



# Highway Engineering

Detailed notes + compact revision summary

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Highway Engineering

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## CHAPTER 01

# Highway Development, Planning and Alignment

History of road development, the twenty-year road plans, road classification, patterns, planning surveys and alignment.

## 1.1 Road development in India

Roads are the most flexible mode of transport: they give door-to-door service, feed railways, ports and airports, and are the only access to most villages. **Highway engineering** deals with planning, location, geometric design, materials, pavement design, construction, operation and maintenance of roads.

### Milestones of road development (frequently asked)

| Year | Event                           | Significance                                                    |
|------|---------------------------------|-----------------------------------------------------------------|
| 1927 | Jayakar Committee (report 1928) | Road development made a national interest; petrol tax for roads |
| 1929 | Central Road Fund (CRF)         | Extra duty on petrol credited to a fund for roads               |
| 1934 | Indian Roads Congress (IRC)     | Semi-official technical body; prepares codes                    |
| 1943 | Nagpur Road Plan                | First 20-year road plan (1943–63)                               |
| 1950 | CRRRI, New Delhi                | Central Road Research Institute                                 |
| 1961 | Bombay Road Plan                | Second 20-year plan (1961–81)                                   |
| 1981 | Lucknow Road Plan               | Third 20-year plan (1981–2001)                                  |
| 1988 | NHAI Act (operational 1995)     | Develops, maintains and manages NHs                             |
| 2000 | PMGSY; CRF Act 2000             | All-weather rural connectivity; cess on petrol and diesel       |

- **Jayakar Committee recommendations:** road development as a national interest; an extra tax on motor spirit to create a road development fund (→ CRF); a semi-official technical body to pool knowledge (→ IRC); a research organisation (→ CRRRI); long-term planning of roads.
- **CRF** — the extra petrol duty was credited to a non-lapsable fund; a part was kept by the Centre for research and special works and the rest was allotted to the states. Under the CRF Act 2000 the fund gets a cess on both petrol and high-speed diesel.
- **Historic road construction:** Roman roads (thick, lime-mortar bound, very heavy); Tresaguet (France) — cambered surface and thinner section; Telford (UK) — heavy foundation stones on a level subgrade; Macadam (UK) — first scientific method: compacted layers of small broken stone on a *cambered subgrade*, no heavy foundation stone.

**Exam trap:** Jayakar Committee = **1927**, CRF = **1929**, IRC = **1934**, CRRRI = **1950**. Do not mix up the committee year (1927) with the year its report came (1928).

## 1.2 Twenty-year road development plans

Three long-term plans fixed targets of **road density** (km of road per 100 km<sup>2</sup> of area) and the network pattern. The Nagpur plan also introduced the five-fold classification of roads that is still used.

### Comparison of the three road plans

| Feature         | Nagpur plan                               | Bombay plan                                                          | Lucknow plan                                                                              |
|-----------------|-------------------------------------------|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| Period          | 1943–1963                                 | 1961–1981                                                            | 1981–2001                                                                                 |
| Target density  | 16 km / 100 km <sup>2</sup>               | 32 km / 100 km <sup>2</sup>                                          | 82 km / 100 km <sup>2</sup>                                                               |
| Pattern assumed | Star and grid                             | —                                                                    | —                                                                                         |
| Expressways     | Not proposed                              | 1600 km                                                              | 2000 km                                                                                   |
| Key feature     | Five road classes; target met before 1961 | Separate targets for developed, semi-developed and undeveloped areas | All villages > 500 population (plains) by all-weather road; NH within 50 km of every part |

**Nagpur road plan formula** for first-category roads (NH + SH + MDR) gave the length of metalled roads needed in a region from its area and the number of towns:

#### Length of NH + SH + MDR (Nagpur)

$$N = \left( \frac{A}{8} + \frac{B}{32} + 1.6n + 8T \right) + D - R$$

A = agricultural area (km<sup>2</sup>); B = non-agricultural area (km<sup>2</sup>); n = number of towns/villages with population 2001–5000; T = towns with population > 5000; D = development allowance (15%); R = railway route length (km); N in km

### 1.3 Classification of roads

Roads are classified by function (traffic they serve), by importance and by location. The Nagpur plan classification is based on *location and function*; the third road plan grouped them as primary, secondary and tertiary systems.

