OPSC 2019

Odisha Public Service Commission

Assistant Engineer Examination

Civil Engineering

Highway Engineering

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

MADE EASY
Publications

Highway Engineering

Contents

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Highway Development and Planning

1.1 Introduction

1. **Roads:** Any hardened surface which can carry the load of moving vehicle is called road.
2. **Pavement:** Road made by number of layers is called pavement.
3. **Highway:** It is a special type of road which is designed for high speed of vehicle.
   - In order to maintain high speed highways are generally constructed over an embankment.
   - Roads over embankment has following advantages.
     - (i) Lateral entry of vehicle/animal/public can be avoided.
     - (ii) Safe from drainage point of view.

1.2 Development of Roads

1.2.1 Roman Roads

During this period of Roman civilization many roads were built of stone blocks of considerable thickness.

Main features of roman roads are:

(*i*)   they were built straight regardless of gradient.

(*ii*) total thickness of the construction was as high as 0.75 m to 1.2 m.

(*iii*) they were built after the soft soil was removed and a hard stratum was reached.

(*iv*) the wearing course consisted of dressed large stone blocks set in lime mortar.
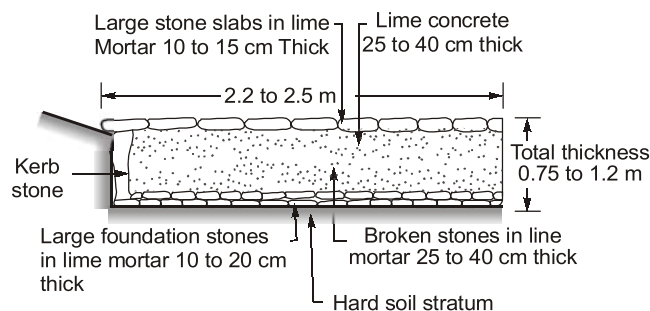

*Figure-***1.1 :** *Typical cross section of Roman Road*

1.2.2 Treseguet Construction:

Pierre treseguet developed an improved method of construction in France during 1764 AD.

Main feature of the Treseguet construction are:

(i)   Thickness of the road was order of 30 cm.

(ii)   Consideration was given to subgrade moisture condition and drainage of surface water

(iii)   The top wearing course was made up of smaller slope having a cross slope of 1 in 45 to the surface to provide surface drainage.

(iv)   Shoulder sloping was also provided of the order of 1 in 20 to drain the surface water to the side drain.
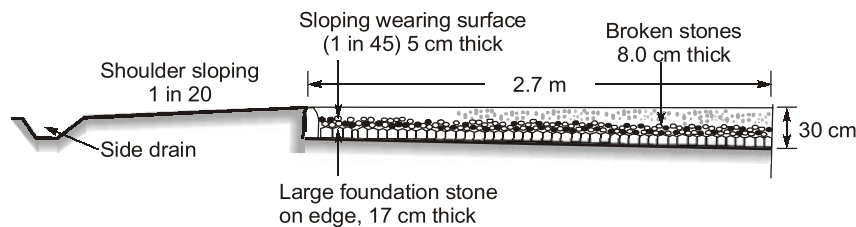

Figure-1.2 : *Typical cross-section of Tresaguet's construction*

1.2.3   Telford Construction:

His work started in early 19th century in England.

Main feature of the Telford construction:

(i)   He proposed a level subgrade of width 9 m.

(ii)   Thickness of foundation stone varied from 17 cm at edges to 22 cm at the centre.

(iii)   A binding layer of wearing course 4 cm thick was provided with cross-slope of 1 in 45.

