UNIT I
HIGHWAY PLANNING AND ALIGNMENT

Significance of highway planning – Modal limitations towards sustainability - History of road development in India – Classification of highways – Locations and functions – Factors influencing highway alignment – Soil suitability analysis - Road ecology - Engineering surveys for alignment, objectives, conventional and modern methods.

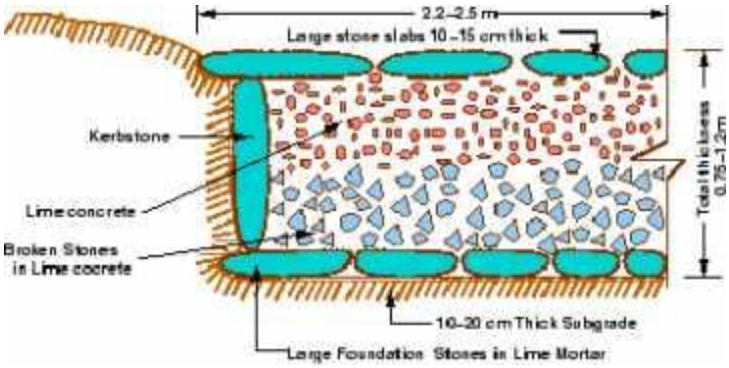
1.1 History of highway engineering

The history of highway enginnering gives us an idea about the roads of ancient times. Roads in Rome were constructed in a large scale and it radiated in many directions helping them in military operations. Thus they are considered to be pioneers in road construction. In this section we will see in detail about Ancient roads, Roman roads, British roads, French roads etc.

1.1.1 Ancient Roads

The first mode of transport was by foot. These human pathways would have been developed for specific purposes leading to camp sites, food, streams for drinking water etc. The next major mode of transport was the use of animals for transporting both men and materials. Since these loaded animals required more horizontal and vertical clearances than the walking man, track ways emerged. The invention of wheel in Mesopotamian civilization led to the development of animal drawn vehicles. Then it became necessary that the road surface should be capable of carrying greater loads. Thus roads with harder surfaces emerged. To provide adequate strength to carry the wheels, the new ways tended to follow the sunny drier side of a path. These have led to the development of foot-paths. After the invention of wheel, animal drawn vehicles were developed and the need for hard surface road emerged. Traces of such hard roads were obtained from various ancient civilization dated as old as 3500 BC. The earliest authentic record of road was found from Assyrian empire constructed about 1900 BC.

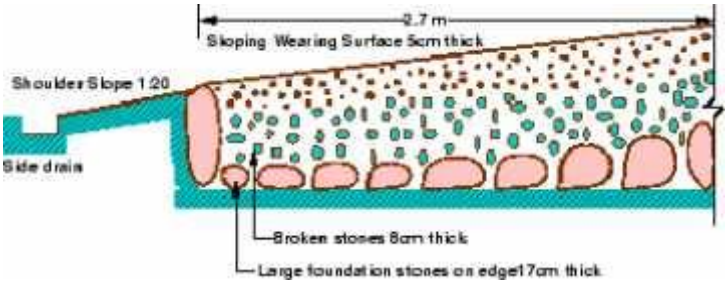
1.1.2 Roman roads



The earliest large scale road construction is attributed to Romans who constructed an extensive system of roads radiating in many directions from Rome. They were a remarkable achievement and provided travel times across Europe, Asia minor, and north Africa. Romans recognized that the fundamentals of good road construction were to provide good drainage, good material and good workmanship. Their roads were very durable, and some are still existing. Roman roads were always constructed on a firm -

formed subgrade strengthened where necessary with wooden piles. The roads were bordered on both sides by longitudinal drains. The next step was the construction of the *agger*. This was a raised formation up to a 1 meter high and 15 m wide and was constructed with materials excavated during the side drain construction. This was then topped with a sand leveling course. The agger contributed greatly to moisture control in the pavement. The pavement structure on the top of the agger varied greatly. In the case of heavy traffic, a surface course of large 250 mm thick hexagonal flag stones were provided. A typical cross section of roman road The main features of the Roman roads are that they were built straight regardless of gradient and used heavy foundation stones at the bottom. They mixed lime and volcanic puzzolana to make mortar and they added gravel to this mortar to make concrete. Thus concrete was a major Roman road making innovation.

1.1.3 French roads



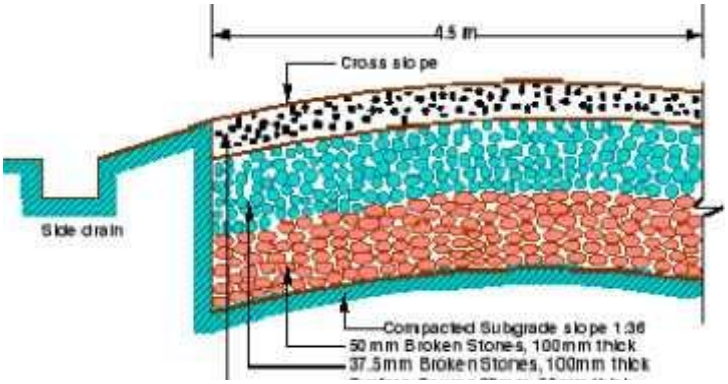
The next major development in the road construction occurred during the regime of Napoleon. The significant contributions were given by Tresaguet in 1764 and a typical cross section of this road. He developed a cheaper method of construction than the lavish and locally unsuccessful revival of Roman practice. The pavement used 200 mm pieces of quarried stone of a more compact form and shaped such that they had at least one flat side which was placed on a compact formation.

Smaller pieces of broken stones were then compacted into the spaces between larger stones to provide a level surface. Finally the running layer was made with a layer of 25 mm sized broken stone. All this structure was placed in a trench in order to keep the running surface level with the surrounding country side. This created major drainage problems which were counteracted by making the surface as impervious as possible, cambering the surface and providing deep side ditches.

He gave much importance for drainage. He also enunciated the necessity for continuous organized maintenance, instead of intermittent repairs if the roads were to be kept usable all times. For this he divided the roads between villages into sections of such length that an entire road could be covered by maintenance men living nearby.

1.1.4 British roads

The British government also gave importance to road construction. The British engineer John Macadam introduced what can be considered as the first scientific road construction method. Stone size was an important element of Macadam recipe. By empirical observation of many roads



, he came to realize that 250 mm layers of well compacted broken angular stone would provide the same strength and stiffness and a better running surface than an expensive pavement founded on large stone blocks. Thus he introduced an economical method of road construction.

The mechanical interlock between the individual stone pieces provided strength and stiffness to the course. But the inter particle friction abraded the sharp interlocking faces and partly destroy the effectiveness of the course. This effect was overcome by introducing good quality interstitial finer material to produce a well-graded mix. Such mixes also proved less permeable and easier to compact.

