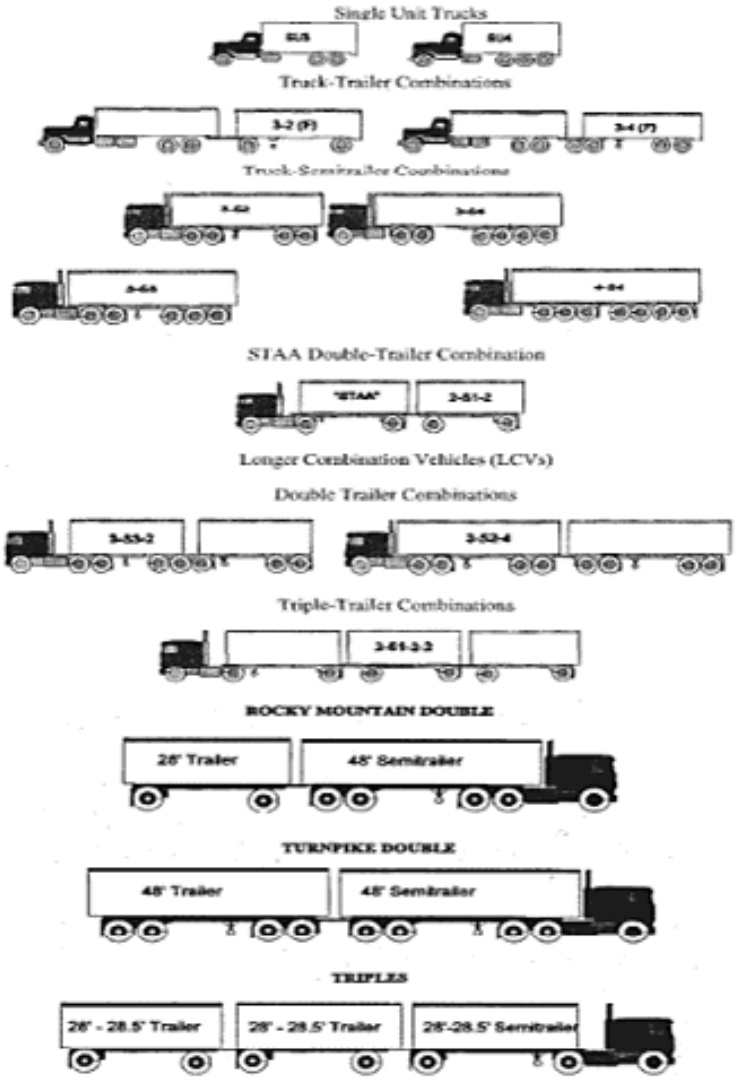
Design Vehicle Type	Symbol	Height (m)	Width (m)	Length (m)
Passenger car	P	1.3	2.1	5.8
Single unit truck	Su	4.1	2.6	9.1
Single unit bus	BUS	4.1	2.6	12.1
Recreation Vehicles				
Motor home	MH		2.4	9.1
Car & camper trailer	P/T		2.4	14.9
Car & boat trailer	P/B		2.4	12.8