(iv)   The central of about 5.5 m width was covered with two layers of angular broken stones to compacted thickness of 10 cm and 5 cm.
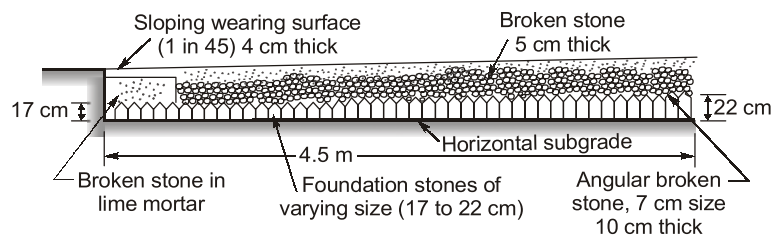

Figure-1.3 : *Typical cross-section of Telford's construction*

1.2.4   Metcalf Construction:

Metcalf believed that a good road should have good foundations, be well drained and have a smooth convex (rounded) surface to allow rainwater to drain quickly into ditches at the side of the road.

1.2.5   Macadam construction:

- John macadam (1756 - 1836) put forward and entirely new method of road construction as compared to all the previous methods.

- Macadam was the first person who suggested that heavy foundation stones are not at all required to be placed at the bottom layer. He provided stones of size less than 5 mm to a uniform thickness of 10 cm.

- The importance to subgrade drainage and compaction was given so the subgrade was compacted and prepared with cross slope of 1 in 36. The size of broken stone for the top layers was decided on the basis of stability under animal drawn vehicles.

- The pavement surface was also given the cross slope of 1 in 36.

- Total thickness was kept uniform from edge to centre to a minimum of 25 cm.
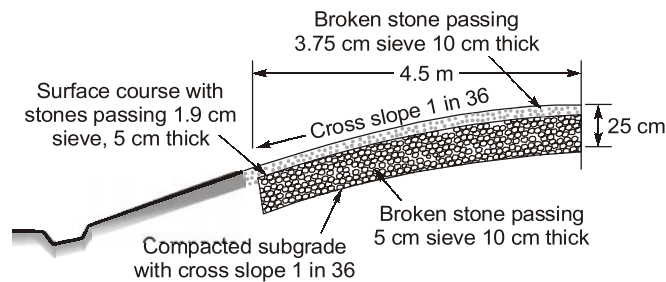
Figure-1.4 : *Typical cross-section of Macadam's construction*

1.3 Difference between Telford and Macadam Construction

The Macadam and Telford methods of construction differ considerably though both the methods were put forward in the early 19th century:

Macadam Method:
- The subgrade was given a cross slope of 1 in 36 to falicitate subgrade drainage.
- The bottom layer of pavement or the sub-base course consisted of broken stones of less than 5 cm size to uniform thickness equal to 10 cm only.
- Base and surface courses consisted of broken stones of smaller sizes to compacted thickness of 10 and 5 cm respectively and the top surface was given a cross slope of 1 in 36.
- The total thickness of pavement construction was kept uniform from edge to centre to a minimum value of only 25 cm.

Telford Method:
- The subgrade was kept horizontal and hence subgrade drainage was not proper.
- Heavy foundation stones of varying size, about 17 cm towards the centre were hand packed and prepared to serve as sub base course.
- Two layers of broken stones were compacted over the foundation stones before laying the wearing course, 4 cm thick with a cross slope of 1 in 45.
- The total thickness of construction varied from about 35 cm at the edge to about 41 cm at the centre.

1.4 Water bound Macadam (WBM):

In this method the broken stones of the base course and surface course are bounded by the stone dust in the presence of moisture.

1.5 Modern Road Developed In India

After the first world war, motor vehicles using the roads increased and demanded a better road network. So, British government passed a resolution in 1927, in response to which Jayekar Committee was consulted in 1927.

1.5.1 Recommendations of Jayekar Committee

(i) Road development should be considered as national interest.
Result: Participation of fund for road development.

(ii) An extra tax should be charged on petrol and diesel for road development and maintenance.
Result: Central road fund established in '1929'.

(iii)   A technical body should be established for design and specification.
         Result: IRC in 1934.

(iv)   A research and development organization should be established for a new roads in India.
         Result: CRRI- Central Road Research Institute Established in 1950.