1.2 Bombay road congress:

The length of roads envisaged under the Nagpur plan was achieved by the end of it, but the road system was deficient in many respects. The changed economic, industrial and agricultural conditions in the country warranted a review of the Nagpur plan. Accordingly a 20-year plan was drafted by the Roads wing of Government of India, which is popularly known as the Bombay plan. The highlights of the plan were:

- It was the second 20 year road plan (1961-1981)
- The total road length targeted to construct was about 10 lakhs.
- Rural roads were given specific attention. Scientific methods of construction was proposed for the rural roads. The necessary technical advice to the Panchayaths should be given by State PWD's.
- They suggested that the length of the road should be increased so as to give a road density of 32kms/100 sq.km
- The construction of 1600 km of expressways was also then included in the plan.

+ Other District Roads + Village Roads

$$= \left[\frac{A}{4} + \frac{B}{8} + \frac{C}{12} + 48\,K + 24\,M + 11.2\,N + 9.6\,P + 12.8\,Q + 5.9\,R + 1.6\,S + 0.64\,T + 0.2\,V\right] \times \left(\frac{D + 100}{100}\right)$$

where

A = Developed and Agricultural Area, km^2

B = Semideveloped Area, km^2

C = Undeveloped Area, km^2

K = Number of towns with population over 1 lakh

M = Number of towns with population between 50000 to 1 lakh

N = Number of towns with population between 20,000 to 50,000

P = Number of towns with population between 10000 to 20000

Q = Number of towns with population between 5000 to 10000

R = Number of towns with population between 2000 to 5000

S = Number of settlements with population between 1000 to 2000

T = Number of settlements with population between 500 to 1000

V = Number of towns with population less than 500

D = Development allowance generally taken as 5 % for the 20 year draft plan period.

Road Way Length Targets

The road lengths for different categories of roads were fixed in miles since km as a unit was not in vogue in 1959. Converted to km these formulas were

(a) National Highway (km)

$$= \left[\frac{A}{64} + \frac{B}{80} + \frac{C}{96}\right] + 32\,K + 8\,M + D\left[\frac{A}{64} + \frac{B}{80} + \frac{C}{96} + 32\,K + 8\,M\right]$$

(b) National Highways + State Highways (km)

$$= \left[\frac{A}{20} + \frac{B}{24} + \frac{C}{32} + 48\,K + 24\,M + 11.2\,N + 1.6\,P\right] \times \left(\frac{100 + D}{100}\right)$$

(c) National Highways + State Highways + Major District Roads (km)

$$= \left[\frac{A}{8} + \frac{B}{16} + \frac{C}{24} + 48K + 24M + 11.2N + 9.5\,P + 6.4\,Q + 2.4R\right] \times \left(\frac{D + 100}{100}\right)$$

(d) National Highway + State Highways + Major District Roads + Other District Roads (km)

$$= \left[\frac{3A}{16} + \frac{3B}{32} + \frac{C}{16} + 48\,K + 24\,M + 11.2\,N + 9.6\,P + 12.8\,Q + 4\,R + 0.8\,S + 0.32\,T\right] \times \left(\frac{D + 100}{100}\right)$$

(e) National Highways - State Highways + Major District Roads

1.3 Road development Plans.

Road Development Plans : Planning forms the forerunner to any development activity. The Congress has been closely associated with road planning in the country ever since the famous Nagpur Plan formulated in the year 1943 which heralded the advent of systematic planning and development of roads in the country on an all India basis. The IRC also had an active role to play in the finalisation of subsequent 20 Year Road Development Plan (1961-81). The latest Road Development Plan 1981-2001, published by the IRC in 1984 provides the general framework for current long term road development keeping in view the need for connecting all villages with a road by the year 2001 as far as possible. It also covers various measures to conserve energy, to preserve the environment and to improve safety on our highways.

Standards : Adoption of standardised practices in design, construction and maintenance with due regard to variabilities in terrain, soil and climate, is imperative for efficient and economical development of highway facilities. On this front, the Congress has made valuable contributions to the profession in preparing Standards, Specifications, Codes of Practice and Manuals on different aspects of roads, bridges and traffic engineering. These include survey and investigations, design of various components of roads and bridges under different situations, standard construction practices, quality control, landscaping and environmental protection. These standards are widely circulated and invariably adopted by all highway authorities in the country. These are also in demand in a number of countries abroad.

Rural Roads : Ever since its inception in 1934 the Indian Roads Congress has shown active concern for the development of rural roads in India. From the very beginning it realised the importance of rural roads in the socio-economic development of an agrarian based country such as ours. In the first Road Development Plan known as the "Nagpur Plan", subsequent Road Plan for 1961 – 81 and the new Road Development Plan for India (1981-2001) due emphasis was laid on the development and expansion of the rural road network.

In 1958 the IRC set up a Committee which was then called the "Community Project Road Maintenance Committee". The aim of the Committee was to recommend measures for proper and adequate maintenance of roads constructed in rural areas. In 1969, the Council of the IRC decided to change the name and ambit of the Committee. It was renamed as the "Rural Roads Committee", and entrusted with the task of bringing out a comprehensive report dealing with planning, specifications, financing, construction and maintenance of all rural roads. The Committee has done commendable work. On its recommendation and under its guidance, the IRC organised four Workshops on Rural Road Development, the First at Gandhinagar (Gujarat) in February, 1981, the Second at Nainital (Uttar Pradesh) in July, 1981, the Third at Ranchi (Bihar) in May, 1982 and the Fourth at Hyderabad (Andhra Pradesh) in November, 1982. The objectives of the Workshops were to identify problems faced, pool the information on methodologies adopted in various regions and disseminate the information at the national level. As a consequence of the deliberations at these Workshops, a

Special Report No. 26 has been brought out which gives detailed recommendations on (i) Planning and investment criteria and organisational aspects, (ii) Pavement aspects and low cost water crossings, (iii) Construction techniques and (iv) Maintenance of rural roads. For better understanding and easier application of the recommendations, supplementary notes on different aspects have also been published.

The Seventh Five Year Plan (1985-90) envisaged that all villages with a population of 1500 and above and 50 per cent of the villages with population between 1000-1500 would be linked by all-weather roads by 1990. For hilly, tribal, coastal and desert areas, the population sizes of villages to be covered are lower. About 41000 villages would be covered under the Plan. However, one of the difficulties in planning of rural highways is the absence of viable criteria to plan and prioritise rural road networks on the basis of parameters such as population, length of roads, unit cost of construction and economic returns. To fill up this void the Rural Roads Committee of the IRC was requested to deliberate and give its recommendations on the socio-economic aspects of rural road development. In the first phase, an analysis was done of the economic data collected in 1972-73 by the Ministry of Agriculture from 20 blocks spread all over the country. The findings of this study was used as inputs for designing the second phase of the study. Accordingly, detailed studies were carried out in 9 districts in various parts of the country covering both pre-investment and post-investment stages. These studies included, inter-alia, (i) socio-economic effects of roads singly and in combination with other inputs at post-investment stages, (ii) collection of pre-investment data and preparation of road development plan for the district based on the evolved criteria and methodology. The result of these studies threw up many important findings which would go a long way in developing new methodologies for planning of investment in rural roads.

A Panel Discussion was also organised in Bhopal at the time of Annual Session in February, 1986 to review the results from the World Bank Studies on Substitution of Labour. Organising an International Seminar in association with the International Labour Office on 'Rural Transportation' in New Delhi from the 26th to 28th April, 1989, is yet another milestone which also signifies the importance being attached by the IRC to the cause of road development.

