NATIONAL INSTITUTE OF TECHNOLOGY SRINAGAR
HAZRATBAL, SRINAGAR, J&K - 190 006

HIGHWAY ENGINEERING AND PMS (CIV-502)

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COURSE CONTENTS

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REFERENCES

S. No.	Name of Books/Authors/Publishers	Year of Publication
1	Khanna, S.K. and Justo, C.E.G. 2002. "Highway Engineering". Nem Chand Brothers, Roorkee.	2002
2	Bhanot, K.L.1990. " Highway Engineering", S. Chand and Company (P) Ltd., New Delhi.	1990
3	Rao, G.V. 1996. "Principles of Transportation and Highway Engineering", Tata McGraw Hill, New Delhi.	1996
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LECTURE 1

1.1 Introduction

The Institute of Transportation Engineers defines Traffic Engineering as a subset of Transportation Engineering as follows:

Transportation Engineering is the application of Technology and Scientific principles to the planning, functional design, operation, and management of facilities for any mode of transportation in order to provide for the safe, rapid, comfortable, convenient, economical, and environmentally compatible movement of people and goods.

and

Traffic engineering is that phase of Transportation engineering which deals with the planning, geometric design and traffic operations of roads, streets, and highways, their networks, terminals, abutting lands, and relationships with other mode of transportation

1.2 Importance of Transportation

The Transportation system is often referred to as the nation's "lifeblood circulation system,". Transport is a key infrastructure of a country. A country's economic status depends upon how well served the country is by its roads, railways, airports, ports, pipelines and shipping. The rate at which a country's economy grows is very closely linked to the rate at which the transport sector grows. Transportation contributes to the economic, industrial, social and cultural development of any country. Transportation is vital for the economic development of any region since every commodity produced, whether it is agricultural or industrial product needs to be transported at various stages from production to distribution. At the production stage, transportation is required for carrying raw materials like seeds, manure, coal, component parts, etc. At the distribution stage, transportation is required from the production centres like the farms and factories to the marketing centres and later to the retailers and to the consumers. Development of adequate transportation system in a country indicate its economic growth and progress in social development.

The speed, cost, and capacity of available transportation have a significant impact on the economic vitality of an area and the ability to make maximum use of its natural resources. Examination of most developed and industrialized societies indicates that they have been noted for high-quality transportation systems and services. Countries that lack an abundance

of natural resources rely heavily on transportation in order to import raw materials and export manufactured products.

1.3 Social Effects of Transportation

Progress follows the lines of transportation. Population have always settled along the transportation routes such as road side, river shore and near railway stations and sea ports. Development have also taken place along the routes where transportation facilities are available, such as road sides. However, in the present concept of road network planning, this kind of ribbon development is very much discouraged, keeping in view the requirements of high speed travel and road safety issues. Attempts are being made to decentralise the population centres away from the sides of the main transportation routes. Thus, town planning patterns are changing. The various social effects of transportation may be further elaborated as follows:

1.3.1 Sectionalism and Transportation

Improved transportation has important implications in reducing sectionalism within the country and also with other countries of the world. The living condition and facilities of under-developed colonies and tribes get improved since the distances are apparently reduced with reduction in travel time. More frequent travels to other parts of the country and outside the country tend to increase the knowledge of the people by learning from other sections of the society resulting in improved trade and cultural exchanges. International understanding for better peace and order also improves with efficient network of transportation

1.3.2 Concentration of population in urban area

Improved transportation facilities bring prosperity to the urban population. The employment opportunities, prosperity and superior facilities for education, medical care, etc. available in urban area attract the population from other areas, resulting in enhanced economic activities. Adequate mass transportation facilities are needed to cater for the internal movements in urban area such as daily movements to and from factories, offices, schools, hospitals and travel for other social needs. If efficient transportation facilities are available, the people would prefer to reside at localities away from urban centres and commute to the city for their work. In general, the transportation facilities are essential for the well-being of the community.

1.3.3 Aspect of safety, law and order

Transport facilities are essential for rushing aid to areas affected by an emergency. To maintain law and order at home, it is required to have an efficient system of transport network. To defend the territory of the country against the external aggression and to guard the borders with the foreign territories, transport facilities are needed, connecting the farthest borders area from the headquarters or the capitals. At times, defence needs alone may be a sufficient reason to develop a transport network which may not provide economic or social benefits directly

The social effects and the resultant advantages of transportation may be summarised as follows:

(i) Transportation helps in the progress and advancement of the community

(ii) Efficient transportation is essential for the economic prosperity and general development of the country, and

(iii) Transportation is essential for strategic movement in emergency for defence of the country and to maintain better law and order

1.4 Modes of Transportation

Transportation has developed along three basic media:

(a) Land

(b) Water

(c) Air

Land has given scope for development of transportation by roads and railways. Water and air media have developed waterways and airways respectively. The roads or the highways not only include the modern highway system but also includes the urban arterials and city streets, feeder roads and village roads, catering for a wide range of road vehicles and the pedestrians. Railways have been developed both for long distance transportation of goods and passengers and also for urban travel. Waterways include transportation by oceans, rivers, canals and lakes for the movement of ships and boats. The airways help in faster transportation by aircrafts and carriers.

Apart from these major modes of transportation, other modes include pipe lines, elevators, belt conveyors, cable cars and aerial rope-ways. Pipe lines are used for the transportation of water, other fluids and even solid particles

Thus, the following are the four major modes of transportation:

(i) Roadways or Highways for road transportation

(ii) Railways for rail transportation

(iii)Water ways for water transportation

(iv) Airways for air transportation

1.4.1 Road Transportation

Transportation by road system is the only mode which could give maximum flexibility of service from origin to destination, to one and all. Various classes of vehicles such as car, bus, truck, two-wheeler, etc. may be permitted to make use of the roads. Apart from road vehicles, pedestrians also make use of the facilities of the road system. Road transport mode has the maximum flexibility for travel with reference to choice of the route, direction, time and speed of travel. Road transport is the only mode which caters for the movement of passengers and goods independently right from the place of origin up to the destination of any trip along the land. In other words, it is possible to provide door to door service only by road transport.

1.4.2 Rail Transportation

The concept of rail transportation is movement of multiple wagons or a train of wagons or passenger bogies fitted with steel wheels running over two parallel steel rails of the railway track. The resistance to traction along the railway track for the movement of the steel wheels of the rail wagons is much lower than that along the more uneven road surface for the movement of road vehicles with rubber tyres, under identical conditions of speed and atmospheric factors. The energy requirement to haul unit load through unit distance by railway is only a fraction (one fourth to one sixth) of that required by road. Therefore, full advantage of rail transportation should be taken for the transportation of bulk goods and passengers, especially for long distance on land routes and where the railway tracks are available

1.4.3 Water Transportation

Transportation by waters offers minimum resistance to traction and therefore needs minimum energy to haul unit load through unit distance. The amount of energy required to propel a vessel on water is much lesser than that required on land and is far lesser than that required to keep an aircraft air-borne. Therefore, water transportation is the most energy efficient. But water transportation is very slow, which is the greatest disadvantage of this mode. In fact, this is the slowest among the four modes. The greatest user of this mode is bulk cargo of

relatively low value, mainly because of the slow speed and low transportation cost for the bulk cargo.