Single Unit Truck
&
Articulated Truck


P·I·E
PACIFIC INTERMOUNTAIN EXPRESS


NINATRANS

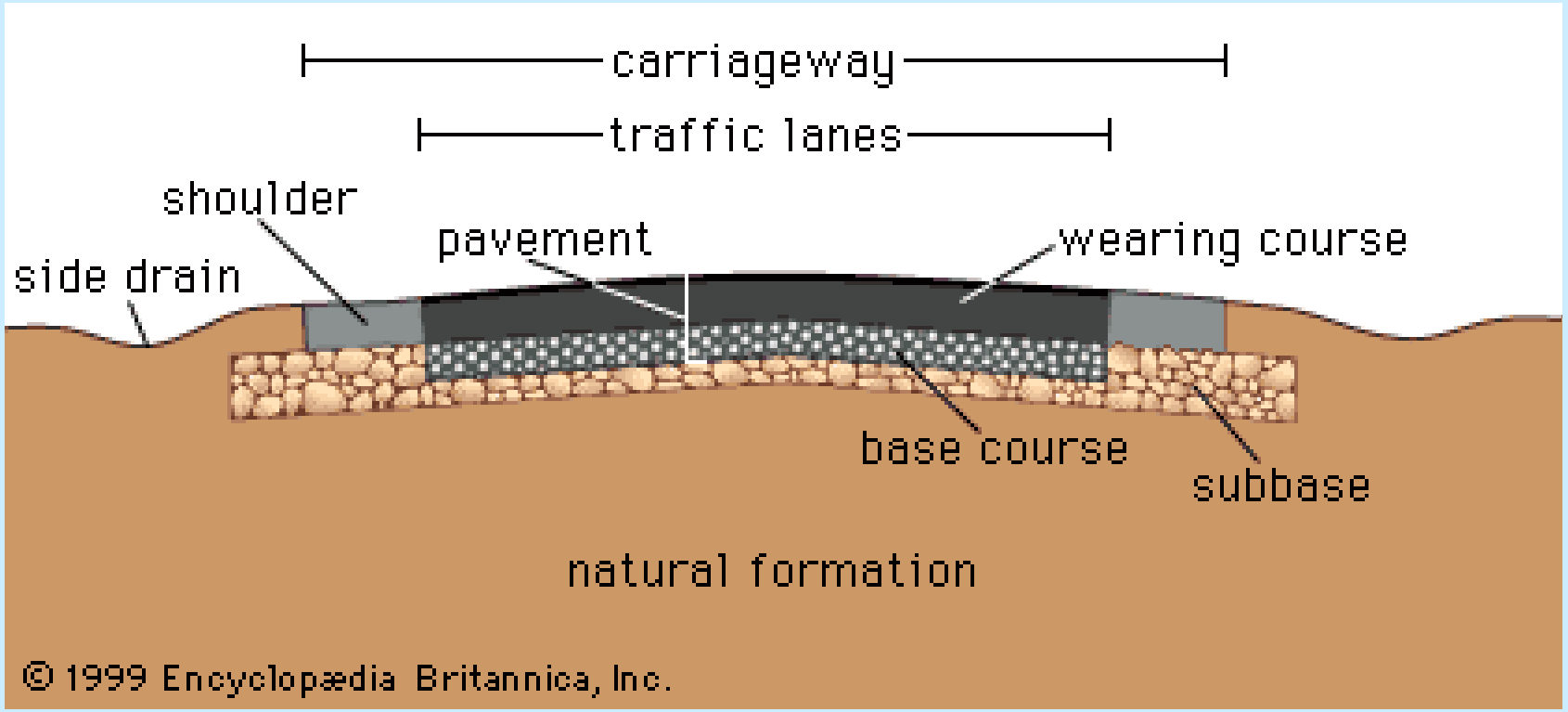

KUEHNE+NAGEL


Single Unit Trucks
Truck-Trailer Combinations
Truck-Semitrailer Combinations
STAA Double-Trailer Combination
Longer Combination Vehicles (LCVs)
Double Trailer Combinations
Triple-Trailer Combinations
ROCKY MOUNTAIN DOUBLE
28' Trailer
48' Semitrailer
TURNPIKE DOUBLE
48' Trailer
48' Semitrailer
TRIPLES
28' - 28.5' Trailer
28' - 28.5' Trailer
28'-28.5' Semitrailer

Cross Section Elements

- Number of travel lanes to be provided
- Width and location of shoulders
- Medians
- Slopes
- Embankments and Ditches