Hill Roads : India has a long history of construction of hill roads spanning over a hundred years, but the experience gained has not been well documented. The expansion of road network in hill areas has been receiving increasing attention in recent times for serving the remote villages and for the socio-economic betterment of these areas. However, it is essential to ensure that the construction of these roads does not unduly upset the fragile eco-system of the hills which is already under severe attack due to deforestation, pressure of population and other factors. Keeping in view the importance of the subject, the Indian roads 'Congress organised a Seminar on Construction of Roads in Hill Areas at Nainital in July, 1985. This Seminar evoked very good response. Based on the discussions and recommendations of the Seminar, a comprehensive Manual on design, construction and maintenance of hill roads will soon be brought out.

1.4 Five Year Plans

After independance, we declared ourselves as socialistic sovereign, state with more or less mixed economy. Systematic planning in public sector and directional planning in private sector started and therefore it is worth while to watch the progress in highways planwise.

1.9.1 Pre-plan Period (1943 – 1951)

During the pre-plan period of 1943 – 1951, the Nagpur plan was already there as a model for road development. However, due to partition of our country, there was paucity of fund and Nagpur plan expectations could not be fulfilled.

1.9.2 First Five Year Plan Period (1951 – 1956)

In this particular plan period, 6.7 % of the total plan expenditure was incurred on roads and this expenditure was about 30.2 per cent of the expenditure on the transport sector. The salient features of road development in the first five year plan could be summarised below.

National Highways : Through the National Highway Act, the national highways became the central subject and the Central Government statutorily took them over. The missing links on N. H. system to the tune of 2000 km were constructed. About 30 major bridges and improvements to nearly 10,000 km of national highway was taken up. Expenditure to the tune of about Rs. 27 crores was incurred. Some important inter-state reads such as Passi - Badarpur Road in Asam, Assam - Agartala Road connecting Assam with Tripura were taken up. The state sector roads also increased in length. The total road length increased from 399940 km to about 498340 km registering an increase of 25 %.

1.9.3 Second Five Year Plan

About 4.8 % of the total plan expenditure and 20 % of the total transport sector expenditure was incurred on roads. The Central Government sponsored Dhar-Udampur Road and construction of west coast road (Bombay - Kanyakumari Road) which was taken during the first plan was continued. About 40 major bridges were constructed. In line with the activities of the Central Government, the State Governments also formulated different schemes and completed them. As a result, there was an increase in road length from 498340 km to 7012120 km. i.e. about 42 % increase. Thirty three per cent of the roads by this time were surfaced roads.

1.9.4 Third Five Year Plan Period (1961 – 1966)

The Bombay road plan served as a frame work for the third fourth and fifth five year plans. In fact this plan saw tremendous growth in highway construction activity. The significant developments that took place in this plan period.

(1) There was the most important and eye opening event of the epoc that is the Chinese external aggression. As a result of this aggression, Border Road Development Board was created under Transport Ministry to deal with problems concerning these roads. Most of these roads were hill roads or desert roads and as such development of hill roads got a boost.

(2) The system of National Highways was strengthened. Sixty six major bridges were constructed on the national highway system, which included Mahanadi Bridge at Cuttack and Sone Bridge in Bihar.

(3) In this particular period, there was a bottleneck in the coal transportation and the planners realised the shortcoming of railways as a means of communications. Therefore, they started looking towards road work as a means to transport coal, since coal as a source of energy is very important.

(4) In general, there was some shift from labour intensive road construction to somewhat mechanised road construction.

(5) Under the central aided scheme, the lateral road project on the foot - hills of Himalayas from Uttarpradesh to Assam was sanctioned and taken up for construction while the work on West Coast Road already started continued.

(6) In this plan period, Government of India received credit from the World Bank for construction of selected national highway. An expenditure of about Rs. 440 crores was incurred in this plan period which constituted 22 % of the expenditure on transport sector and 6 % of the overall plan expenditure. The total road length registered a rise of 49 % over the length at the end of the second plan.

1.9.5 The Fourth Plan Period (1969 – 1974)

In between 1966 - 1969, there was plan holiday and the actual fourth plan commenced in 1969. The salient achievements of this plan were as follows.

(1) In June, 1971, certain new additions to the highway system were done. These were (a) Highway No. NH 44 - connecting Shillong, Passi, Badarpur and Agartala, (b) NH 21 Highway connecting Bilaspur, Kulu and Mandi with Chandigarh, (c) Highway NH 5A connecting Pardeep port to NH 5 at Haridaspur and (d) NH 4 A connecting Belgaum, Phonda and Panaji.

(2) One important happening in this period was that the Government set up one - man commission with Mr. H. P. Sinha as chairman to study the condition and possible development of rural roads. This happened in 1967 and the report got published in 1968 just before the plan period. The recommendations of the committee were.

(a) High-level rural board should be set up in each state for planning and allocation of funds for the rural roads and these should be a post of chief engineer in the state to look after these roads. This recommendation was not followed.

(b) It also envisaged that at least third of the rural road construction cost should come from the beneficiaries. In fact the committee made the proposal that if the third road cost is deposited by the people concerned, the state should come forward to spend the rest 2/3 and construct the road.

(c) The chairman Mr. Sinha favoured a total length of at least 324000 km of village roads and 230,400 km of other district road. Of course the implication of the findings of the committee were felt in fifth plan period.

near Cochin. (e) NH 15. National Highway connecting Pathankot Bhatinda Ganganagar, Bikaner Jaisalmer, Barmer, and Sama Khiali on NH 8 nea Kandla. (f) NH 8 C National Highway connecting Ghandhinagar in Gujarat with NH 8 and NH 8 A, (g) NH 7 A - National Highway connecting Palayamkottai with Tutikorin and (h) NH 1 B - National Highway connecting Batote with Doda and Kishtwar.

(2) As a part of Minimum Needs Programme (M.N.P.) it was proposed to construct all weather rods so that the villages with a population of more than 1500 are interconnected. This was not totally achieved.

(3) Expenditure in this plan period including the plan period 1979 - 1980 was around 31 % of the total transport sector and the road length increased from 1393930 km to about 1534200 km. This expenditure includes the cost that went for conversion of single lane widths to two lane wicths for certain National Highways.

1.9.6 The Fifth Plan Period (1974 – 1979)

The significant achievements of this plan period were

(1) The additions to National Highway network namely (a) NH 48 National Highway connecting Nalmangala near Bangalore with Hasan and Mangalore, (b) NH 23 connecting Chas, Ranchi, Rourkela, Talcher, and terminating on NH 42, (c) NH 17 A connecting MarmuGao Port with NH 17, (d) NH 17. National Highway connecting Panvel on NH 4 to Mahad, Panaji Karwar, Mangalore, Caunanore, Calicut and Edapalli

near Cochin. (e) NH 15. National Highway connecting Pathankot Bhatinda Ganganagar, Bikaner Jaisalmer, Barmer, and Sama Khiali on NH 8 nea Kandla. (f) NH 8 C National Highway connecting Ghandhinagar in Gujarat with NH 8 and NH 8 A, (g) NH 7 A - National Highway connecting Palayamkottai with Tutikorin and (h) NH 1 B - National Highway connecting Batote with Doda and Kishtwar.