1.4.4 Air Transportation

Transportation by air is the fastest among the four modes. Air transport provides more comfort and fast travel resulting in substantial saving in travel time for the passengers between the airports. The shipment of high-value freight on long hauls is possible in the shortest time by air transport. Unlike other modes of transport, air transport allows continuous journey over the land and water, even across inaccessible places in between two airports. One of the limitations is that the energy required and the overall operating expenses for air transportation are the highest in comparison to other modes.

1.5 Characteristics of Road Transport

It is an accepted fact that of all the modes of transportation, road transport is the nearest to the people. All classes of road vehicles consisting of both personal or public transport vehicles and also the pedestrians can make use of the roadway system. The passengers and the goods can be transported by any suitable type of road vehicle either for the full trip from the place of origin to the destination or to and from the terminal of other modes of transportation, such as the railway station, airport or the harbour. Often road transport is preferred even for longer trip lengths at a higher transportation cost, to avoid the inconvenience of shifting from one mode to another.

The characteristics of road transport are briefly listed here:

(i) Roads are used by various types of road vehicles like passenger cars, buses, trucks, two and three wheeled automobiles, pedal cycles and animal drawn vehicles. But railway tracks are used only by rail locomotives and wagons. Waterways are used by only ships and boats

(ii) Road transport requires a relatively small investment from the government. Motor vehicles are much cheaper than other carriers like rail locomotives and wagons, water and air carriers. Construction and maintenance of roads is also cheaper than that of railway tracks, docks, harbours and airports

(iii) Road transport offers a complete freedom to road users to transfer the vehicle from one lane to another and from one road to another according to the need and convenience. This flexibility of changes in location, direction, speed and timings of travel is not available to other modes of transport

(iv) In particular for short distance travel, road transport saves time. Trains stop at junctions and main stations for comparatively longer time.

(v) Speed of movement is directly related with severity of accident. The road safety decreases with increasing dispersion in speed. Road transport is subjected to a high degree of accidents due to flexibility of movements offered to the road users. Derailment of railway locomotives and air crash of air planes are also not uncommon. They are in fact more disastrous

(v) Road transport is the only means of transport that offers itself to the whole community alike

LECTURE 2

2.1 Historical Development of Road Construction

2.1.1 Early Development

The oldest mode of travel obviously was on the footpaths. Animals like horses & oxen were also used to transport men & materials over pre-identified tracks. The first improvements would have been that of clearing trees & big stones from the identified paths. These paths were later flattened or widened to accommodate increase in animal & human traffic. Further wheel transport created the need for better roads. In urban areas, it began to be worthwhile to build stone paved streets and in fact the first paved streets appear to have been built in ur in 4000 BC. Only during the Roman Empire, roads were constructed in large scale & the earliest construction techniques known are of Roman roads. Infarct Romans are considered to be the pioneers in road construction.

2.1.2 Roman Roads

The greatest systematic road builders of the ancient world were the Roman who were conscious of the military, economic & administrative of good road system. The main features of the roman roads were:

- They were built in a straight line regardless of obstacles.
- In its highest stage of Development, it was constructed by excavating parallel trenches about 40 feet apart to provide longitudinal drainage- a hallmark of roman road engineering.
- The foundation was then raised about three feet above ground level, employing material taken from the drains & from adjacent cleared ground.
- As the importance of road increased, this embankment was progressively covered with light bedding of sand or mortar on which four main courses were constructed.

(a) The Statumen layer 10 to 24 inches (250 to 600 millimeters) thick, composed of stones at least 2 inches in size.

(b) The Rudeus, a 9-inch-thick layer of concrete made from stones under 2 inch in size.

(c) The Nucleus Layer, about 12 inches thick, using concrete made from small gravel and coarse sand.

(d) The Summum dorsum, a wearing surface of large stone slabs at least 6 inches deep.

The total thickness thus varied from 3 to 6 feet.

Figure 1.1 shows a typical cross section of Roman Road.

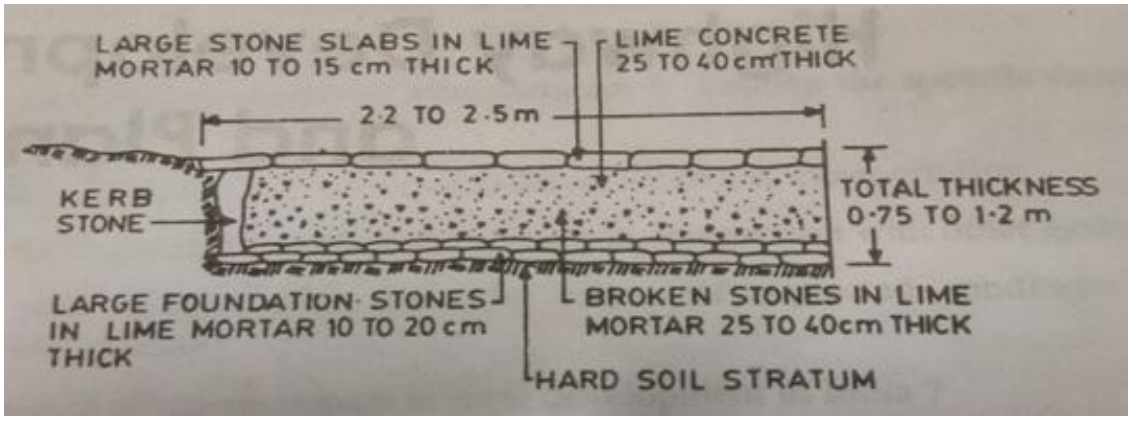

Figure 1.1 Typical Cross Section of Roman Road

2.1.3 Tresaguet Construction

Pierre-Treasguet, an engineer was appointed in 1975 as inspector general **of** roads & Bridges for France. in that year, he developed an entirely new type of relatively light road surface, based on the theory that the underlying natural formation, rather than pavement, should support the load. The typical cross section of tresguet's road construction is given in fig. & construction steps are enumerated below:

(a) The sub grade was prepared & a layer of large foundation stones were laid on edge by hand. at the two edges of the pavement large stones were embedded edgewise to serve as submerged kerb stones.

(b) The corners of these heavy foundation stones were hammered & then interstices filled with smaller stones. Broken stones were packed to a thickness of about 8cm & compacted.