Components of a flexible pavement



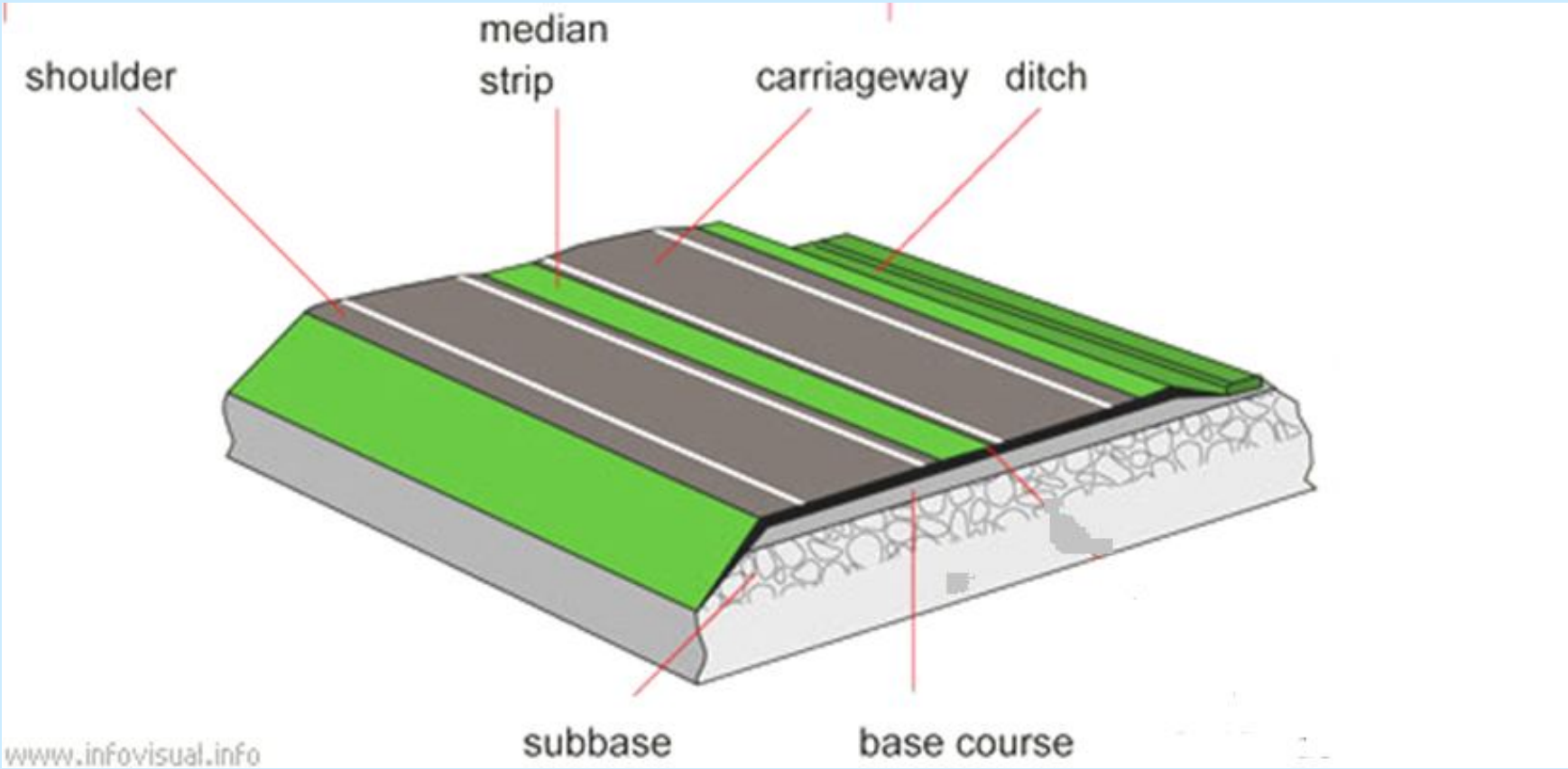
Cross section of a road

- Platform
  - horizontal surface raised above the surrounding ground.
- Shoulder
  - space between the roadway and ditch.
- Median strip
  - separation between two roadway.

Cross section of a road

- Carriageway
  - central part reserved for vehicle traffic.
- Ditch
  - channel that carries away water.
- Sub-grade
  - upper surface of prepared ground.
- Base course - middle surface of a road.
- Subbase- lower surface of a road.