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1.9.7 The Sixth Five Year Plan 1980 – 1985

Sixth Five Year Plan is characterised by the following achievements :

(1) Many highways to the tune 2500 km were constructed in the strategic North Eastern Zone.

(2) The minimum needs programme of the sixth plan was reinforced.

(3) In general, this plan could be said to be stock checking plan, the deficiencies in the previous plans were made up, missing links provided, certain inter - state roads of economic importance and border roads were constructed. The sixth plan contained a provision of 3440 crores representing around 29 % of the outlay in the transport sector and around 3.5 % outlay in the total plan.

(4) The system of National Highway was strengthened. The expenditure that is to be in curred on National Highways in this plan as a comparison to other previous plans is indicated in the table 1.2.

(5) For the first time, provision of new generation of roads along high density corridors with divided carriageway facilities were proposed.

(6) The seventh plan makes an outlay of Rs. 892 crores for National Highways and Rs. 128 for other centrally sponsored schemes and Rs. 4180 crores for the state sector roads.

1.9.8 The Seventh Plan (1985 – 1990)

The main objectives and the achievements of this plan are -

(1) Proposal to construct expressways i.e. Ahmedabad - Vadodara and Kolkata - Durgapur. These will be first expressways of the country.

(2) Continued rural road activity so that the minimum needs programme is completed. These rural roads will be constructed if required under Employment Gurantee Scheme or Rural Landless Employment Gurantee Programme (NLEGRP) or National Rural Employment Programme (NREP). Presently out of nearly 6,00,000 villages, about 2,60,000 villages only are connected by all-weather roads. The level of accessibility in respect of villages of 1500 population or above is 86 % and that of 1000 - 1500 is 63%.

(3) No National Highways as such were proposed and most of the expenditure went in consolidating the gains.

(4) The system of National Highway was strengthened. The expenditure that is to be in curred on National Highways in this plan as a comparison to other previous plans is indicated in the table 1.2.

(5) For the first time, provision of new generation of roads along high density corridors with divided carriageway facilities were proposed.

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1.9.9 Eighth Five Year Plan Roads (1990 - 1995)

General

Along with other modes like railways, waterways and air services, roads provide the basic infrastructure for transportation of goods and passengers. Roads cater to all types of traffic; the long distance traffic is served by National highways and State highways, inter district and intra district traffic by major district roads, feeder traffic connecting rural centres of production to market outlets by other district roads and local traffic by village roads and urban roads.

Thrust Areas and Strategy for the Eighth Plan

- The existing deficiencies in national highways (NH) would require construction of missing links, four laning and two laning of various sections, construction of bridges and by-passes etc. The first priority will be given to complete the ongoing works. For systematic development of the NH system, different strategies will need to be adopted for low, medium and high volume traffic density routes. Capacity augmentation of high density traffic corridors carrying more than 15,000 passenger car units traffic per day, through four laning will need to be taken up during the Eighth Plan. For selected high density corridors, it may be necessary to consider expressway facility for rapid and safe movement of fast traffic. Levy of tolls may be considered for highway users. For national highways carrying medium traffic density, traffic upto 15000 PCUs, strengthening of pavement and widening to two-lanes including reconstruction of bridges, wherever necessary, need to be taken up. For low traffic density routes carrying traffic upto 5,000 PCUs, widening to two-lanes may be considered only on a selective basis, depending upon the resource availability. However, weak and narrow bridges have to be replaced.
- As regards additions to the National Highways system, it would be necessary to adopt a very selective approach in view of the resource constraints and the need to give priority to removal of deficiencies on the existing NH-system
- Constraints of resources may not permit removal of all the existing deficiencies in the State highways during the Plan period and a selective approach based on economic cost benefit analysis may have to be adopted. Consolidating the existing network should receive high priority. It would be necessary to widen and strengthen the pavement

structure to minimize vehicle operating costs and maintenance expenditure. A number of bridges would be required to be constructed/ reconstructed. Special attention has to be given to those State Highways which would require to be upgraded to National Highway in the future on the basis of traffic densities and growth it is essential that the State Governments make arrangements to prepare suitable road and bridge inventories covering the existing physical status and structural condition of the main network comprising the State Highways and major district roads and then update them at regular periodic intervals. Regular traffic counts on these roads would be necessary in order to decide on the inter-se priority of development of various sections.

- Rural roads are essential for achieving the objective of integrated rural development. The priority for rural road development in the Eighth Plan would be as under :-
  (a) Linking of all villages with a population of 1000 and above on the basis of 1981 census.
  (b) Special efforts to accelerate village connectivity in respect of backward regions and tribal areas.
- It would be appropriate to integrate rural road construction and maintenance under Minimum Needs Programme (MNP) with local area development planning. State Governments may pool the resources, made available under MNP and special employment programmes and undertake rural road construction under the respective local area development plan.

1.9.10 Ninth Five Year Plan (1995 - 2000)

The following goals and objectives have been kept in view while framing the outline of the Ninth Plan :

(a) Phased removal of deficiencies in the existing NH network in the tune with traffic needs for 10-15 years with emphasis on high density corridors for four-laning.
(b) Bring in highway-user oriented project planning in identifying package of projects section-wise rather than isolated stretches.
(c) Greater attention to rehabilitation and reconstruction of weak/dilapidated bridges for the safety of the traffic.
(d) Modernization of road construction technology for speedy execution and quality assurance.
(e) Engineering measures to improve road safety and conservation of energy.
(f) Continued emphasis on research and development
(g) Integrating the development plans with Railways and other modes of transport.
(h) Providing employment opportunities to the labour force in rural areas.
(i) Special attention for development of roads in the North-Eastern Region.
(j) Encouraging private sector participation in development of roads.

1.9.11 Tenth Five Year Plan (2001-05)

The following broad goals end objectives for road sector development have been set for the Tenth Plan :

1. Balanced development of the total road network comprising three functional groups viz. the primary system (National Highways (NH) and expressways), secondary system (State Highways and Major District Roads) and rural roads.
2. Development of roads to be considered an integral part of the total transport system supplementing other modes, integrating the development plans with railways and other modes of transport.
3. Completion of the National Highways Development Project comprising the Golden Quadrilateral and the North-South and East-West corridors.
4. Phased removal of deficiencies in the existing NH network in tune with traffic for the next 10-15 years with emphasis on four-laning of high-density corridors.
5. To plan and take preliminary action for expressways to be built in future in those sections where these can be economically justified.
6. To make long distance travel safer and faster so as to give a boost to the economy.
7. Priority is to be accorded to areas like overloading of trucks, control of encroachments and unplanned ribbon development, energy conservation and environment protection.
8. Greater attention to be paid to rehabilitation and reconstruction of weak/dilapidated bridges for traffic safety.
9. Special attention is to be paid to the development of roads in the North-Eastern region.
10. Particular emphasis needs to be given to the commercialisation of highways particularly the National Highways and State Highways and bringing in the concept of user-charges for sustainable financing of the road sector. Further steps must also be taken to encourage private sector participation in the highway sector. It is necessary to implement the policy of levying toll on all four-lane roads on the National Highway network. States must adopt a similar strategy in respect of State Highways etc.
11. High-density corridors within the network of National and State Highways and Major District Roads should be identified. Such corridors and major inter-state roads should be developed on a priority basis.
12. To improve the quality of life in rural areas and ensure balanced regional development by achieving the PMGSY target of providing connectivity through all-weather roads to all habitations with a population of over 500 persons (as per the 2001 Census).
13. To encourage industry and export by providing sufficiently wide roads leading to industrial centres, ports, mining areas and power plants.
14. To encourage tourism by improving roads leading to centres of tourist importance.
15. To provide wayside amenities along highways.