(v)   Jayakar Committee gives more stress for long term planning.
         Result: Various 20 years plan.

First 20 years Road Plan (Nagpur Road Plan): (1943 - 1963)

Features: This plan was a major attempt in planning for road development in a scientific manner. The total road length of 5,32,700 km with a density of 16 km of road length per 100 km^2 area would be available by 1963. All the roads were classified into five categories.

(i)   National Highway (NH)

(ii)   State Highway (SH)

(iii)   Major District Roads (MDR)

(iv)   Other District Roads (ODR)

(v)   Village Roads (VR)

They recommended the construction of star and grid pattern of roads throughout the country. They recommended development allowance of 15%. Nagpur plan give formula for road length of different classes, considering the geographical, agricultural and population conditions.

(i)   Length of national highway and state highway and major district roads (in miles):

$$= \frac{A}{5} + \frac{B}{20} + N + 5T + D - R$$

where,

B = Non-agricultural area in (sq. miles)

N = Number of towns and villages having a population of 2000 - 5000

T = Number of towns and villages having a population of over 5000.

D = An allowance for agricultural and industrial development.

R = Railway mileage in the area under consideration.

(ii)   Length of other district and village roads (in miles):

$$= \frac{V}{5} + \frac{Q}{2} + R + 2S + D$$

where, Q = Number of villages with population 501-1000.

R = Number of villages with population 1001-2000.

S = Number of villages with population 2001-5000.

D = An allowance for agricultural and industrial development during the next 20 years.

Second 20 years Road Plan (Bombay Road Plan): (1961 - 1981)

Features:

(i)   At the end of plan, the target road length was 32 km per 100 sq. km area.

(ii)   Maximum distance of any place in a developed or agricultural area would be 6.4 km from a metalled road and 2.4 km from any category of roads.

(iii)   1600 km expressways have been considered in this plan within proposed target of national highway.

(iv)   Every town with a population above 2000 in plans and above 1000 in semihilly areas and above 500 in hilly areas should be connected by metalled road.

(v)   A development allowance of 5% is provided for future developments.

(vi)   Traffic engineering cells should be established in each state.

Third 20 years Road Plan (Lucknow Road Plan): (1981 - 2001)

Features:

(i) In this plan roads are classified into primary, secondary and territory road system.

(ii) All village with over 500 population should be connected by all weather roads.

(iii) The overall road density was targeted as 82 km per 100 sq. km area.

(iv) The NH network should be expanded to form square grids of 100 km sides so that no part of the country is more than 50 km away from a NH.

(v) 2000 km expressway have been considered in this plan along major traffic corridors to provide fast travels.

Primary Road: (EH + NH) $\rightarrow$ (Express highway + National highway)

Secondary Road: (SH + MDR) $\rightarrow$ (State highway + Major District Road)

Tertiary Road: (ODR + VR) $\rightarrow$ (Other district road + Village road)

Note: Total length of national highway is approximately about 90000 km which is just 2% of total road length. Which carries 40% of total traffic.

Road lengths as per 3rd 20 year road plan:

(i) Total length of road (km) $= \max \begin{cases} 4.74 \times (\text{No. of towns + village}) \\ \qquad\qquad \text{or} \\ \text{Road density} \times \text{Area} \end{cases}$

(ii) Length of NH (km) $= \dfrac{\text{Area (km}^2)}{50}$

(iii) Length of SH(km) $= \max \begin{cases} \dfrac{\text{Area (km}^2)}{25} \\ \qquad \text{or} \\ 62.5 \times \text{No. of town} - \text{NH length} \end{cases}$

(iv) Length of MDR(km) $= \max \begin{cases} \dfrac{\text{Area (km}^2)}{12.5} \\ \qquad \text{or} \\ 90 \times \text{No. of town} \end{cases}$

Example 1.1 Area of Maharashtra is 308,000 km^2 number of towns is 216 and number of villages 41833. Find out the length of all the roads according to 3rd 20 years road plan.