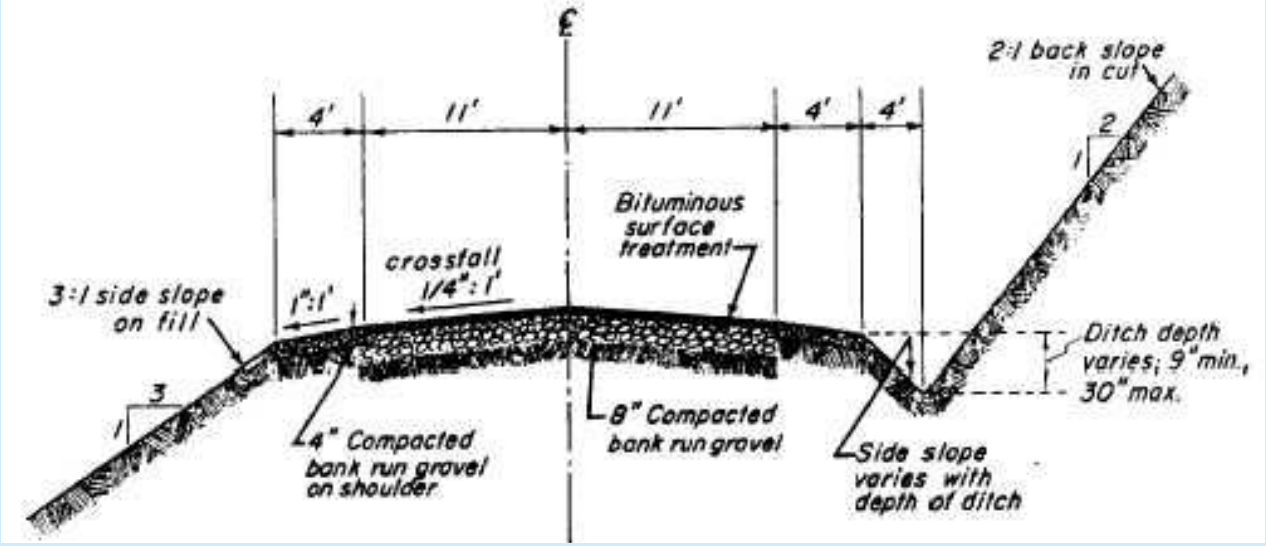
Cross Section of a Road



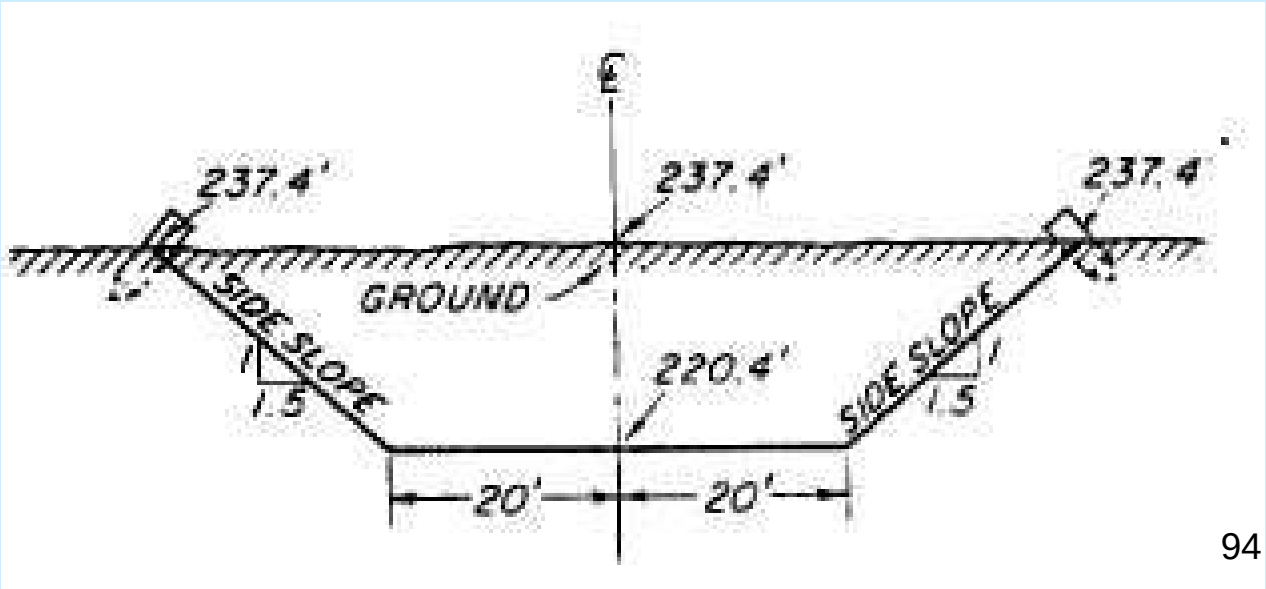

SYNERGY

Road Structure

Partial in Filling and Partial in Cutting



In Cutting



Highway Travel Lanes

- The width of the surfaced road and number of lanes should be adequate to accommodate the type and volume of anticipated traffic and assumed design speed of vehicles.
- Roads presently in use have traditionally been separated into generalized categories that include two-lanes, three-lanes, multilane undivided, multilane divided, and limited access highways.

Two Lane Highways

- Two lane roads vary from low type roads, which follow the natural ground surface, to high speed primary highways with paved surface and stabilized shoulders.
- As traffic density, vehicle speeds, and truck widths have increased, two lane highways have also increased in width from 4.8 m to the current recommended value of 7.2 m with 3 m stabilized or paved shoulders on either side along primary routes.