(c) The top wearing course was made of smaller stones & compacted to a thickness of about 5 cm at the edges & gradually increased towards the centre, giving a cross slope of 1 in 45 to the surface, to provide surface drainage.

(d) The shoulders were also provided cross slope to drain the surface water to the side drain.

Figure 1.2 shows a typical cross section of Tresaguet road construction.

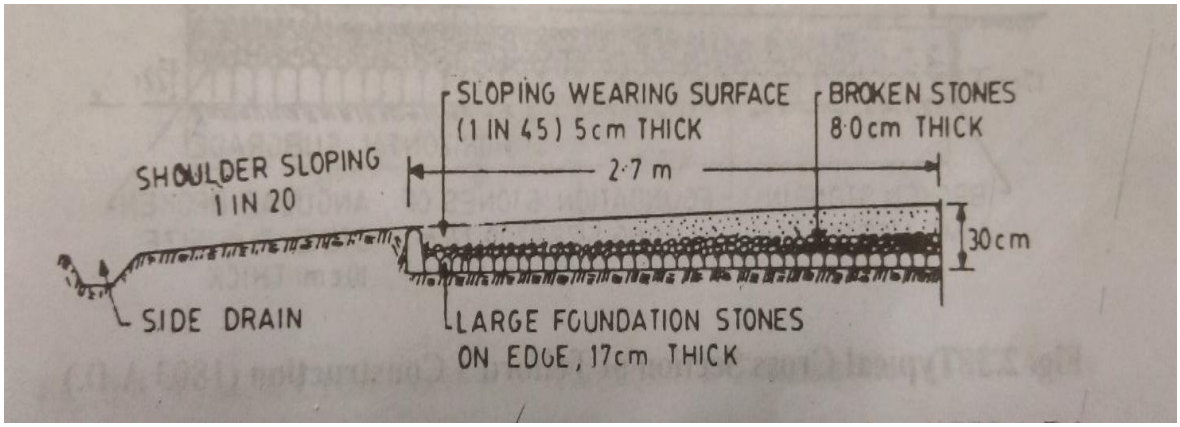

Figure 1.2 Tresaguet Road Construction

2.1.4 Telford Construction:

Thomas Telford (1757-1834) was the founder of Institution of civil engineers at London. His roadways were 18 feet wide & built in three courses:

(a) A lower layer, seven inches thick, consisting of good-quality foundation stone carefully placed by hand (this was known as Telford Base)

(b) A middle layer, also seven inches thick, consisting of broken stone of two-inch maximum size and

(c) A top layer of gravel or broken stone up to one inch thick.

Figure 1.3 shows a typical cross section of Telford road construction.

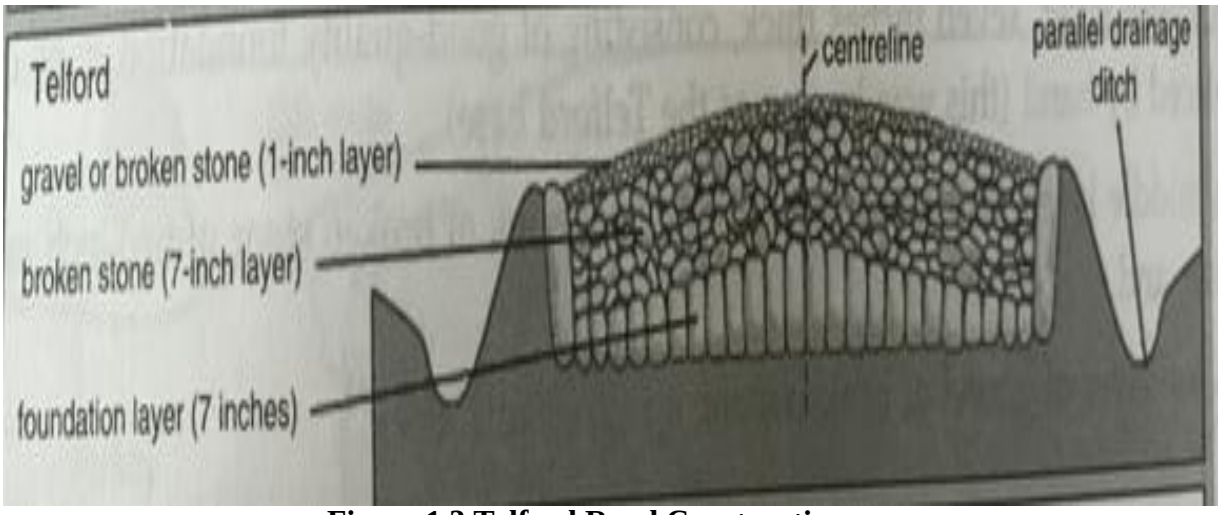

Figure 1.3 Telford Road Construction

2.1.5 Metcalf Construction

Metcalf was engaged in road construction works in England**.** He was responsible for the construction of about 290 km of road in the northern region of England surfaced his roads with a "compact layer of small, broken stones with sharp edges", rather than naturally rounded stones traditionally used in European road buildings.

2.1.6 Macadam Construction

John macadam (1756-1836) put forward an entirely new method of road construction as compared to all previous methods. A typical cross section of Macadam construction is shown in Figure 1.4.

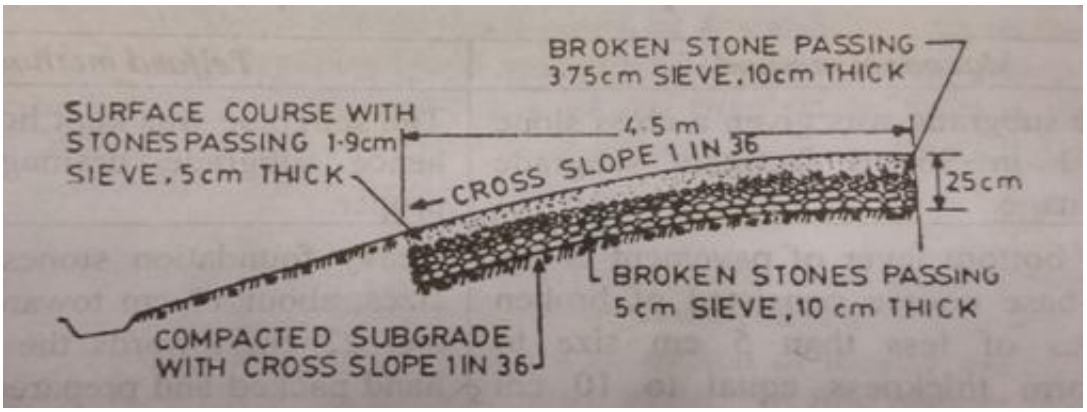

Figure 1.4 Macadam Road Construction

The most important modifications made in macadam's methods with respect to older methods are:

- The sub grade was compacted & was prepared with a cross slope of 1 in 36.
- Macadam Realized that the sub grade being the lowest portion of the pavement should be prepared properly & kept drained so as to carry load transmitted through the pavement.
- The size of the broken stones for the top layer was decided based on the stability under animal drawn vehicles.
- Though the total thickness of construction, was less than previous methods, this technique was better due to load dispersion characteristics of compacted broken stone aggregates of smaller size.