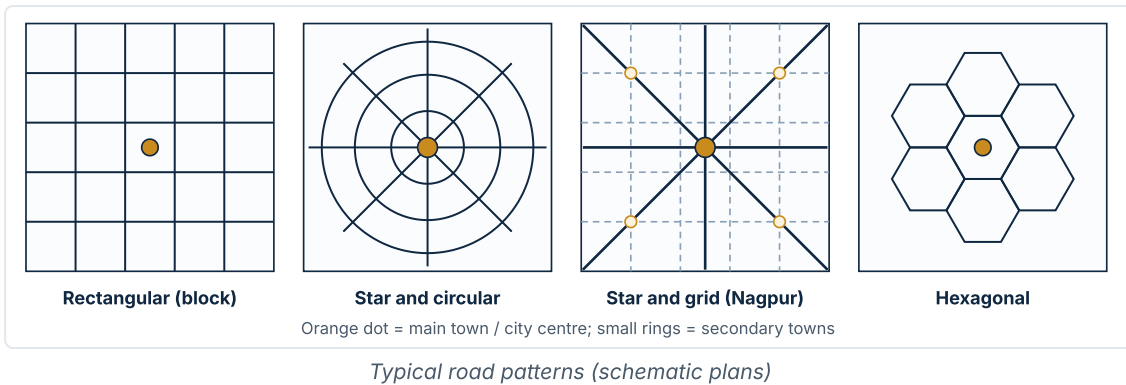
#### Non-urban (rural) roads — Nagpur plan classification

| Class                     | Function / connects                                                          | Maintained by         |
|---------------------------|------------------------------------------------------------------------------|-----------------------|
| National Highway (NH)     | State capitals, major ports, foreign highways; arterial roads of the country | Centre (MoRTH / NHAI) |
| State Highway (SH)        | District headquarters and important cities within a state; link with NH      | State PWD             |
| Major District Road (MDR) | Production and market areas within a district; link with SH/NH               | District / State      |
| Other District Road (ODR) | Rural areas of production to markets, taluka HQ, MDR                         | District              |
| Village Road (VR)         | Villages or groups of villages to each other and to the nearest higher road  | Panchayat / district  |

- **Third road plan (Lucknow):** Primary system — expressways and NHs; Secondary system — SHs and MDRs; Tertiary (rural) system — ODRs and VRs.
- **Expressways** — divided, high-speed (design speed ≈ 120 km/h) arterials with full control of access, grade-separated interchanges and no at-grade crossings.
- **Urban roads** (local streets give access, arterials give mobility): *arterial* (through traffic, continuous, signals at main junctions, parking restricted); *sub-arterial* (lower mobility, links arterials); *collector streets* (collect traffic from local streets and feed arterials); *local streets* (direct access to residences and shops, low speed).

### 1.4 Road patterns

The pattern of a road network decides travel distances between towns. Patterns are named by the shape of the network around the main town. The Nagpur plan formulae assumed a **star and grid** pattern, in which the whole area is divided into a grid of squares with a star of radial roads from each important town.



Rectangular (block) patterns are simple but make diagonal travel long; star and circular patterns use ring roads to divert through traffic from the centre; in the hexagonal pattern three roads meet at 120°; the *minimum travel* pattern joins the main town to satellite towns by the shortest routes.

### 1.5 Planning surveys and the saturation system

Before preparing a master plan, four groups of **planning surveys** are carried out. Their data are used to fix priorities and to choose between alternative road networks.