Three Lane Highways

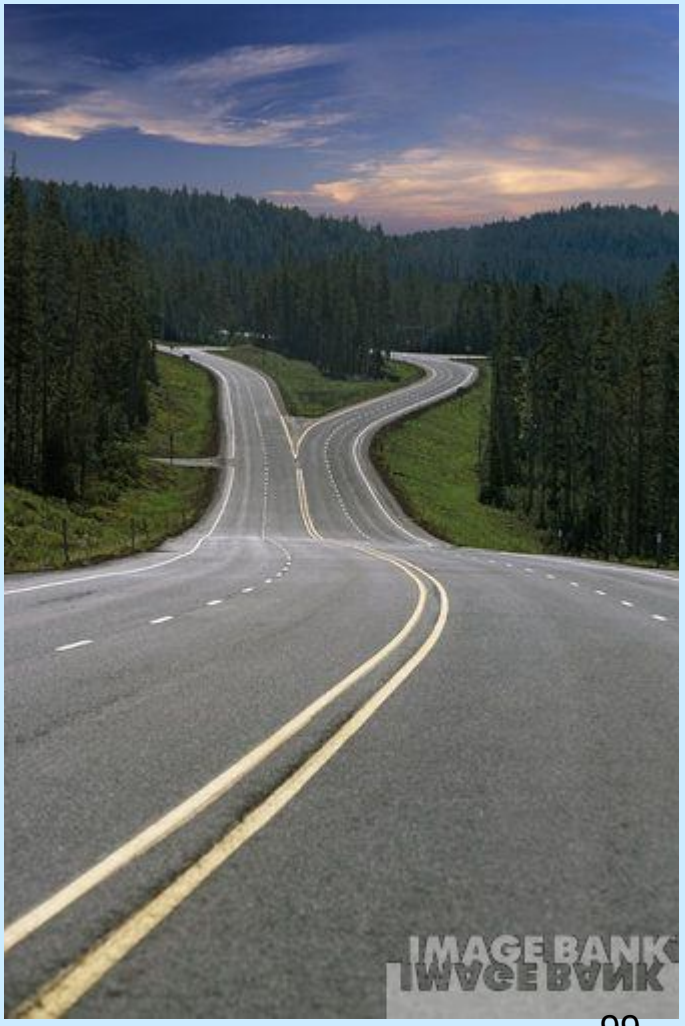
- Three lane roads were built in previous years. Their great advantage come from an operational improvement over the two lane road, with only a moderate increase in construction and right of way costs.
- The center lane is either used as two way center left turn lane or alternate in the uphill direction as directional passing lane. The three lane road does appear to have a high accident rate, and construction of these types of roads is no longer recommended except in special cases

Four Lane Highways

- On four lane highways traffic flows in opposite directions on each pair of lanes, and passing is accomplished within the lanes of forward movement and not in the lanes of opposing traffic.
- Four lane highways provide at least four times the capacity of a two lane highway for the same assumed design speed. Sometimes up to eight lane highways are also used. The undivided multilane highway does, however, appear to have an accident rate higher than that of the two lane highway.

Four Lane Highways

It is preferable that when traffic volumes are sufficient to require multilane construction, traffic separation is desirable.



Divided Highways

- Highways are frequently divided by a median strip to avoid conflicts of opposing traffic.
- Minimum lane widths is 3.6 m, while 4 m lanes provided where many large trucks combinations are anticipated in divided highways.
- The width of these median strips vary from 1.2 m to 18 m or more.
- A median strip less than 1.2 m in width is considered as center line strip and its use is not recommended except for special conditions.

Divided Highways (cont'd)

- The median should be of sufficient width to maintain vegetation and support low growing plants that reduce the headlight glare of opposing traffic.
- Median strips at intersections should be designed to permit necessary turning movements, which may require single or even dual turn lanes. It is recommended that width of medians should be such that additional travel lanes can be added in the future, by reducing the width of median.

Divided Highways (cont'd)

- Divided highways need not be of a constant cross section. The median strip may vary in width; the road may be at different elevations; and super elevation may be applied separately on each set of lanes.
- In rolling terrain, substantial saving may be effected in construction and maintenance costs by this variation in design. This type of design also tends to eliminate the monotony of a constant width and equal grade alignment.

Divided Highways

Limited Access Highways

- A very important feature of the design of a multilane highway is the control of access from adjacent property.
- A limited access highway may be defined as a highway especially designed for through traffic, to which motorists and owners of abutting properties have only restricted right of access.
- Limited or controlled access highways may consist of freeways that are open to all types of traffic or parkways from which all commercial traffic is excluded.