The Construction Steps of Macadam's Method are:

(i) Subgrade is compacted and prepared with a cross slope of 1 in 36 upto a desired width (about 9 meters)

(ii) Broken stones of a strong variety, all passing through 5 cm size sieve were compacted to a uniform thickness of 10cm.

(iii) The 2^{nd} layer of strong broken stones of size 3.75cm were compacted to thickness of 10cm.

(iv) The top layer consisted of stones of size less than 2cm compacted to a thickness of about 5cm & finished so that cross slope of pavement surface was also 1 in 36.

Various subsequent improved methods were based on macadam's construction such as water bound macadam, penetration macadam & bituminous macadam constructions.

LECTURE 3

3.1 Road Development in India

3.1.1 General

During the second decade of the 20th century, soon after the first world war the motor vehicles using the roads in India also increased and this demanded better road. However, the roads that existed then with 'water bound macadam' (WBM) surface and other inferior surfaces were not able to withstand the mixed traffic consisting of slow moving vehicles and the motor vehicles. The predominant component of the traffic consisted of bullock carts with steel tyred wheels which could abrade, grind and even crush the stone aggregates of the WBM road surface and form dust on the road surface during the dry season; the dust on the road surface would form mud during the monsoon season. The passage of fast moving automobiles would raise the dust behind them during dry weather and churn up the mud and deteriorate the road surface at a rapid rate during the wet weather. Due to the combined effect of the mixed traffic movement, the roads deteriorated fast during the post war period

A resolution was passed by both chambers of the Indian legislature in the year 1927 for the appointment of the committee to examine and report on the question of road development in India. In response to the resolution, a Road development committee was appointed by the Government in 1927, with M.R. Jayakar as the chairman

3.1.2 Jayakar Committee Recommendations

Jayakar committee submitted its report by the year 1928. The important recommendations made by the committee are:

(a) The road development in the country should be considered as a national interest as this has become beyond the capacity of provincial governments and local bodies

(b) An extra tax should be levied on petrol from the road users to develop a road development fund called 'Central road fund'

(c) A semi-official technical body should be formed to pool technical know-how from various parts of the country and to act as an advisory body on various aspects of roads

(d) A research organisation should be instituted to carry out research and development work pertaining to roads and to be available for consultations

Most of the recommendations of Jayakar committee were accepted by the government, and the major recommendations were implemented subsequently. The Central road fund was formed by the year 1929, the semi-official technical body called the 'Indian roads congress' was formed in 1934 and the Central road research institute was started in the year 1950

3.1.3 Central Road Fund

One of the recommendations of road development committee was to place duty on petrol and to keep a part of additional revenues for the road development programme. In its accordance, the central government created a dedicated fund, called Central road fund through collection of cess from petrol and diesel on Ist march 1929. At that period the consumers of petrol were charged an extra levy of 2.64 paisa per litre. Presently, Rs. 2/- per litre is collected as cess on petrol and high speed diesel (HSD) oil. The fund is distributed for development and maintenance of national highways, state roads, rural roads and for provision of road over bridges/under bridges and other safety features at un-manned railway crossings as provided in central road fund act,2000. The fund will remain under the control of central government and will be utilized for the:

a. Development and maintenance of national highways

b. Development of rural roads,

c. Development and maintenance of other state roads including roads of interstate and economic importance,

d. Construction of roads either under or over the railways by means of a bridge and erection of safety works at unmanned rail-road crossing, and

e. Disbursement in respect of such projects as may be prescribed

The Central government shall be responsible for the administration, management, coordination, timely utilization and release of funds, and sanction of schemes, formulation of fund allocation criteria and project sanction criteria.

3.1.4 Indian Roads Congress

The Indian Roads Congress (IRC) is a premier technical body of highway engineers in the country. The IRC was set up in December, 1934 on the recommendations of the Indian road development committee best known as Jayakar committee. As the activities of the IRC expanded, it was formally registered as a society in 1937 under the societies registration act of 1860. The congress provides a national forum for sharing of knowledge and pooling of experience on the entire range of subjects dealing with the construction and maintenance of

roads and bridges, including technology, equipment, research, planning, finance, taxation, organisation and all connected policy issues. In more specific terms the objectives of the congress are:

(i) To promote and encourage the science and practice of building and maintenance of roads

(ii) To provide a channel for the expression of collective opinion of its members regarding roads

(iii) To promote the use of standard specifications and to propose specifications

(iv) To advise regarding education, experiment and research connected with roads

(v) To hold periodical meetings, to discuss technical questions regarding roads

(vi) To suggest legislation for the development, improvement and protection of roads

(vii) To publish, or arrange for the publication of proceedings, journals, periodicals and other literature for the promotion of the objects of the society

(viii) To grant pay, prizes honoraria, or scholarships (including traveling scholarships) for meritorious work in furtherance of the object of the society

3.1.5 Motor Vehicle Act

In 1939, the Motor vehicle act was brought into effect by Government of India to regulate the road traffic in the form of traffic laws, ordinances and regulations. The three phases primarily covered are control of the driver, vehicle ownership and vehicle operation on roads and in traffic stream. The Motor Vehicle Act has been appended with several ordinances subsequently. The Motor Vehicle Act -1939 was consolidated and revised in the year 1988 and various laws regulating road transport were rationalised.

Motor Vehicle Act, 1988 lays down the principles and procedures and the authorities responsible for the following:

a) Issue of driving licenses

b) Issue of permits

c) Grant of fitness certificates for the vehicles on roads

d) Prescribing of emission and safety related norms for motor vehicles

e) Norms for type approval in conformity of production of new motor vehicles

f) Issues relating to compensation in case of motor vehicles accidents etc.

3.1.6 Road Development Plan, 1943-1963 (Nagpur Road Plan)

First long-term vision for road development in India was drafted in the conference of chief engineers of all the states and union territories that was held at Nagpur in the year 1943. The plan was prepared for a twenty-year period of 1943-1963.