Solution:

Given: Area = 308 000 km^2

Number of towns $=$ 216

Number of villages $=$ 41833

Total length of road $= \max \begin{cases} 4.74 \times (216 + 41833) = 199312.26 \text{ km} \\ \qquad\qquad\qquad \text{or} \\ \dfrac{82}{100} \times 308000 = 252560 \text{ km} \end{cases}$

$=$ 252560 km

$$\text{Length of NH (km)} = \frac{\text{Area (km}^2)}{50} = \frac{30800}{50} = 6160 \text{ km}$$

$$\text{Length of SH(km)} = \max \begin{cases} \dfrac{\text{Area (km}^2)}{25} = \dfrac{308000}{25} = 12320 \text{ km} \\ \qquad\qquad \text{or} \\ 62.5 \times 216 - 6160 = 7340 \text{ km} \end{cases}$$

$$= 12320 \text{ km}$$

$$\text{Length of MDR(km)} = \max \begin{cases} \dfrac{\text{Area (km}^2)}{12.5} = \dfrac{308000}{12.5} = 24640 \text{ km} \\ \qquad\qquad \text{or} \\ 90 \times 216 = 19400 \text{ km} \end{cases}$$

$$= 24640 \text{ km}$$

Primary Road: (NH + EH) $\rightarrow$ 6160 + 0 = 6160 km

Secondary Road: (SH + MDR) $\rightarrow$ 12320 + 24640 = 36960 km

Rural Road: (Total length) – (Primary + secondary) = 252560 – (6160 + 36960) = 209440 km

1.6   Road Patterns

The various road patterns may be classified as follows:

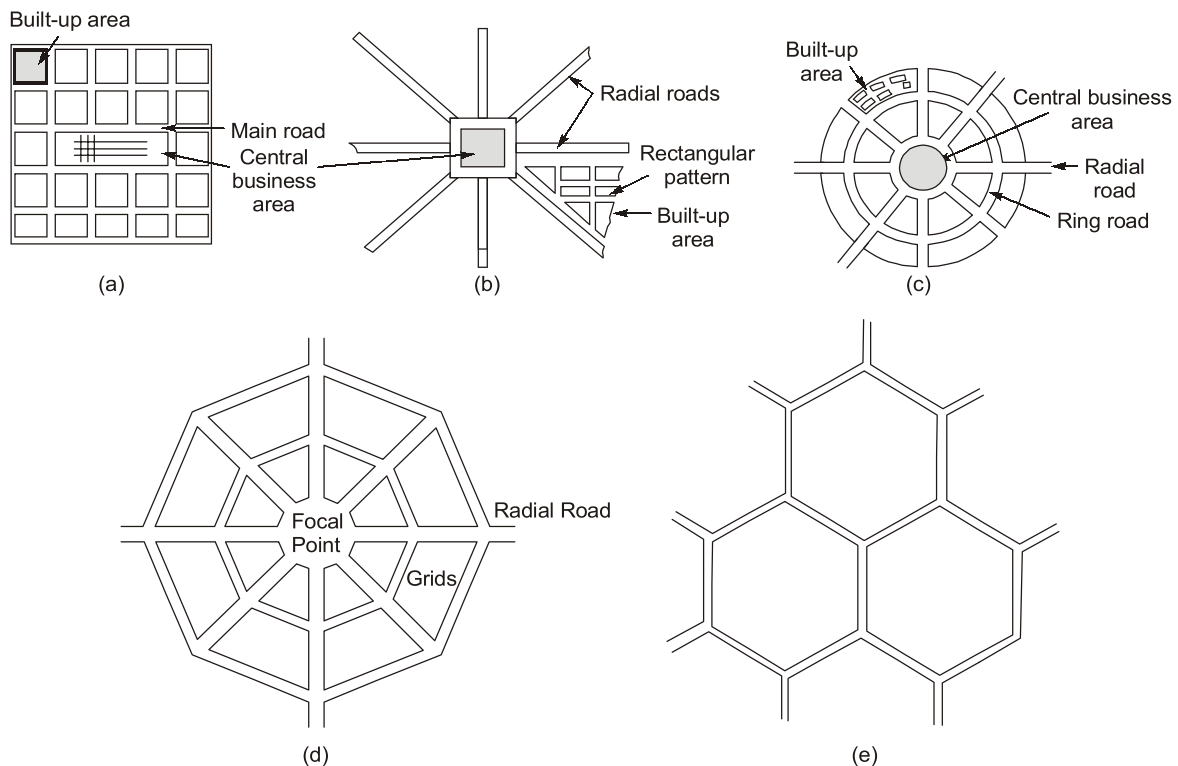(a)   (b)   (c)