Limited Access Highways (cont'd)

- In urban areas, the design of a limited access facility is usually accompanied by providing frontage roads, parallel to the facility, which serve local traffic and provide access to adjacent land.
- Such roads may be designed for either one way or two way operation.
- Reasonably convenient connection should be provided between through traffic lanes and frontages. In general, spacing of access points along limited access facilities is 1.5 km (1 mile) or greater in urban areas and 4 to 7 km (3 to 5 miles) in rural areas.

Pavement Crown

- Pavement crown is the raising of the centerline of the roadway above the elevation of the pavement edges.
- Pavement crowns have varied greatly throughout the years.
- On the early low-type roads, high crowns were necessary for good drainage and were commonly constructed at a 4 % slope rate or more (1/2 in. or more per foot).

Pavement Crown (cont'd)

- With the improvement of construction materials, road-building techniques and equipment innovations that permit closer control, pavement crowns have been decreased.
- Present-day high-type pavements with good control of drainage now have crowns as low as 1 percent slope rate (1/8 in. per foot).

Pavement Crown (cont'd)

- Low crowns are satisfactory when little or no settlement of the pavement is expected and when the drainage system is of sufficient capacity to quickly remove the water from a traffic lane to prevent a motor vehicle from hydroplaning.
- When four or more traffic lanes are used, it is desirable to provide a higher rate of crown on the outer lanes in order to expedite the flow of water from the pavement into the gutter or onto adjacent unpaved shoulder

Shoulders

- Closely related to the lane width is the width of the shoulders.
- It is necessary to provide shoulders for safe operation and to allow the development of full traffic capacity.
- Well-maintained, smooth, firm shoulders increase the effective width of the traffic lane as much as 0.6 m (2 ft), as most vehicle operators drive closer to the edge of the pavement in the presence of adequate shoulders.

Shoulders

- Shoulders should be wide enough to permit and encourage vehicles to leave the pavement when stopping.
- The greater the traffic volume, the greater is the likelihood of the shoulders being put to emergency use.
- A usable shoulder width of at least 3 m (10 ft) and preferably 3.6 m (12 ft) clear of all obstructions is desirable for all heavily traveled and high-speed highways.

Shoulders

- In mountainous areas or low- type highways, a minimum width of 1.2 m (4 ft) may be provided; a width of 1.8 to 2.4 m (6 to 8 ft) is preferable to save extra cost.
- Emergency parking pull-outs should be provided at proper intervals in mountainous area when shoulders are not provided.
- For areas of terrain where guardrails or other vertical elements (such as retaining walls) are required, an additional 0.6 m (2 ft) of shoulder widening should be provided.

Shoulders

- The slope of the shoulder should be greater than that of the pavement.
- A shoulder with a high-type surfacing should have a slope of at least 3 percent (3/8 in. per foot)

Guardrail

- Guardrail should be provided
  - where fills are over 2.4 m (8 ft) in height
  - when shoulder slopes are greater than 1:4
  - In location, where there is sudden change in alignment
  - Where a greater reduction in speed is necessary.

Guardrail

- In locations with deep roadside ditches, steep banks, or other right-of-way limitations, it is often necessary to steepen the side slopes and to require the use of guardrail.
- The width of the shoulders is increased approximately 0.6 m (2 ft) to allow space for placing the posts where guard rails are used.

Crash Cushion

- Crash Cushion" is another useful safety feature on our roads.
- It is an energy absorbing crash attenuator with yellow and black chevron sign placed in front of the hard gore areas along expressways and major arterial roads.
- Gore area refers to location where the road is diverged into more directions, whereas hard gore refers to area with concrete platform.

Crash Cushion

- As the term "Crash Cushion" suggests, it is designed to help "soften" the impact of crashes.
- By redirecting the vehicles in the event of a collision, crash cushion helps to absorb the impact and minimize the damage caused to the impacting vehicle and thereby reduce the severity of injuries.

Crash Cushion

Curbs, Curb and Gutter, and Drainage Ditches

- The use of curbs is generally confined to urban and suburban roadways. The design of curbs varies from a low, flat, angle-type to a nearly vertical barrier-type curb.
- In areas where sidewalks are not provided, curbs adjacent to traffic lanes should be low in height and constructed with a flatter vertical angle so as not to create an obstruction.