Some of the major recommendations of Nagpur plan are:

1. Road development plan should consist of short-term measures to overcome the damages caused by war and a long-term planning for good communication throughout India.
2. Though road was a provincial subject, it was brought under centre to bring balanced and coordinated development.
3. National highways should work as a framework for road development and centre should be responsible for their construction and maintenance.
4. The national highways, provincial highways and major district roads must be provided with a durable hard pavement crust
5. The other district roads and village roads should be provided with a properly engineered earth surface, with modifications as necessary.
6. All national highways, provincial highways and major district roads should be adequately bridged. The interruptions to submersible bridges and causeways should not generally be more than twelve hours at a time or more than six times a year

Salient features of the road development plan were:

1) The plan was formulated keeping in view the requirements of growing population and increasing vehicular traffic for the next twenty years
2) The road network development was based on ‘star and grid’ pattern
3) The area was classified based on the potential of agricultural production as agricultural area and non-agricultural area
4) The connectivity by road was defined based on population residing in villages so that each village gets some length of the road inducing development. A wide range of population was considered for the categorization of villages.
5) The target length of the roads was defined based on the size of the area that it will serve and was decided as 16 km per 100 km sq. of area.
6) The size of the grid for the first category of roads in agricultural area was decided as grid of 16 km side and for non-agricultural area it was of 64 km side
7) An allowance of 15 percent of the road length calculated based on the formulae recommended by the committee should be provided for agricultural and industrial development that may take place during the next twenty years.

8) The existing length of railway track was also considered while computing the length of road falling in the first category.

3.1.7 Central Road Research Institute

In the year 1950, the Central Road Research Institute (CRRI) was started at New Delhi for carrying out research pertaining to road technology. It may be indicated that one of the recommendations of Jayakar committee report was to set up a central organisation for research and dissemination of information.

The CRRI is one of the national laboratories of the council of scientific and industrial research (CSIR). The institute is mainly engaged in carrying out applied research in various aspects of highway engineering and offers technical advice to state governments and the industries on various problems concerning roads.

3.1.8 National Highway Act

In 1956 the 'National Highway Act' was passed in the country. Some of the main features of the act include powers:

(a) To declare certain selected highways as 'National Highways', responsibility of development and maintenance of which to be with the Central government

(b) To enter into any land for carrying out surveys

(c) To acquire land and take possession for the development of the national highway

The National Highway Act was subsequently revised and the 'National Highways Authority of India Act-1988' was passed by the Parliament of India in 1988. The National Highways Authority of India (NHAI) started operating in February 1995.

3.1.9 Road Development Plan, 1961-1981 (Bombay Road Plan)

The first twenty-year road development programme became deficient in many respects due to the changed economic, agricultural and industrial scenario. Further, the plan objectives or targets were achieved by the year 1961 and hence, there was a need to redraw the targets of road development that should be achieved in the future. Another twenty-year road development plan was drafted by the roads wing of the government of India, and the same after deliberations was adopted by the chief engineers of all States and Union territories at their conference meeting held at Bombay in 1959. The plan has also been known as Bombay plan.

The main objectives of the plan were:

1) Provision of good communication facilities in the rural areas is essential to check the increasing rate of urbanization and migration to urban areas.

2) The road density should be increased to 32 km per 100 km sq. area. This target was set taking into account the level of expected development and the need of the rural as well as urban areas.

3) To achieve the overall road density target, the road density in classified areas should be 44 km per 100 km sq. in developed and agricultural area, 19 km per 100 km sq. in semi-developed area and 12 km per 100 km sq. in undeveloped and uncultivable area.

4) Every town with population above 2000 in plains, above 1000 in semi-hills, and above 500 in hilly areas should be connected by a metalled road

5) An allowance of 100 percent should be made in hilly regions. Hills with altitude more than 2300 meters may be ignored in road length calculations.

6) A target length of 1600 km should be changed in expressway

7) Specifications of works to be adopted should permit 'Stage Construction' in view of limited funds available

8) Arterial roads should be fully bridged and made two-lane wide to withstand truck-trailer loads and movements

9) An allowance of 5 percent should be given for future development and other unforeseen factors

3.1.10 Road Development Plan, 1981-2001 (Lucknow Road Plan)

The chief engineers of States and Union territories, and Indian Roads Congress at their Lucknow conference formulated a long-term road development plan for the country for the period 1981-2001.

The goals and policies defined in this plan were:

1. Road network should be developed to provide accessibility to all villages with a population of above 500 by the turn of the century.

2. Roads should be built in less industrialized areas so as to attract the growth of industries

3. Roads should be a major choice of construction programme to generate employment

4. Expressways should be constructed on all major traffic corridors to provide speedy travel

5. Road safety measures should be given importance to bring down road accidents

6 The annual rate of growth of 7.5 percent for passenger traffic and 10 percent for freight traffic was recommended.

7. The overall road density in the country should be increased to 82 km per 100 km sq. area by the year 2001.

8. Expressways with a total length of 200o km should be developed based on traffic requirements

9. By 2001, 72 percent of NH and 25 percent of existing SH should be double-lane

3.1.11 Road Development Plan Vision: 2021

The current road development plan was approved by the Council of Indian Roads Congress at its meeting held at Kolkata on November 4th, 2000. Salient features of this plan are as:

1. Expressways of length 10000 km should be constructed by 2021

2. Road density achieved at the end of the plan should be 1.00 km per sq.km of area.

3. Environmental clearance is needed if the cost of the project is Rs. 50 crores or more

4. Rehabilitation plan should be prepared if the people displaced due to a project are 1000 or more

3.2 Classification of Roads

3.2.1 Different Approaches

Types of roads based on weather:

The roads are generally classified into two categories, depending on whether they can be used during different seasons of the year:

1) All-weather roads: are those which are negotiable during all seasons of the year, except at major river crossings where some interruption to traffic is permissible up to certain extent, but the road pavement should be negotiable during all weathers.

2) Fair weather roads: are those where the traffic may be interrupted during monsoon season at causeways where streams may overflow across the roads.

Based on type of carriageway, the roads are classified as:

1) Paved roads: The roads with hard pavement surface on the carriageway are called paved roads.

2) Un-paved roads: The roads without a hard pavement surface on the carriageway are called un-paved roads e.g. earth roads and gravel roads.

Based on type of pavement surfacing, the roads may be classified as:

1) Surfaced roads: Road pavements with any type of bituminous surface or cement concrete.

2) Un-surfaced roads: Road pavements which are not provided with a bituminous or cement concrete surfacing.

3.2.2 Methods of Classification of Roads

The roads are generally classified based on following:

(a) Traffic volume

(b) Load transported or tonnage

(c) Location and function

The classification based on traffic volume or tonnage have been arbitrarily fixed by different agencies and there may not be a common agreement regarding the limits for each of the classification group. Based on traffic volume or flow, the roads are classified as heavy, medium and low volume roads. These terms are relative and so the limits under each class should be clearly defined and expressed as vehicles per day or annual average daily traffic (AADT), etc. Likewise, the classification based on load or tonnage is also relative and the roads may be classified as class I, II etc. or class A, B etc. and the limits may be expressed in terms of tonnes per day.

The classification based on location and function should therefore be a more acceptable classification method for a country as they may be defined clearly.