#### Planning surveys

| Survey              | Data collected                                                                                                          |
|---------------------|-------------------------------------------------------------------------------------------------------------------------|
| Economic studies    | Population and its distribution, agricultural and industrial products, existing transport facilities, per-capita income |
| Financial studies   | Sources of income, estimated revenue from taxes and tolls, living standards, future trends                              |
| Traffic studies     | Traffic volume, origin–destination (O-D), traffic flow pattern, mass transport, accidents, future trends                |
| Engineering studies | Topography, soil, road location and alignment, drainage, special problems in construction and maintenance               |

In the **saturation system** (maximum utility system) the network giving the **maximum utility per unit length** of road is selected. Utility is expressed in *utility units* given to population served (villages grouped by population) and to productivity served (agricultural and industrial products).

#### Worked example — Choosing between two road proposals

Utility units: population groups < 500, 501–1000, 1001–2000, 2001–5000 = 0.25, 0.5, 1 and 2 respectively; 1 unit per 1000 t of produce. Road A (20 km) serves 12, 10, 5, 2 villages of these groups and 12,000 t of produce. Road B (25 km) serves 15, 14, 6, 3 villages and 15,000 t. Which road should get priority?

- Road A, population units =  $12(0.25) + 10(0.5) + 5(1) + 2(2) = 3 + 5 + 5 + 4 = 17$ ; produce = 12; total = 29.
- Road B, population units =  $15(0.25) + 14(0.5) + 6(1) + 3(2) = 3.75 + 7 + 6 + 6 = 22.75$ ; produce = 15; total = 37.75.
- Utility per km: A =  $29/20 = 1.45$ ; B =  $37.75/25 = 1.51$ .

**Answer:** Road B gives higher utility per km ( $1.51 > 1.45$ ) and gets priority.

### 1.6 Highway alignment and engineering surveys

**Alignment** is the position of the centre line of a road on the ground. A badly fixed alignment cannot be corrected later without heavy cost, so it must satisfy four basic requirements: it should be **short, easy, safe and economical** (in initial, maintenance and operation cost).

## CHAPTER 06

# Traffic Characteristics, Studies and Flow

Road user and vehicle characteristics, volume, speed, O-D, parking and accident studies, PCU, capacity, LOS and traffic flow theory.

## 6.1 Traffic characteristics

**Traffic engineering** is the branch of highway engineering that deals with the study of traffic characteristics, traffic studies, traffic operation and control, and the planning and geometric design of intersections, so that people and goods move safely and efficiently. Design depends on the characteristics of **road users** and **vehicles**.

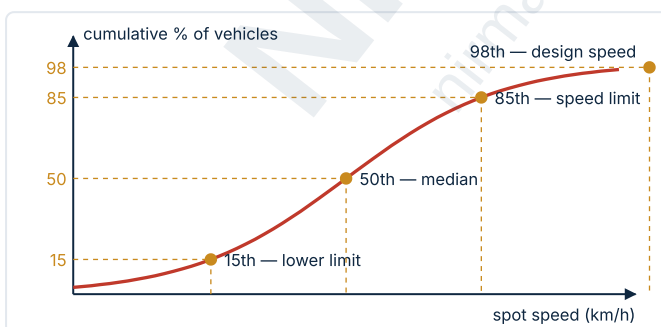
- **Road user characteristics:** physical (vision, hearing, strength, reaction), mental (knowledge, skill, intelligence, experience), psychological (attentiveness, fear, anger, impatience) and environmental factors. Total reaction time is explained by the PIEV theory.
- **Vehicle characteristics:** dimensions (width affects lane width and clearance; height affects overhead clearance; length affects extra widening and turning), weight (pavement design), power (gradients), speed and braking (sight distance).
- **IRC maximum vehicle dimensions:** width 2.5 m; height 3.8 m for normal vehicles (4.2 m for double-deckers); length 11 m for a single-unit truck, 12 m for a single-unit bus, 16 m for a semi-trailer and 18 m for a truck-trailer combination.