Mountable Curb

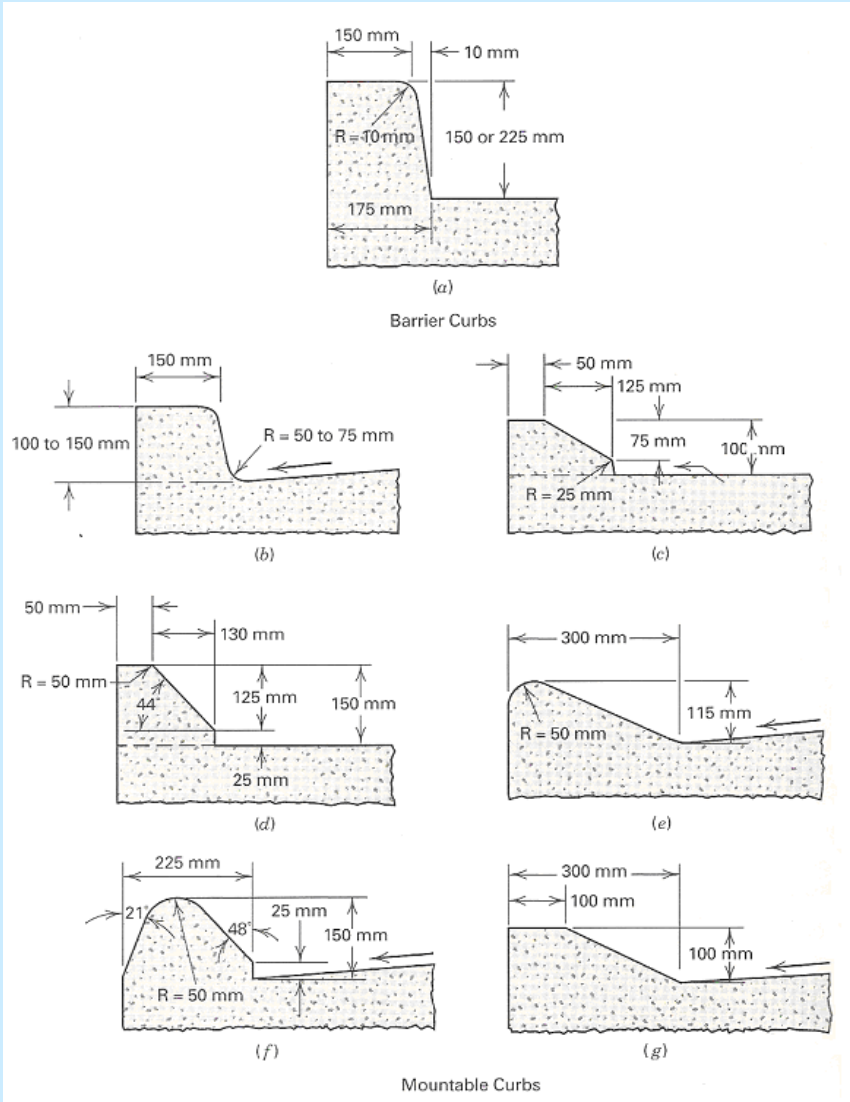
The face of the curb should be no steeper than 45° so that vehicles may drive over the curb without difficulty.

Curbs at parking areas and adjacent to sidewalks should be 150 to 200 mm (6 to 8 in.) in height.

Clearance should be sufficient to clear passenger car bumpers and to permit the opening of car doors without scraping.

Curbs, Curb and Gutter, and Drainage Ditches

- Storm water drainage will also affect the shape and height of the curb.
- From a pedestrian's viewpoint, curbs should be limited to one step in height.



Curbs, Curb and Gutter, and Drainage Ditches

- Drainage ditches should be located and shaped to avoid creating a hazard to traffic safety.
- Under normal conditions, ditches should be low enough to drain the water from under the pavement.

Slopes

- Side slopes and back slopes may vary considerably depending on soil characteristics and the geographic location of the highway.
- Well-rounded flat slopes present a pleasing appearance and are most economical to build and maintain.
- Side slopes of 1:4 are used a great deal in both cut and fill sections up to about 3 m (10 ft) in depth or height, but where the height of cut or fill does not exceed 1.8 m (6 ft), a maximum side slope of 1:6 is recommended.

Slopes

- Slopes may be as high as 1:1.5 Slopes as high as 1:1 are generally not satisfactory and exhibit long-term maintenance problem.
- In certain fill sections, special slopes may be built with riprap, mechanically stabilized fabric applications, reinforced concrete cribbing, and various types of retaining walls.

Right of Way

- The right-of-way width for a two-lane highway on secondary roads with an annual average daily traffic volume of 400 to 1000 vehicles, as recommended by the American Association of State Highway and Transportation Officials (AASHTO), is 20 m (66 ft) minimum and 25 m (80 ft) desirable.
- Along the Interstate Highway, minimum widths vary, depending on local conditions, from 46 m (150 ft) without frontage roads and 76 m (250 ft) with frontage roads, to 60 to 90 m (200 to 300 ft) for an eight-lane divided highway without frontage roads.