16. To reduce transportation costs by providing better riding surface and popularising the use of containers and multi-axle vehicles in the haulage of goods.
17. Utmost attention to the proper upkeep and maintenance of the existing road network.
18. To ensure road connectivity where rail link is not available or possible.
19. Integrating the development plan with railways and other modes of transport and to :
    (a) Identify feeder roads to important railway routes and undertake needed improvement including periodic maintenance;
    (b) link minor important ports with minimum two-lane NHs/SHs;
    (c) link all Inland Container Depots/container freight stations with minimum two-lane NHs/SHs.
20. Use of modern management techniques for scientific assessment of maintenance strategies/priorities.
21. Development of a road data bank and computerised project monitoring system and promotion of the use of information technology in the highway sector.

1.9.12 An approach to Eleventh Five Year Plan (2007-2012)

1. The Tenth Plan stressed the need for improving mobility and easy accessibility. Accordingly, the National Highway Development Programme (NHDP) consisting of four laning of the Golden Quadrilateral (NHDP I) with a length of 5,846 km and the North-South and East-West Corridor (NHDP II) with a length of 7472 km coupled with Pradhan Mantri Gram Sadak Yojana (PMGSY) for rural roads were taken up. The PMGSY programme has been recently expanded to achieve the Bharat Nigam target of connecting 1000 + habitation (500 + for hilly and tribal areas) by 2008-09 with all-weather roads. This programme will help bring India's villages into the market economy. It will also help us to tackle social sector problems like illiteracy, high IMR and MMR) which are dragging India down because while roads connect villages to markets, they also connect them to schools and hospitals. The "Special Accelerated Development Road Programme for the North Eastern Region (SARDP-NE)", will help in developing and integrating these regions with the rest of the country.

2. The problems of development of our roads network are diverse and future requirements are formidable magnitude. Therefore, the strategy for development of roads would would have to vary keeping in view the nature of problem and the development required. It is proposed to undertake an expanded programme for highway development going beyond NHDP I and II to include NHDP III to VII. This programme will involve substantial resources from public private partnership based on build, operate and transfer (BOT) model which has many advantages over the

traditional contracts (See *Box* on PPPs). All contracts on provision of road services for high density corridors to be taken up under NHDP III onwards would be awarded only on BOT basis, and the traditional construction contracts will be awarded only in specified exceptional cases. A model concession agreement has been developed to facilitate speedy award of contracts. This is a very significant innovation in the areas of public-private partnership. This would leave a substantial part of National Highways network which would also require development during the Eleventh Plan period. These sections are characterised by low density of traffic. Some of these stretches fall in backward and inaccessible areas and others are of strategic importance. The development of these categories of National Highways would be carried out primarily through budgetary resources.

3. The present traffic mix consisting of non-motorised and low-powered vehicles compels low speed Furthermore, most of the National Highways pass through habitations and ribbon development is a perennial problem. It is, therefore, necessary to establish a network of access controlled Expressways across the country for which advance planning would be undertaken during the Eleventh Plan. The actual construction (except for 1000 kms already taken up) would be undertaken during the Twelth Plan period and would be prioritised according to the density of traffic.

4. Vehicular traffic needs more than just the arterial routes to be of world class. Adequate attention has not been given in the past to other roadways, which are the responsibility of the state governments. Priority would be accorded for ensuring integrated development of road networks including State Highways, Major District Roads and Other District Roads. The increased emphasis on rural roads would also continue and a major proportion of the 1.72 lakh unconnected habitations would be connected with all weather roads under the PMGSY.

5. The maintenance of roads has not been given adequate importance by the states mainly due to paucity of resources. This has resulted in poor riding quality of the road network which is highly uneconomic. A rupee spend on maintenance saves two to three rupees in vehicle operating costs, besides improving traffic flow. Therefore, there is a need to accord higher priority to the needs of maintenance by providing more allocation or considering it as a part of Plan. In fact, the 12th Finance Commission has recommended additional grants to the States, to the tune of Rs. 15,000 crore for maintenance of roads and bridges for the four-year period 2006-07 to 2009-10.

6. The National Highway Authority of India (NHAI) has an enormous task before it to implement a road programme. The Authority is being restructured to give it greater professional skills combined with a measure of autonomy and accountability.

7. Indian roads are considered very accident prone and claim a large number of casualties representing an enormous human and economic loss. This problem is compounded by the phenomenal growth in road transport fleet, particularly personalized vehicles and the consequent problems of increase in vehicular pollution and road safety. Steps need to be taken to improve the public transport system and safety of road transport operations.

1.5 Classifications of roads

2.1.1 Classification Based on the Weather Condition

The different types of road are classified into two categories, depending on whether they can be used during different seasons of the year.

1. All-weather roads
2. Fair-weather roads

All-weather roads : All-weather roads are those which are negotiable during weather, except at major river crossing where interruption to traffic is permissible upto a certain extent, the road pavement should be negotiable during all weathers.

Fair-weather roads : Roads which are called fair-weather roads on these, the traffic may be interrupted during monsoon season at causeways where stream may overflow across the road.

2.1.2 Classification Based on the Road Pavement

Based on road pavement, roads are classified as paved roads and unpaved roads.

1. Paved road
2. Unpaved road

Pavement roads : If they are provided with a hard pavement course which should be at least water bound macadam (WBM) layer.

Unpaved roads : If they are not provided with a hard pavement course of at least a WBM layer. Thus, earth road and gravel road may be called unpaved roads.

2.1.3 Classification Based on the Pavement Surfacing

Based on the type of pavement surfacing providing, the roads are divided into two categories as :

1. Surfaced road
2. Unsurfaced road

Surfaced Roads : Surface roads which are provided with a bituminous or cement concrete surfacing.

Unsurfaced Roads : Unsurfaced roads which are not provided with bituminous or cement concreting.

2.1.4 Classification Based on the Road Plan

- **Classification of Rural Roads** : (I.R.C-1980)

The road plan classified the roads in India based on location and function into following categories.

1. Expressways
2. National Highways (NH)
3. State Highways (SH)
4. Major District Roads (MDR)
5. Other District Roads (ODR)
6. Village Roads (VR)

Expressways : Expressways are a separate class of highways with superior facilities and design standards and are meant as through routes having very high volume of traffic. The expressways are to be provided with divided carriageways, controlled, grade separations at cross roads and fencing. These highways should permit only fast moving vehicles. Expressways may be owned by Central Government or a State Government, depending on whether the route is a National Highway or State Highway. Example : Mumbai-Pune Expressway.