## 6.2 Traffic volume and speed studies

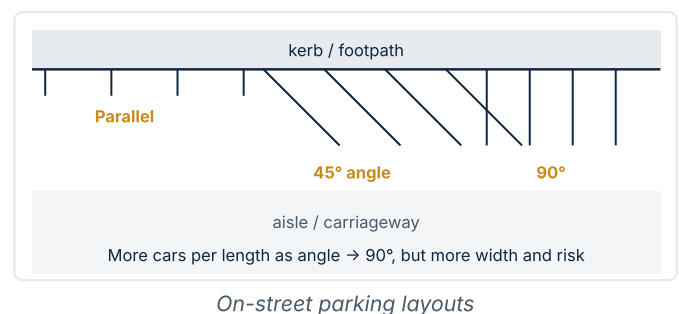
**Traffic volume** is the number of vehicles crossing a section of road per unit time. Counts are taken manually, by automatic counters (pneumatic tubes, inductive loops) or video. Volumes are expressed in **PCU** for mixed traffic.

- **ADT** — average daily traffic over a period; **AADT** — average daily traffic over a full year.
- **30th highest hourly volume** — used as the **design hourly volume** for rural highways (economical: higher volumes occur only in a few hours of the year).
- **Peak hour factor PHF** =  $\text{hourly volume} \div (4 \times \text{peak 15-minute volume}) \leq 1$ .
- Results are presented as annual/daily/hourly variation charts, flow maps and intersection flow diagrams.

**Spot speed** is the instantaneous speed of a vehicle at a point; it is measured by an enoscope (mirror box) over a short base, radar speed meter, pressure contact tubes or video. The data are plotted as a frequency curve and a **cumulative frequency curve**.



Cumulative spot speed distribution and its uses



On-street parking layouts

- **85th percentile speed** — upper speed limit for regulation; **98th percentile** — design speed for geometric design; **15th percentile** — lower speed limit on expressways; **50th** — median speed.
- **Journey (overall) speed** = distance / total journey time including stops; **running speed** = distance / running time (excluding stops).
- **Speed and delay studies** — floating car method, *moving observer method* (Wardrop and Charlesworth), licence-plate method, interview and elevated observation.

**Time mean speed**

$$\bar{v}_t = \frac{\sum v_i}{n}$$

Arithmetic mean of spot speeds at a point

**Space mean speed**

$$\bar{v}_s = \frac{n}{\sum (1/v_i)}$$

Harmonic mean;  $\bar{v}_t = \bar{v}_s + \sigma_s^2/\bar{v}_s$  so  $\bar{v}_t \geq \bar{v}_s$

**Moving observer — flow**

$$q = \frac{x + y}{t_a + t_w}$$

x = vehicles met while moving against the stream; y = vehicles overtaking the test car minus those overtaken by it (with stream);  $t_a, t_w$  = journey times against and with the stream

**Moving observer — mean journey time**

$$\bar{t} = t_w - \frac{y}{q}$$

Mean stream speed = length /  $\bar{t}$

**Worked example — Moving observer method**

A test car runs over a 3 km stretch. Moving against the stream it takes 5.0 min and meets 107 vehicles; moving with the stream it takes 4.5 min, is overtaken by 17 vehicles and overtakes 7. Find the flow and mean speed of the stream.

1.  $y = 17 - 7 = 10$
2.  $q = (107 + 10)/(5.0 + 4.5) = 12.32 \text{ veh/min} = 739 \text{ veh/h}$
3.  $\bar{t} = 4.5 - 10/12.32 = 4.5 - 0.81 = 3.69 \text{ min}$
4. Speed =  $3/(3.69/60) = 48.8 \text{ km/h}$

**Answer:** Flow  $\approx 739 \text{ veh/h}$ ; mean stream speed  $\approx 48.8 \text{ km/h}$ .

**Worked example — Time mean and space mean speed**

Spot speeds of five vehicles are 40, 50, 55, 60 and 45 km/h. Find the time mean and space mean speeds.