3.2.3 Road Classification as per Nagpur Road Plan

The Nagpur Road Plan classified the roads in India based on location and function into following five categories and described below:

(i) National Highways (NH)

(ii) State Highways (SH)

(iii) Major District Roads (MDR)

(iv) Other District Roads (ODR)

(v) Village Roads (VR)

National Highways (NH) are main highways running through the length and breadth of India, connecting major ports, foreign highways, capitals of large states and large industrial and tourist centres including roads required for strategic movements for the defence of India. It was specified that national highways should be the frame on which the entire road communication should be based and that these highways may not necessarily be of same specification, but they must give an uninterrupted road communication throughout the

country and should connect the entire road network. The responsibility of construction and maintenance of national highways was decided to be with the central government.

State Highways (SH) are arterial roads of a state, connecting the national highways of adjacent state, district headquarters and important cities within the state and serve as main arteries for traffic to and from district roads. These highways are considered as main arteries of commerce by road within a state or a similar geographic unit. The NH and SH have the same design speed and geometric design specifications.

Major District Roads (MDR) are important roads within a district serving areas of production and markets and connecting with other major roads or main highways of a district. The MDR has lower speed and geometric design specifications than NH/SH.

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

Village Roads (VR) are roads connecting villages or groups of villages with each other and to the nearest road of higher category.it was specified that these village roads should be in essence farm tracks, but it was desired that the prevalent practice of leaving such tracks to develop and maintain by themselves should be replaced by a plan for a designed and regulated system.

3.2.4 Modified Road Classification as per 20-Year Road Development Plan, 1981-2001

The road classification system was modified in the third 20-year road development plan. The roads in the country are now classified into three classes, for the purpose of transport planning, function identification, earmarking administrative jurisdictions and assigning priorities on the road network.

(i) Primary system
(ii) Secondary system
(iii) Tertiary system or rural roads

Primary system consists of two categories of highways:

(a) Expressways and
(b) National Highways (NH)

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 access, grade

separations at cross roads and fencing. These highways should permit only fast moving vehicles. Expressways may be owned by the central government or a state government, depending on whether the route is NH or SH. The national highways form the main category of primary system in the country.

The secondary system consists of two categories of roads:

(a) State Highways (SH) and

(b) Major District Roads (MDR)

The tertiary systems are rural roads and these consist of two categories of roads:

(a) Other District Roads (ODR)

(b) Village Roads (VR)

3.2.5 Classification of Urban Roads

The road systems within urban areas are classified as Urban Roads and will form a separate category of roads to be taken care by respective urban authorities. The lengths of urban roads are not included in the targets of the Third Twenty Year Road Development Plan 1981-2001.

The urban roads are classified as:

(a) Arterial roads

(b) Sub-arterial roads

(c) Collector streets and

(d) Local streets

Arterials and sub-arterials are urban roads primarily for through traffic on a continuous route, but the sub-arterials have a lower traffic mobility than the arterials.

Collector streets provide access to arterial roads and they collect and distribute traffic from and to local streets which provide access to abutting property

----------End of Unit 1----------

LECTURE 4

4.1 Highway Alignment and Location Surveys

4.1.1 Highway Alignment: All road projects related to the new constructions start with the finalization of alignment of the desired road. In case of road improvements, sometimes the work relates to the improvement in road alignment with the objective of making traffic movements more easy and smooth. In general, the alignment can be defined as follows,

Alignment of a road is a location in space depicted by a line, drawn straight or curved or as a combination of both, between two desired places whose locations are fixed in space, and that fulfils the desired objectives by fitting in well over the political and physical map of the area.

The direction and position given to the centreline of the road on ground is its alignment. The horizontal alignment includes the straight path, the horizontal deviations and curves. Changes in gradient and vertical curves are covered under vertical alignment of roads.

A new road should be aligned very carefully as improper alignment would result in one or more of the following disadvantages:

(a) Increase in construction cost

(b) Increase in maintenance cost

(c) Increase in vehicle operation cost

(d) Increase in accident rate

Once the road is aligned and constructed, it is not easy to change the alignment due to increase in cost of adjoining land and construction of costly structures by the road side. Hence the importance of careful considerations while finalizing the alignment of a new road need not be over emphasised.

4.1.2 Ideal Alignment

An ideal alignment is the one that satisfies the economic, social, geographical, environmental and political constraints in best of the way; needs minimal resources for its construction, operation and maintenance; maximizes user's safety and comfort; and provides proper connectivity with equal emphasis to accessibility and mobility. An ideal alignment in this sense should fulfil the following:

a). Shortest Path: It is desirable to a have shortest alignment between two terminal stations. A straight alignment would be the shortest, though there may be several practical considerations which would cause deviations from the shortest path

b). Easy Profile: The alignment should be such that it is easy to construct and maintain the road with minimum problems. Also, the alignment should be easy for the operation of vehicles with easy gradients and curves.

c). Safety along Profile: The alignment should safe enough for construction and maintenance from the view point of stability of natural hill slopes, embankment and cut slopes and foundation of embankments. Also, it should be safe for the traffic operation with safe geometric features.

d). Aesthetics: As far as possible, the profile should pass through an area that gives pleasant feelings to the travellers moving along that profile. It improves level of comfort during ride and removes monotony. The profile should be such that the road fully integrates with the surrounding landscape of the area

e). Economical: The road alignment could be considered economical only if the total cost including initial cost, maintenance cost and vehicle operation cost is lowest.

All these factors should be given due consideration before working out the economics of each alignment. The alignment should be such that it would offer maximum utility by serving maximum population and products. The utility of a road should be judged from its utility value per unit length of road

4.2 Factors Controlling Alignment

For an alignment to be shortest, it should be straight between the two terminal stations. This is not always possible due to various practical difficulties such as intermediate obstructions and topography. A shortest route may have very steep gradients and hence not easy for vehicle operation. Similarly, there may be construction and maintenance problems along a route which may otherwise be short and easy. Roads are often deviated from the shortest route in order to cater for intermediate places of importance or obligatory points.

A road which is economical in the initial construction cost, need not necessarily be the most economical in maintenance or in vehicle operation cost. It may also happen that the shortest and easiest route for vehicle operation may work out to be costliest of the different alternatives from construction view point. Thus, it may be seen that an alignment can seldom

fulfil all the requirements simultaneously; hence a judicial choice is made considering all the factors.

The various factors which control the highway alignment in general may be listed as:

a) Cost-Economics of The Project: The cost of the project is dependent upon the selection of the profile and the terrain through which it passes. If the terrain is quite tough and construction of the road requires specialized techniques and equipment than the cost of the road project would be very high, whereas, if the design features are kept within acceptable limits or guidelines, then the cost would be much lower than the former case. The economics of the project depends upon the source from where the money will come for the construction of the road and on the operation and maintenance of the facility provided. If the operating cost is quite high, very few will like to use the facility, whereas, if it is beneficial in terms of savings made in travel time or improvement in the quality of riding then more persons will like to use the facility. It is therefore, important to look at two factors that govern the cost-economics, i.e. cost-benefit ratio and internal rate of return that will make the repayment of the capital cost feasible within a certain time frame. Another way of achieving economics is to select the profile that balances the cutting and filling

b) Obligatory Points: These are the control points governing the alignment of the highways. These control points may be divided broadly into two categories.