(d)   (e)

***Figure*-1.5 : *Road Pattern :** (a) Rectangular or Block pattern (b) Radial or Star and Block pattern*
(c) Radial or Star and Circular pattern (d) Radial or star and Grid pattern and (e) Hexagonal pattern

- The rectangular pattern has been adopted in the city roads of Chandigarh. Radial and circular pattern is the road network of Cannaught place in New Delhi.

1.7   Engineering Survey for Highway Locations

Before highway alignment is finalized engineering survey are to be carried out in following stages.

(i)   **Map study:** Different alignment are drawn on map (contour, topographical and cadastral), crossing minimum number of obstruction and passing maximum utilization area.

(ii)   **Reconnaissance:** It is done by visiting at sites locations for detailing of features which are not available on map.

(iii)   **Preliminary survey:** Chain survey, traverse survey, levelling work and other various survey are done along with → soil investigation, traffic study, and drainage study.
* Survey alignment is finalized in the preliminary survey.

(iv)   **Detailed survey:** Planning, designing, material estimation, cost estimation are done along finalized alignment and a DPR is prepared.

1.8   National Highway Development Program (NHDP)

It consists the following program:

Before highway alignment is finalized engineering survey are to be carried out in following stages.

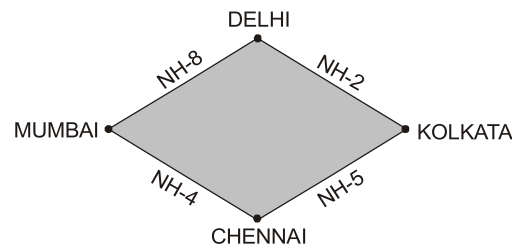(i)   Golden quadrilateral: (Delhi -Mumbai-Chennai-Kolkata)

Figure-1.6 (Golden quadrilateral)

Total length of highway in golden quadrilateral is approximately 4500 km.

(ii)   North-South and East-West corridor: Srinagar to Kanyakumari and slichar to Porbander
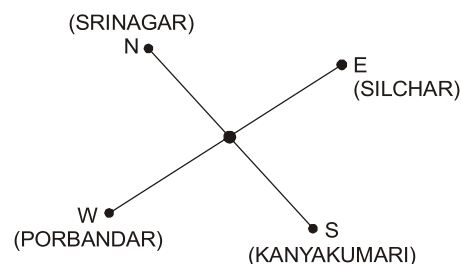
Figure-1.7

Total length of highway in N-S and E-W corridor is approximately 7250 km.

1.9   Concept of Saturation System and Maximum Utility System

This system is used to find optimum road length. It depends upon length of road, population and production.

Rules to provide utility value:

(i)   Provide utility value of 0.5 to lowest population range and increase it as multiple of 2 for next population range.

(ii)   Provide utility factor of 1 to production.