1.  $\bar{v}_t = (40 + 50 + 55 + 60 + 45)/5 = 250/5 = 50 \text{ km/h}$
2.  $\sum 1/v = 0.02500 + 0.02000 + 0.01818 + 0.01667 + 0.02222 = 0.10207$
3.  $\bar{v}_s = 5/0.10207 = 48.99 \text{ km/h}$

**Answer:** Time mean speed = 50 km/h; space mean speed  $\approx 49 \text{ km/h}$ .

### 6.3 O-D studies, PCU, capacity and level of service

**Origin–destination (O-D) studies** find the number of trips between zones, their purpose, mode and route; they are used for planning new roads, bypasses, transport systems and for fixing priorities. Methods: road-side interview, licence-plate method, return post-card, tag-on-car, home interview and work-spot interview. Results are shown as an **O-D matrix** and **desire lines** (straight lines between zones with thickness proportional to trips).

#### Passenger car units for rural roads (IRC:64)

| Vehicle type                                        | PCU | Vehicle type        | PCU |
|-----------------------------------------------------|-----|---------------------|-----|
| Car, jeep, van, auto-rickshaw, agricultural tractor | 1.0 | Cycle               | 0.5 |
| Motor cycle, scooter                                | 0.5 | Cycle-rickshaw      | 2.0 |
| Light commercial vehicle                            | 1.5 | Hand cart           | 3.0 |
| Truck, bus, tractor-trailer                         | 3.0 | Horse-drawn vehicle | 4.0 |
| —                                                   | —   | Bullock cart        | 8.0 |

- **Capacity** is the maximum number of vehicles that can pass a section in one hour under the prevailing conditions. *Basic (theoretical) capacity* — under ideal road and traffic conditions; *possible capacity* — under prevailing conditions; *practical capacity* — the volume that can pass without unreasonable delay or restriction to drivers (used for design).
- **Level of service (LOS)** is a qualitative measure of operating conditions (speed, freedom to manoeuvre, comfort). Six levels: **A** free flow, **B** reasonably free, **C** stable flow, **D** approaching unstable, **E** at capacity, **F**

**PART B**

# Compact Summary Notes

## Highway Engineering

Illustrated one-page-per-topic revision sheets — read these in the last days before the exam, after studying the detailed notes in Part A.

Summary notes

page 52

5 pages of summary notes

# HIGHWAY ENGINEERING

## Handwritten Notes

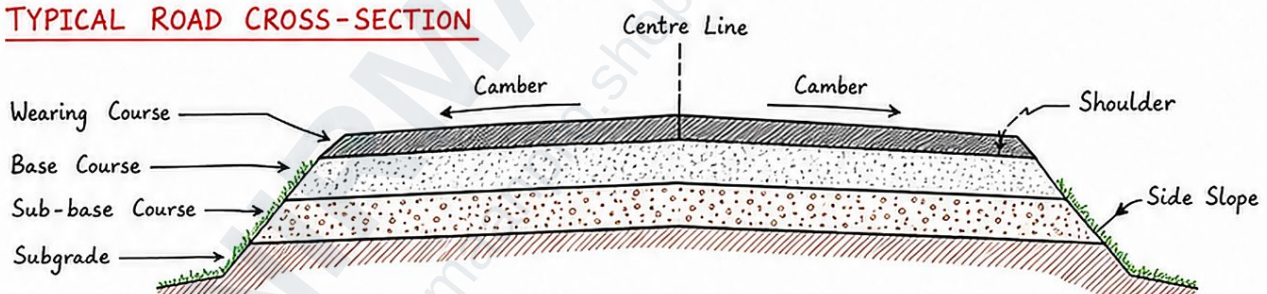
### TOPICS COVERED

1. Introduction
2. Geometric Design
3. Traffic Engineering
4. Highway Materials
5. Pavement Design
6. Highway Construction
7. Highway Maintenance