National Highways (NH) : National highways are highways running through the length and breadth of India, connecting major ports, foreign highways, capital of large states and large industrial and tourist centres including roads required for strategic movements for the defence of India. Example NH-1 Delhi-Ambala-Amritsar, NH-50 Nasik-Pune.

State Highways (SH) : State highways are arterial roads of a state, connecting up with the national highways of the adjacent states, district head quarters and important cities within the state and serving as the main arteries for traffic to and from district roads. The NH and SH have the same design speed and geometric design specifications. Examples :

SH-61 Belha Pabal Shikrapur Astapur Road

SH-70 Mahad-Pandharpur Road.

Major District Roads (MDR) : Major district roads are important roads within a district serving areas of production and markets and connecting those with each other or with the main highways of a district. The MDR has lower speed and geometric design specifications than NH / SH. Example, MDR-2 Kendur Dhamani Hirare Ranjangaon Road.

Other District Roads (ODR) : Other district roads are roads serving rural areas of production and providing them with outlet to market centres, taluka head quarters, block development head quarters or other main roads. These are of lower design specifications than MDR.

Village Roads (VR) : Village roads are roads connecting village or groups of villages with each other to the nearest road of a higher category. Example.

VR-183-Hiware-Jategaon Road

2.1.5 Classification of Urban Roads (I.R.C. - 1977)

The road systems within urban areas are classified as Urban Roads and will form a separate category of roads to be taken care by the respective urban authorities. They are divided into following types.

1. Arterial roads
2. Sub-arterial roads
3. Collector streets and
4. Local streets

Arterial Roads : The city roads which are meant for through traffic usually on a continuous route are called arterial streets. Arterial streets are generally spaced at less than 15 km in developed business centres whereas in less important areas, these may be 8 km apart. Arterial roads are also divided highways with fully or partially controlled access. Parking, loading and unloading activities are carefully regulated. Pedestrians are permitted to cross them at intersections only.

Sub-Arterial roads : The city roads which provide lower level of travel mobility than arterial streets are called as sub-arterial streets. Their spacing may vary from 0.5 km in central business districts to 3 to 5 km in sub-urban areas. Loading and unloading are usually restricted. Pedestrians are allowed to cross these highways at intersections.

Collector Streets : The city roads which are constructed for collecting and distributing the traffic to and from local streets, and also to provide an access to arterial and sub-arterial streets, are also called collector streets. These are located in residential, business and industrial areas. These roads are accessible from the building along them. Parking restrictions are few that too during peak hours.

Local Streets : The city roads which provide an access to residence, business and other building are called local streets. The traffic carried either originates or terminates along the local streets. Depending upon the importance of the adjoining areas, a local street may be residential, commercial or industrial. Along local streets, pedestrians may move freely and parking may be permitted without any restriction.

1.6 Road patterns

The road network can be laid in various patterns. These patterns can vary. The patterns in which the road network is laid could be (1) Rectangular or block pattern, (2) Radial or star and block pattern, (3) Radial or star and circular pattern, (4) Radial or star and grid pattern, (5) Hexagonal pattern, (6) Minimum travel pattern. These patterns are illustrated in the next subarticles. The Nagpur road plan formulae were prepared on the assumption of star and grid pattern. Connaught place in New Delhi has radial and circular pattern, whereas Chandigarh has rectangular or block pattern. If the city is being planned from scratch, some pattern can be given. In most of our cities, some of the pattern is already existing and one has to go with them.

Rectangular or Block Pattern : In this pattern, the whole area is divided into rectangular blocks of plots, with streets intersecting at right angles. The main road which passes through the centre of the area should be sufficiently wide and other branch roads may be comparatively narrow. The main road is provided a direct approach to outside the city.

The rectangular plots may be further divided into small rectangular blocks for construction of buildings placed back to back, having roads on their front. The rectangular pattern has been adopted for the city roads of Chandigarh. The construction and maintenance of roads of this pattern is comparatively easier but from traffic point of view, this pattern is not very much convenient because at the intersections, the vehicles face each other.

Radial or Star and Block Pattern : In this pattern, the entire area is divided into a network of roads radiating from the business outwardly. In between radiating main roads, the built-up area may be planned with rectangular blocks.

Radial or Star and Circular Pattern : In this system, the main radial roads radiating from the central business area are connected together with concentric roads. In these areas, boundary by adjacent radial roads and corresponding circular roads, the built-up area is planned with a curved block system. An example of this road pattern is the road network of co naught place in New Delhi.