Right of Way

- Sufficient right-of-way should be acquired in order to avoid the expense of purchasing developed property or the removal of other physical encroachments from the highway right-of-way.

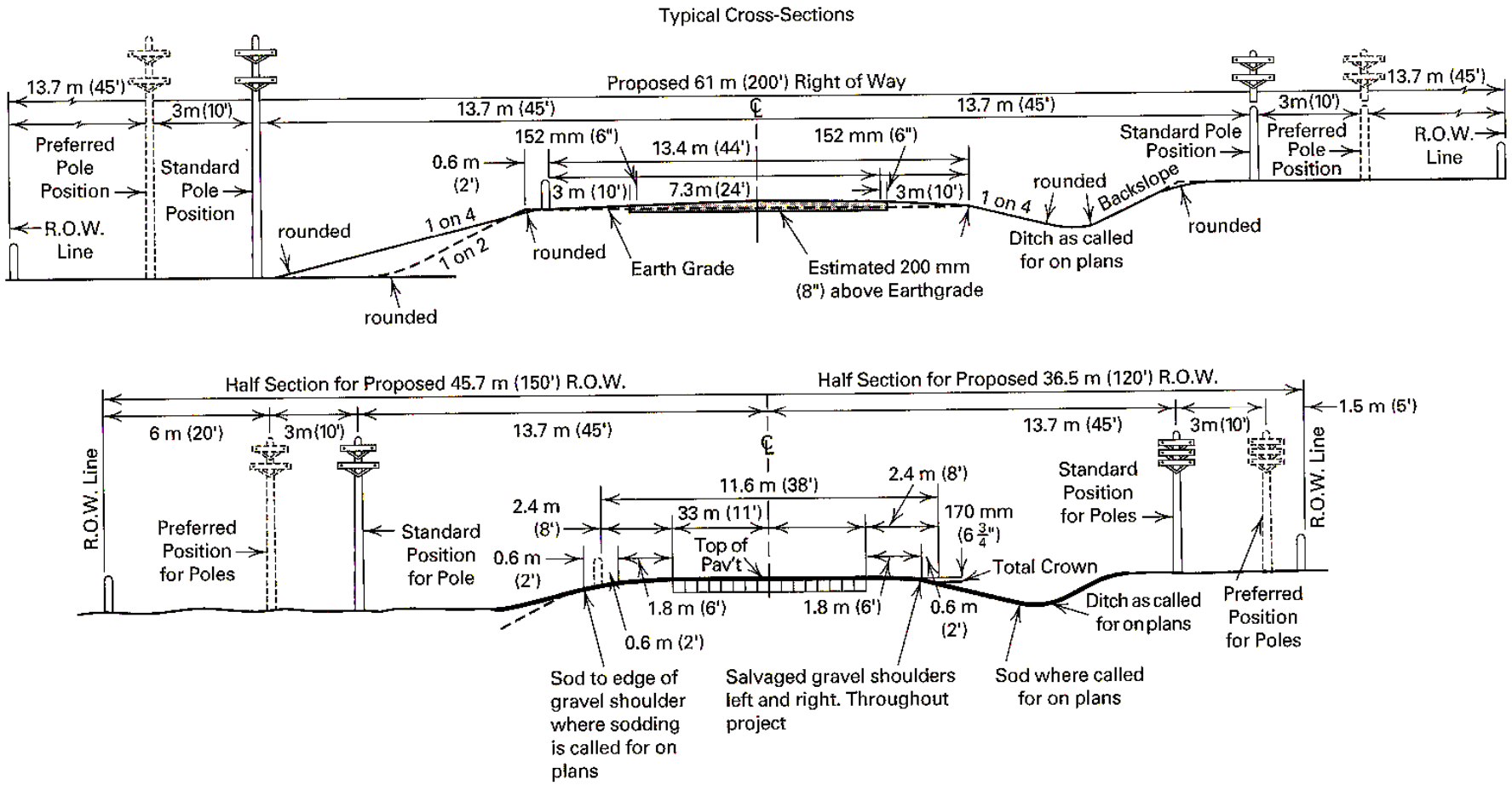


FIGURE 7-5 Typical cross-section dimensions for arterial streets. (Courtesy American Association of State Highway and Transportation Officials.)