Example 1.2   Four new roads P, Q, R and S are planned in a district. The data for these roads are given below:

Table-1.1

Road Lines	Length (km)	Number of towns and villages served with population ranges				Total production in 1000 tonnes
		1001 - 2000	2001 - 5000	5001 - 10000	> 100000	
P	300	160	80	30	6	200
Q	400	200	90	60	8	270
R	500	240	110	70	1	315
S	500	248	112	73	1	355

Based on the principle of maximum utility, find out the order of priority for these four roads.

Solution:

$$\text{Utility per unit length for } P = \frac{160 \times 0.5 + 80 \times 1 + 30 \times 2 + 6 \times 4 + 200 \times 1}{300} = 1.48$$

$$\text{For } Q = \frac{200 \times 0.5 + 90 \times 1 + 60 \times 2 + 8 \times 4 + 200 \times 1}{400} = 1.53$$

$$\text{For } R = \frac{240 \times 0.5 + 110 \times 1 + 70 \times 2 + 1 \times 4 + 315 \times 1}{500} = 1.37$$

$$\text{For } S = \frac{248 \times 0.5 + 112 \times 1 + 73 \times 2 + 1 \times 4 + 355 \times 1}{500} = 1.482$$

Priority order: $Q > S > P > R$

STUDENT'S ASSIGNMENTS

Q.1 The star and grid pattern of road network was adopted in
(a) Nagpur road plan
(b) Lucknow road plan
(c) Bombay road plan
(d) Delhi road plan

Q.2 The construction of 'expressway' was planned for first time in _____.
(a) Jayakar Committee
(b) Bombay plan
(c) Nagpur road plan
(d) Lucknow plan

Q.3 Consider:
1. Creation of central road fund.
2. National Highway Act
3. Formation of Indian Road Congress
4. Creation of Highway Research Board
The correct chronological order of these events is_____
(a) 4, 3, 2, 1   (b) 2, 1, 3, 4
(c) 1, 3, 2, 4   (d) 2, 3, 1, 4

Q.4 The saturation system of development of optimum road length is based on
(a) Population only
(b) Population and agricultural productivity
(c) Agricultural and industrial productivity
(d) Population and productivity of both agricultural and industrial sectors.

Q.5 The new roads P, Q and R are planned in a district. The data for these roads are given below in the table. Based on the principle of maximum utility the order of priority for these three roads should be_____

Road	Length (km)	Number	of villages with	Population
		< 2000	2000 - 5000	> 5000
P	20	8	6	1
Q	28	19	8	4
R	12	7	5	2

(a) P, Q, R   (b) Q, R, P
(c) R, P, Q   (d) R, Q, P

Q.6 According to the recommendations of Nagpur conference the width formation of an ideal national highway in hard rock cutting is_____.
(a) 8.9 m   (b) 7.9 m
(c) 6.9 m   (d) 6.5 m
[SSC-JE: 2017]

Q.7 The length of national highway as per 3rd 20 years (Lucknow) road plan is given by
(a) Area of the country/75
(b) Area of the country/50
(c) Area of the country/40
(d) Area of the country/25

Q.8 The road foundation for modern highway construction was developed by
(a) Treseguet
(b) Telford
(c) Macadam
(d) Macadam and Telford Simultaneously

ANSWER KEY // STUDENT'S ASSIGNMENTS

1. (a)   **2.** (b)   **3.** (c)   **4.** (d)   **5.** (d)
6. (b)   **7.** (b)   **8.** (d)

HINTS & SOLUTIONS // STUDENT'S ASSIGNMENTS

5. **(d)**

Utility per unit length

For P = $\dfrac{8 \times 0.5 + 6 \times 1 + 1 \times 2}{20} = \dfrac{12}{20} = 0.6$

For Q = $\dfrac{19 \times 0.5 + 8 \times 1 + 4 \times 2}{28} = \dfrac{25.5}{28} = 0.91$

For R = $\dfrac{7 \times 0.5 + 5 \times 1 + 2 \times 2}{12} = 1.04$

$\therefore$ Priority order, $R > Q > P$

■■■■