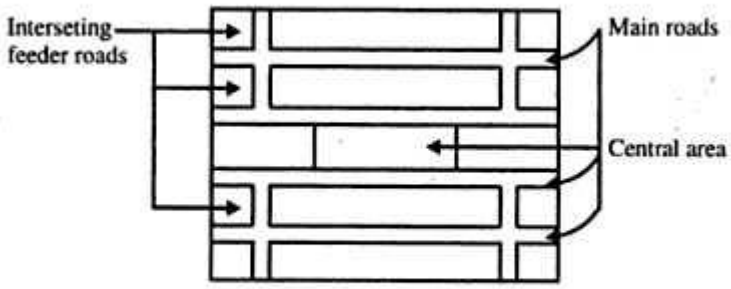


Fig. 2.1 : Rectangular or block pattern

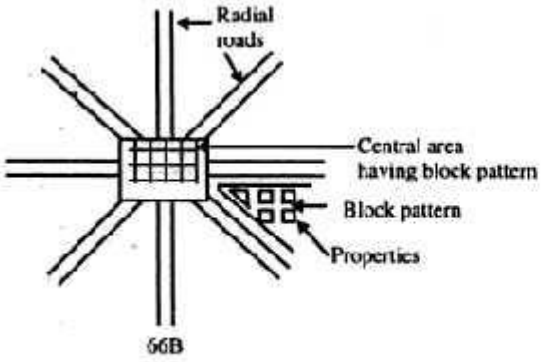


Fig. 2.2 : Radial or star and block pattern

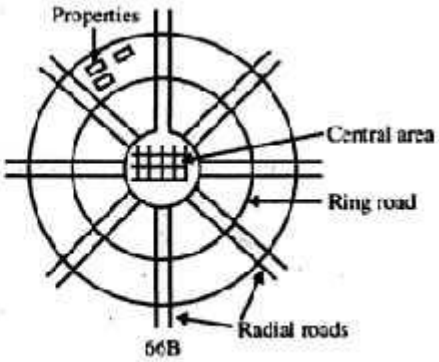


Fig. 2.3 : Radial or star and circular pattern

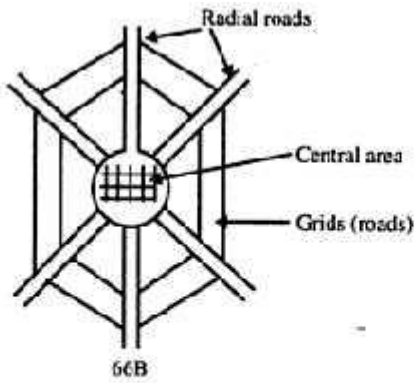
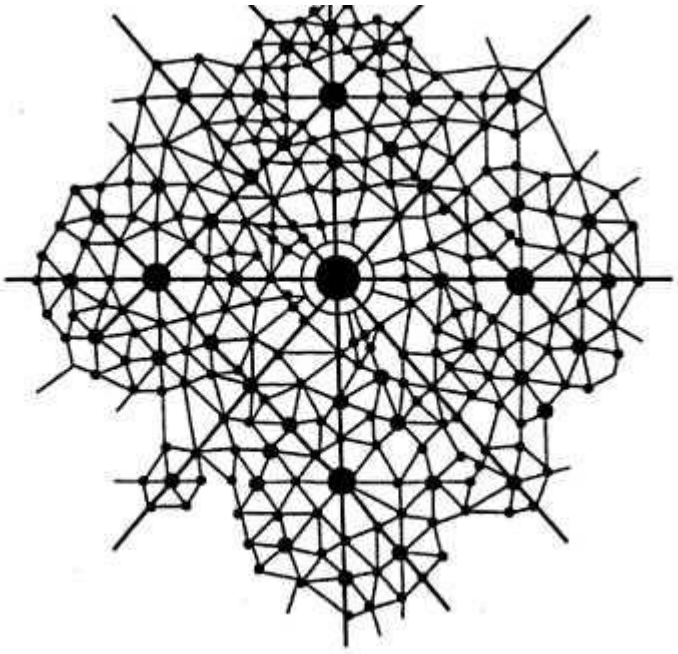


Fig. 2.4 : Radial or star and grid pattern

Fig. 2.5 : Hexagonal pattern

Hexagonal Pattern : In this pattern, the entire area is provided with a network of roads forming hexagonal figures. At each corner of the hexagon, three roads meet The built-up area bounded by the sides of the hexagons is further divided in suitable sizes.



Minimum Travel Pattern : In this road pattern, city (city centre) is contented by sector centres, suburban centres and neighbourhood centres by the road which required minimum to connect the city centre.

1.7 Camber

Camber or cant is the cross slope provided to raise middle of the road surface in the transverse direction to drain of rain water from road surface. The objectives of providing camber are:

_ Surface protection especially for gravel and bituminous roads
_ Sub-grade protection by proper drainage
_ Quick drying of pavement which in turn increases safety

Too steep slope is undesirable for it will erode the surface. Camber is measured in 1 in n or n% (Eg. 1 in 50 or 2%) and the value depends on the type of pavement surface. The values suggested by IRC for various categories of pavement is given in Table .

1.7.1 Types of cambers.

The common types of camber are parabolic, straight, or combination of them

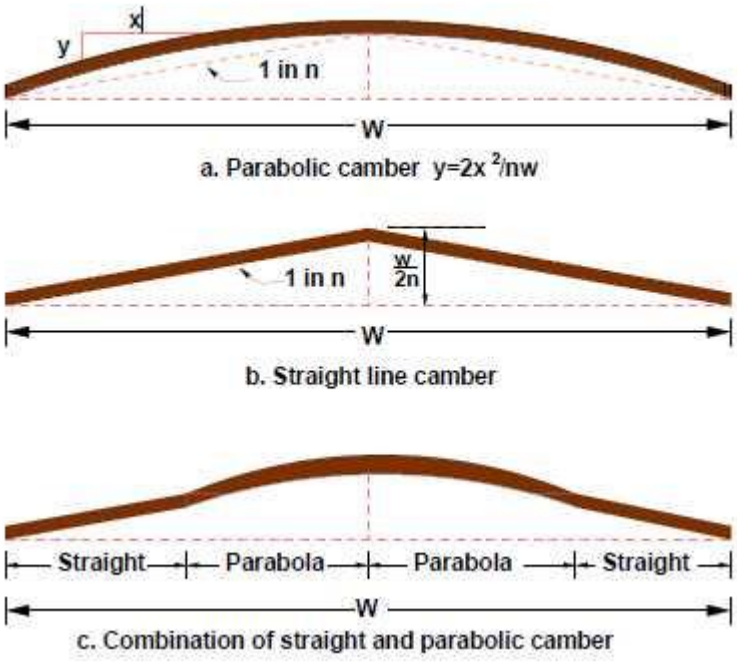


Table 12:1: IRC Values for camber

Surface type	Heavy rain	Light rain
Concrete/Bituminous	2 %	1.7 %
Gravel/WBM	3 %	2.5 %
Earthen	4 %	3.0 %

1.8 Width of carriage way

Width of the carriage way or the width of the pavement depends on the width of the traffic lane and number of lanes. Width of a traffic lane depends on the width of the vehicle and the clearance. Side clearance improves operating speed and safety. The maximum permissible width of a vehicle is 2.44 and the desirable side clearance for single lane traffic is 0.68 m. This require minimum of lane width of 3.75 m for a single lane road .However, the side clearance required is about 0.53 m, on either side and 1.06 m in the center. Therefore, a two lane road require minimum of 3.5 meter for each lane The desirable carriage way width recommended by IRC is given in Table

Table 12:2: IRC Specification for carriage way width

Single lane	3.75
Two lane, no kerbs	7.0
Two lane, raised kerbs	7.5
Intermediate carriage	5.5
Multi-lane	3.5

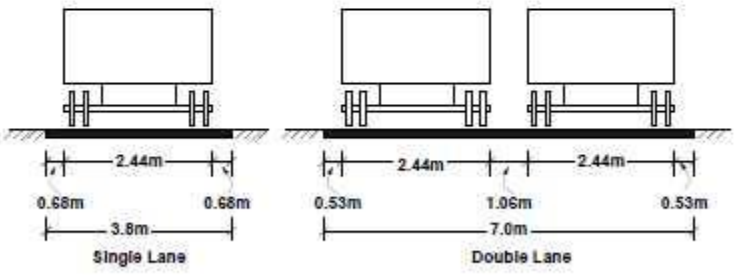


Figure 12:2: Lane width for single and two lane roads

1.9 Importance of Kerbs

Kerbs indicate the boundary between the carriage way and the shoulder or islands or
footpaths.

Different types of kerbs are

Low or mountable kerbs : This type of kerbs are provided such that they encourage the traffic to remain in the through traffic lanes and also allow the driver to enter the shoulder area with little difficulty. The height of this kerb is about 10 cm above the pavement edge with a slope which allows the vehicle to climb easily. This is usually provided at medians and channelization schemes and also helps in longitudinal drainage.

Semi-barrier type kerbs : When the pedestrian traffic is high, these kerbs are provided. Their height is 15 cm above the pavement edge. This type of kerb prevents encroachment of parking vehicles, but at acute emergency it is possible to drive over this kerb with some difficulty.

Barrier type kerbs : They are designed to discourage vehicles from leaving the pavement. They are provided when there is considerable amount of pedestrian traffic. They are placed at a height of 20 cm above the pavement edge with a steep batter.

Submerged kerbs: They are used in rural roads. The kerbs are provided at pavement edges between the pavement edge and shoulders. They provide lateral confinement and stability to the pavement.