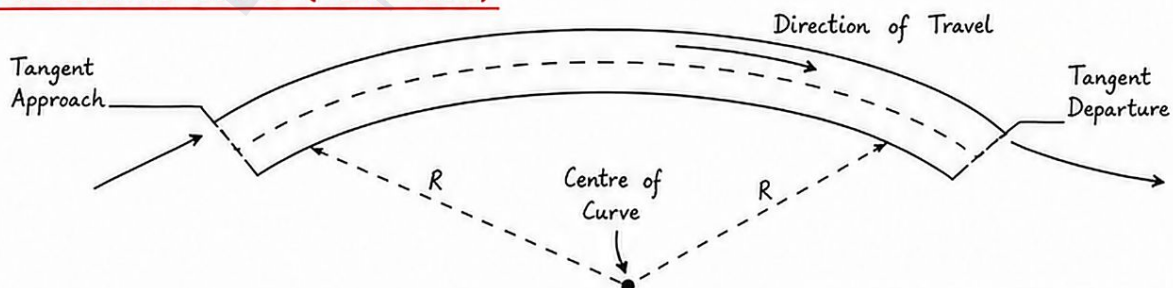
### IMPORTANT BASIC TERMS

- **Camber** — Transverse slope provided on the pavement for drainage.
- **Gradient** — Longitudinal slope of the road along its length.
- **Super-elevation** — Transverse slope provided on horizontal curves to counteract centrifugal force.
- **Sight Distance** — Distance visible to a driver along the roadway ahead.
- **CBR** — California Bearing Ratio; measure of subgrade soil strength.
- **Flexible Pavement** — Pavement that distributes load by grain-to-grain contact in multiple layers.
- **Rigid Pavement** — Pavement that distributes load by slab action (concrete slab).

### TYPICAL ROAD CROSS-SECTION



### HORIZONTAL CURVE (PLAN VIEW)



#### NOTE

- Highways are planned, designed, constructed and maintained to provide safe, economical and efficient movement of traffic.
- Good design and proper maintenance increase safety, comfort and service life of the road.

#### KEY POINTS

- Safety
- Economy
- Comfort
- Durability
- All-weather service

# HIGHWAY ENGINEERING

## Introduction, Development, Classification & Surveys

### 1. IMPORTANCE & SCOPE OF HIGHWAY ENGINEERING

- Highways are the lifelines of a nation.
- Promote socio-economic development and national integration.
- Provide mobility of people and goods.
- Reduce travel time, operating cost and accidents.
- Support defence, tourism, agriculture and industries.
- Scope includes planning, design, construction, maintenance and management of roads.

### 3. ROAD CLASSIFICATION IN INDIA

- **Expressway (EW)** — Fully access controlled highways with high design speed.
- **National Highways (NH)** — Connects important cities, ports, capitals; of national importance.
- **State Highways (SH)** — Connects state capital with district HQs or important places.
- **Major District Roads (MDR)** — Connects district HQs with taluk HQs or important villages.
- **Other District Roads (ODR)** — Connects villages to other villages or to MDR.
- **Village Roads (VR)** — Connects villages to farms and rural habitations.

### 5. FACTORS CONTROLLING ALIGNMENT

- **Topography** — Follow favourable ground conditions; avoid steep gradients.
- **Geology & Soil** — Stable, economical and durable foundations.
- **Traffic** — Volume, composition and future growth.
- **Economy** — Minimum cost of construction, maintenance and user.
- **Safety** — Adequate sight distance, gentle curves and proper gradients.
- **Drainage** — Natural drainage to be maintained.
- **Environment** — Minimum damage to forest, wildlife and ecology.
- **Land Use & Utilities** — Existing land use and relocation of utilities.