(i) Points through which alignment is to pass.

(ii) Points through which the alignment should not pass.

(i) Obligatory points through which the road alignment has to pass may cause the alignment to often deviate from the shortest or easiest path. The various examples of this category may be bridge site, intermediate town, a mountain pass or a quarry.

When it is necessary to cross hill range, mountains or high ridges the various alternatives are to cut a tunnel across or to go around the hills or to deviate until a suitable hill pass is available. the suitability of these alternatives depends on many other factors, like the topography and the site conditions and cost considerations. The road bridge across a river can be located only at a place where the river has straight and permanent path and where the bridge abutment and pier can be properly founded

(ii) Obligatory points through which the road should not pass also may make it necessary to deviate from the proposed shortest alignment. The obligatory which should be avoided while aligning a road include religious places, very costly structures, unsuitable land etc. religious

places like temple, mosques, church, grave or tomb have been protected by the law from being acquired for any purpose. Acquiring costly structures would mean heavy compensation resulting in increased cost. Marshy, peaty and water logged areas are generally unsuitable for road construction and should be avoided as far as possible.

c) Physical Features of The Alignment: While an alignment is selected, one of the important decisions that are usually taken simultaneously is the level of the road facility that is to be constructed or provided between two desired locations. Thus, has its effects on certain aspects like the land that is to be acquired for the construction of the road and for its future expansion.

d) Political will and Obligations: The decision makers in most of the governing systems are the politicians in power. the ideology and policies of a government defines the areas of importance for that government. the planned outlay dedicated to the cause decides the amount of work that can be executed in a given time frame. Fortunately, the transportation and communication have been given due importance over the planning years and hence, there is a substantial growth in the two sub-sectors. Sometimes, the population of an area demand for certain links between the desired places or for the upgradation of the existing links, and these are sanctioned out of political obligations of the politicians towards the area they represent in the parliament or the legislative council. It may happen that such obligations may fall short of economic feasibilities

e) Traffic: The alignment should suit traffic requirements. Origin and Destination study should be carried out in the area and the desire lines be drawn showing the trend of traffic flow. The new road to be aligned should keep in view the desired lines, traffic flow patterns and future trends

f) Other considerations: various other factors which may govern the alignment are design factors, drainage considerations, hydrological factors and monotony. The vertical alignment is often guided by drainage considerations. The subsurface water level, seepage flow and high flood level are the factors to be kept in view

4.3 Special considerations while Aligning Roads on Hilly areas

i) Stability: While aligning hill roads, special care should be taken to align the road along the side of hill which is stable. A common problem in hill roads is that of landslides. The cutting and filling of earth to construct roads on hill-side cause steepening of existing slopes and affect its stability

ii) Drainage: Numerous hill-side drains should be provided for adequate drainage facilities. but the cross-drainage structure being costly, attempts should be made to align the road in such a way where the number of cross drainage structures are minimum

iii) Resisting length: The resisting length is calculated based on the concept of work done in moving the loads along the profile and takes into consideration the horizontal length between the places to be connected by the profile, the difference in elevation of the two places under consideration, and the sum of ineffective rise and fall in excess of floating gradients

iv) Stability of rock and soil mass: The stability of rock and soil mass in hilly areas is one of the most important factors that need consideration. It is important to examine the characteristics of these masses with respect to stability, strength, moisture movements, dip of the strata, faults and folds, if any, unstable hilly features, areas having frequent landslides or settlement problems. careful study should be done of the geological maps of the area

LECTURE 5

5.1 Engineering Surveys for Highway Alignment

5.1.1 Stages of Engineering Surveys:

Before a highway alignment is finalized in a new highway project, engineering surveys are to be carried out. These engineering surveys may be completed in the following four stages:

(a) Map study

(b) Reconnaissance survey

(c) Preliminary surveys

(d) Final location and detailed surveys

The first three stages consider all possible alternate alignments keeping in view the various requirements of highway alignment. The fourth stage is meant for the detailed survey of the selected alignment.

a) Map Study

If the topographic map of the area is available, it is possible to suggest the likely routes of the road. In India, topographic maps are available from the Survey of India, with 15 or 30 metre contour intervals. The main features like rivers, hills valleys, etc. are also shown on these maps. By careful study of such maps, it is possible to have an idea of several possible alternate routes so that further details of these may be studied later at the site. The probable alignment can be located on the map from the following details available on the map.

(i) alignment avoiding valleys, ponds or lakes

(ii) when the road has to cross a row of hills or mountains, possibility of crossing through a mountain pass

(iii) approximate location of bridge site for crossing rivers, avoiding bend of the river, if any
(iv) when a road is to be connected between two stations, one of the top and the other on the foot of the hill, then alternate routes can be suggested keeping in view the design or ruling gradient and the maximum permissible gradient

b) Reconnaissance

The second stage of engineering surveys for highway alignment is the reconnaissance survey. During the reconnaissance, the engineer visits the site and examines the general characteristics of the area before deciding the most feasible routes for detailed studies. A field survey party may inspect a fairly broad stretch of land along the proposed alternative routes of the map in the field. Only very simple survey instruments are used by the reconnaissance party to collect additional details rapidly, but not accurately. All relevant details which are not available in the map are collected and noted down. Some of the details to be collected during reconnaissance are given below:

(i) Valleys, Ponds, Lakes, Marshy land, Ridge, Hills, Permanent structures and other obstructions along the route which are not available in the map
(ii) Approximate values of gradient, length of gradients and radius of curves of alternate alignments

(iii) Number and type of cross drainage structures, maximum flood level and natural ground

water level along the route.

(iv) Soil type along the routes from field identification tests and observation of geological features

(v) Sources of construction materials, water and location of stone quarries
(vi) when the road passes through hilly or mountainous terrain, additional data regarding the geological formation, type of rocks, dip of strata, seepage flow etc. may be observed so as to decide the stable and unstable sides of the hill for highway alignment

A rapid reconnaissance of the area, especially when it is vast and the terrain is difficult, may be done by an aerial survey. From the details collected during the reconnaissance, the alignment proposed after map study may be altered or even changed completely. As a result of the reconnaissance, a few alternate alignments may be chosen for further studies based on practical considerations observed at the site

c) Preliminary Survey

The main objectives of the preliminary survey are:

(i) To survey the various alternate alignments proposed after the reconnaissance and to collect all the necessary physical information and details of topography, drainage and soil

(ii) To compare the different proposals in view of the requirements alignment of a good

(iii) To estimate quantity of earth work materials and other construction aspects and to work out the cost of alternate proposals

(iv) To finalize the best alignment from all considerations The preliminary survey is carried out to collect all the physical information which are necessary in connection with the proposed highway alignment.