Width of formation:

Width of formation or roadway width is the sum of the widths of pavements or carriage way including separators and shoulders.

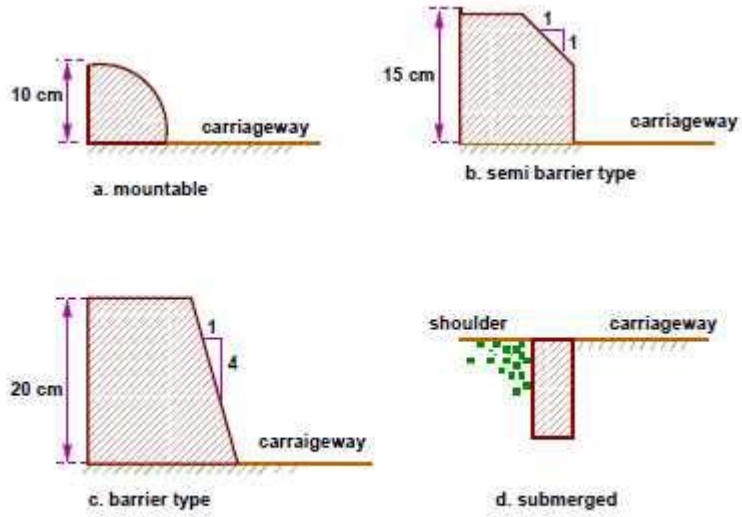


Figure 12:3: Different types of kerbs

Table 12:3: Width of formation for various classed of roads

Road classification	Roadway width in m	
	Plain and rolling terrain	Mountainous and steep terrain
NH/SH	12	6.25-8.8
MDR	9	4.75
ODR	7.5-9.0	4.75
VR	7.5	4.0

1.10 Right of way.

Right of way (ROW) or land width is the width of land acquired for the road, along its alignment. It should be adequate to accommodate all the cross-sectional elements of the highway and may reasonably provide for future development. To prevent ribbon development along highways, control lines and building lines may be provided. Control line is a line which represents the nearest limits of future uncontrolled building activity in relation to a road. Building line represents a line on either side of the road, between which and the road no building activity is permitted at all. The right of way width is governed by:

Width of formation: It depends on the category of the highway and width of roadway and road margins.

Height of embankment or depth of cutting: It is governed by the topography and the vertical alignment.

Side slopes of embankment or cutting: It depends on the height of the slope, soil type etc.

Drainage system and their size which depends on rainfall, topography etc.

Sight distance considerations : On curves etc. there is restriction to the visibility on the inner side of the curve due to the presence of some obstructions like building structures etc.

Reserve land for future widening: Some land has to be acquired in advance anticipating future developments like widening of the road.

Table 12:4: Normal right of way for open areas

Road classification	Roadway width in m	
	Plain and rolling terrain	Mountainous and steep terrain
Open areas		
NH/SH	45	24
MDR	25	18
ODR	15	15
VR	12	9
Built-up areas		
NH/SH	30	20
MDR	20	15
ODR	15	12
VR	10	9

The importance of reserved land is emphasized by the following. Extra width of land is available for the construction of roadside facilities. Land acquisition is not possible later, because the land may be occupied for various other purposes (buildings, business etc.)

The normal ROW requirements for built up and open areas as specified by IRC is given in Table 12:4 A typical cross section of a ROW is given in Figure 12:4.

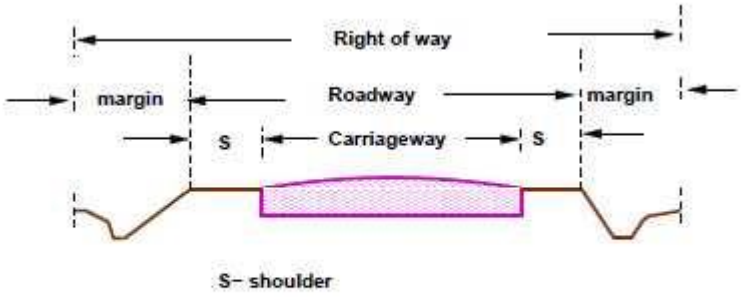


Figure 12:4: A typical Right of way (ROW)

1.11 Alignment

The position or the layout of the central line of the highway on the ground is called the alignment. Horizontal alignment includes straight and curved paths. Vertical alignment includes level and gradients. Alignment decision is important because a bad alignment will enhance the construction, maintenance and vehicle operating costs. Once an alignment is fixed and constructed, it is not easy to change it due to increase in cost of adjoining land and construction of costly structures by the roadside.

Requirements

The requirements of an ideal alignment are

- The alignment between two terminal stations should be short and as far as possible be straight, but due to some practical considerations deviations may be needed.
- The alignment should be easy to construct and maintain. It should be easy for the operation of vehicles. So to the maximum extend easy gradients and curves should be provided.
- It should be safe both from the construction and operating point of view especially at slopes, embankments, and cutting. It should have safe geometric features.
- The alignment should be economical and it can be considered so only when the initial cost, maintenance cost, and operating cost are minimum.

Factors controlling alignment

We have seen the requirements of an alignment. But it is not always possible to satisfy all these requirements. Hence we have to make a judicial choice considering all the factors.
The various factors that control the alignment are as follows:

1.Obligatory points: These are the control points governing the highway alignment. These points are classified into two categories. Points through which it should pass and points through which it should not pass. Some of the examples are:

- Bridge site: The bridge can be located only where the river has straight and permanent path and also where the abutment and pier can be strongly founded. The road approach to the bridge should not be curved and skew crossing should be avoided as possible. Thus to locate a bridge the highway alignment may be changed.
- Mountain: While the alignment passes through a mountain, the various alternatives are to either construct a tunnel or to go round the hills. The suitability of the alternative depends on factors like topography, site conditions and construction and operation cost.
- Intermediate town: The alignment may be slightly deviated to connect an intermediate town or village nearby.

These were some of the obligatory points through which the alignment should pass. Coming to the second category, that is the points through which the alignment should not pass are:

- Religious places: These have been protected by the law from being acquired for any purpose. Therefore, these points should be avoided while aligning.
- Very costly structures: Acquiring such structures means heavy compensation which would result in an increase in initial cost. So the alignment may be deviated not to pass through that point.
- Lakes/ponds etc: The presence of a lake or pond on the alignment path would also necessitate deviation of the alignment.

2. Traffic: The alignment should suit the traffic requirements. Based on the origin- destination data

of the area, the desire lines should be drawn. The new alignment should be drawn keeping in view the desire lines, traffic flow pattern etc.

3. Geometric design: Geometric design factors such as gradient, radius of curve, sight distance etc. also govern the alignment of the highway. To keep the radius of curve minimum, it may be required to change the alignment. The alignments should be finalized such that the obstructions to visibility do not restrict the minimum requirements of sight distance. The design standards vary with the class of road and the terrain and accordingly the highway should be aligned.
4. Economy: The alignment finalized should be economical. All the three costs i.e. construction, maintenance, and operating cost should be minimum. The construction cost can be decreased much if it is possible to maintain a balance between cutting and filling. Also try to avoid very high embankments and very deep cuttings as the construction cost will be very higher in these cases.