#### NOTE

- Proper planning, correct alignment and good surveys are essential for safe, economical and durable highways.
- Roads evolve with time — from simple tracks to modern engineered highways.
- Good design today ensures better mobility and development tomorrow.

### 2. HISTORICAL DEVELOPMENT OF ROADS

#### Roman Roads (300 B.C. – 400 A.D.)

- Built with proper planning and straight alignments.
- Layers of stone and gravel with side drains.
- Example — Appian Way (Italy).

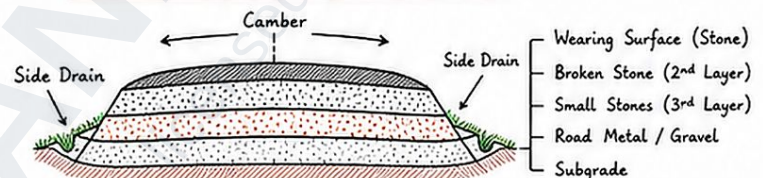
#### Telford (Early 19<sup>th</sup> Century)

- Introduced scientific road construction.
- Road camber and strong, well-drained structure.

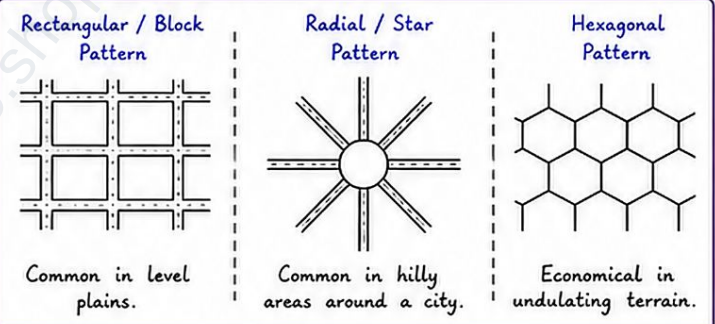
#### Macadam (Early 19<sup>th</sup> Century)

- John Loudon Macadam developed the macadam road.
- Broken stone aggregate in a well-graded layer.
- Foundation of modern road construction.

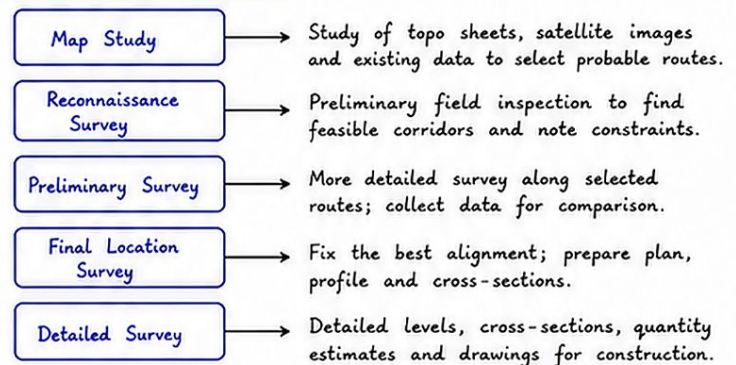
#### TYPICAL TELFORD / MACADAM ROAD SECTION



### 4. ROAD PATTERNS



### 6. HIGHWAY SURVEYS





# End of the free preview

Highway Engineering

## The full PDF has 56 pages:

Part A — detailed typed notes: 11 chapters, 47 pages

Part B — handwritten compact summary: 5 pages

## Chapters in the full notes

- 01 Highway Development, Planning and Alignment
- 02 Cross-Section Elements
- 03 Sight Distance
- 04 Horizontal Alignment
- 05 Vertical Alignment
- 06 Traffic Characteristics, Studies and Flow
- 07 Traffic Control and Intersections
- 08 Highway Materials
- 09 Pavement Design
- 10 Highway Construction
- 11 Drainage, Maintenance & Pavement Evaluation

Formula boxes with every symbol explained · IS / IRC code values in tables · labelled sketches  
Worked examples step by step · exam tips & traps · quick revision points after every chapter

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