The preliminary survey may be carried out by any one of the following methods:

(a) Conventional approach, in which a survey party carries out surveys using the required field equipment, taking measurements, collecting topographical and other data and carrying out soil survey

(b) Rapid approach, by aerial survey taking the required aerial photographs and by photogrammetric methods and photo-interpretation techniques for obtaining the necessary topographic and other maps including details of soil and geology.

(c) Modern techniques by use of Global Positioning System (GPS) The procedure of the conventional methods of preliminary survey is given in following steps:

(i) Primary traverse

(ii) Topographical features

(iii) Levelling work

(iv) Drainage studies and hydrological data

(v) Soil survey

(vi) Material survey

(vii) Traffic studies

Primary traverse

The first step in the preliminary survey is to establish the primary traverse, following the alignment recommended in the reconnaissance. For alternate alignments either secondary traverses or independent primary traverses may be necessary. As these traverses are open

traverses and adjustment of errors is not possible later, the angles should be very accurately measured using a precision theodolite. The length of the centre line should be measured using very good and accurate chaining methods or by tachometry or by modern distance measuring instruments

Topographic features

After establishing the centre lines of preliminary survey, the topographical features are recorded. All geographical and other man made features along the traverse and for a certain width on either side are surveyed and plotted. The width to be surveyed is generally decided by the survey party, but the absolute minimum width is the land width of the proposed alignment.

Levelling work

Levelling work is also carried out side by side to give the centre line profiles and typical cross sections. Permanent and temporary bench marks should be first established at appropriate locations and the levels should be connected to the GTS datum. The levelling work in the preliminary survey is kept to a minimum just sufficient to obtain the approximate earth work in the alternate alignments. To draw contours of the strip of land to be surveyed, cross section levels should be taken at suitable intervals, generally 100 to 200 m in plain terrain, up to 50 m in rolling terrain and up to 30 m in hilly terrain.

Drainage studies and hydrological data

Drainage investigations and hydrological data are collected so as to estimate the type, number and approximate size of cross drainage structures. Also, the vertical alignment of the highway, particularly the grade line is decided based on the hydrological and drainage data, such as HFL, ponded water level, depth of water table, amount of surface runoff, etc.

Soil survey

Soil survey is an essential part of the preliminary survey soil as the suitability of the proposed location is to be finally decided based on the soil survey data. The soil survey conducted at this stage also helps in working out details of earth work, slopes, suitability of materials, subsoil and surface drainage requirements and pavement type and the approximate thickness requirements. All these details are required to make a comparative study of alternate proposals. At this stage, a detailed soil survey is not necessary. Post-hole auger or

any other suitable types of hand augers may be used depending on the soil type to collect the soil sample up to a depth of 1 to 3 meter below the likely finished road level or the existing ground level, whichever is lower. When the road is expected to be constructed over an embankment, the depth of exploration should extend up to twice the height of embankment from the ground level. During the soil exploration if the ground water table is struck, the depth from the ground surface is also noted. When the work has to be done rapidly, geophysical method of soil exploration is, best suited as accuracy is not very important during the preliminary survey. The electrical resistivity method is commonly used in road projects. The method is based; on the principle-that-the earth and rock materials may be identified by the different) values of the resistance to flow of a direct current. The soil samples collected during the field work are subjected to identification and classification tests in the laboratory. Soil profile is obtained drawing the longitudinal section along the proposed road alignment up to the depth of exploration the types of soils encountered along the route up to the depth under consideration are; marked on the soil profile either symbolically or by suitable colour coding.

Material survey

The survey for naturally occurring materials like stone aggregates, soft aggregates, etc. and identification of suitable quarries should be made. Also, availability of manufactured materials like cement, lime, brick, etc. and their locations may be ascertained.

Traffic survey

Traffic surveys conducted in the region form the basis for deciding the number of traffic lanes and roadway width, pavement design and economic analysis of the highway project; Traffic volume counts of the classified vehicles are to be carried out on all the existing roads in the region, preferably for 24 hours per day for seven days. Origin and destination surveys are very useful for deciding the alignment of the roads. This study may be carried out on a suitable sample of vehicle users or drivers. In addition, the required traffic data may also be collected so that the traffic forecast could be made for 10 to 20year periods. Determination of final centre line. After completing the preliminary surveys and conducting the comparative studies of alternative alignments, the final centre line of the road is to be decided in the office before the final location survey. For this, the preliminary survey maps consisting of contour plans, longitudinal profile and cross sections of the alternate alignments should be prepared and carefully studied to decide the best alignment satisfying engineering, aesthetic and

economical requirements. After selecting the final alignment, the grade lines are drawn and the geometric elements of the horizontal and vertical alignments of the road are designed.

d) Final Location and Detailed Survey

The alignment finalized at the design office after the preliminary survey is to be first located on the field by establishing the centre line. Next detailed survey should be carried out for collecting the information necessary for the preparation of plans and construction details for the highway project. Location The centre line of the road finalised in the drawings is to be transferred on the ground during the location survey. This is done using a transit theodolite and by staking of the centre line. The location of the centre line should follow, as closely as practicable, the alignment finalised after the preliminary surveys. Major and minor control points are established on the ground and centre pegs are driven, checking the geometric design requirements. However, modifications in the final location may be made in the field, if found essential. The centre line stakes are driven at suitable intervals, say at 50 metre intervals in plain and rolling terrains and at 20 metre in hilly terrain. Detailed survey Temporary bench marks are fixed at intervals of about 250 m and at all drainage and under pass structures. Levels along the final centre line should be taken at all staked points. Levelling work is of great importance as the vertical alignment, earth work calculations and drainage details are to be worked out from the level notes. The cross-section levels are taken up to the desired width, at intervals of 50 to 100 m in plain terrain, 50 to 75 m in rolling terrain, 50 m in built-up areas and 20 m in hilly terrain. The cross sections may be taken at closer intervals at horizontal curves and where there is abrupt change in cross slopes. All river crossing, valleys etc. should be surveyed in detail up to considerable distances on either side. All topographical details are noted down and also plotted using conventional signs. Adequate hydrological details are also collected and recorded. A detailed soil survey is carried out to enable drawing of the soil profile. The depth up to which soil sampling is to be done may be 1.5 to 3.0 m below the ground line or finished grade line of the road whichever is lower. However, in case of high embankments, the depth should be up to twice the height of the finished embankment. The spacing of auger borings very much depends upon the soil type and its variations. CBR value of soils along the alignment may be determined for designing the pavement.

Note: For any queries / clarifications, contact

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