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History of Roads and Road Construction

1·1. Introduction

Transport has a very important role to play in general development of the country and specially in its economic development. It has been described as veins and arteries for the flow of the economy of the nation. In a vast developing country like ours the goal of industrial development can only be achieved through an efficient transportation system of wide and varied nature. Our social, cultural and political institution can be built up and life of the people in general can be enriched only through efficient transportation system. In the absence of suitable transportation network, life would get confined to the primitive style of *adivasis* and the tribals living in remote mountains and jungles. Though our transportations system compares nowhere with that of the advanced countries, yet it has helped in the elimination of famine and reduction of diseases and distribution of consumer goods and their necessities. It has helped in maintaining peace and order of the country and improved defence of the nation.

India is a vast country and stands second in population and seventh in area of the world. It has vast quantities of natural resources like minerals, water, resources, forest and agricultural resources and has most varied terrain in the world. It has a number of attractive hill stations, beautiful sea-beaches, charming scenic spots and beautiful snow clad peaks. On the other hand, it has thousands of undeveloped villages lacking elementary amenities like water, sanitary facilities not to say of electricity and transport facilities. Inspite of considerable achievements of the country during the last quarter of a century, and in spite of a few heavy industries and numerous small scale industries, it still comes under the category of a backward underdeveloped country. Apart from other shortcomings one of the main reasons for backwardness of the nation is its disorganised transport system. Other factors being lack of financial resources, inadequacy of management skills and want of determination and the will for achievement.

The transportation system in India comprises of distinct services such as railways, roads, shipping, inland water transport, airlines, ropeways and pipe lines. These topics will be discussed in the respective parts that follow. In order to have proper co-

co-ordination between the above mentioned various modes of transportation, special emphasis has to be laid on advance planning for making the right type of transportation available where needed.

Realising the need of coordinate approach to the problem of transportation systems of the country, Government had set up a Committee on Transport Policy and co-ordination for the country. The committee submitted its report to the Government in Feb. 1966. The committee recommended the urgent need for developing each mode of transport system with respect to its individual demand as well as in relation to the rest of transport system.

To understand the importance of transport in India, it would be illuminating to compare the investment in transport in terms of total investment of the various five-year plans. In the first three five-year plans against a total investment of approximately Rs. 22,000 crores, the allotment for the expansion of transport facilities amounted to Rs. 4250 crores *i.e.* 19%. In the Fourth Five-Year Plan the total investment on transport of Rs. 3245 crores formed 20% of the total outlay. In the Fifth Five-Year Plan the proposed investment of Rs. 5700 crores against a total outlay plan of Rs. 37,250 crores forms just over 15%. The various modes of transportation in order of their importance are as below—Railways, roads, shipping, ports and harbours and inland water transport, air transport. Pipe lines, ropeways, and conveyors are specialised modes of transportation, for specific purposes.

1·2. Development of Transport Systems in India

The various modes of transport mentioned above are detailed below with a view to give their historical developmental background.

(1) **Railways**. The Indian Railways are the second biggest railways of the world. In 1973-74 its capital investment was approximately Rs. 4,000 crores and assets of Rs. 5,000 crores. It employs 20 lakh people with an annual revenue of approximately 1200 crores. It is the largest industry in the country. Every year 2500 million passengers and 200 million tonnes of goods are transported by the Indian Railways. Among its assets are about 4 lakh freight wagons, thirty thousand passenger coaches and eleven thousand locomotives.

During the first two Five Year Plans about 1900 km of track was doubled. During Third Five-Year Plan approximately 3200 km was doubled. During Fourth Five Year Plan 2500 km track was doubled in addition to some conversion from metre gauge to broad-gauge was undertaken.

The electrification and dieselisation of traction has also been taken up during the Second and Third Five Year Plans when about 2100 km of track was electrified.

The Chittaranjan Locomotive Works and the Integral Coach Factory at Perambur, near Madras, have contributed considerably

in achieving self sufficiency in wagons, coaches, trade material and mechanical signalling equipment.

The outlay on railways during the first three Five-Year Plans was respectively Rs. 423 crores, 1014 crores and 1686 crores. The Fourth Five-Year Plan provided Rs. 1575 crores The Fifth Five-Year Plan provides Rs. 2350 crores.

The capacity of additional passenger trains is limited on account of the availability of engines, adjusting timings etc hence efforts have been made to increase the number of bogies per train. Inspite of the considerable raise in freights, the Indian Railways are the cheapest as compared to the other railway systems of the world.

(2) **Roads.** The various phases of the development of roads in India are as given below—

Ancient Roads. Excavation of Mohanjodaro and Harappa indicate that the science of road construction was known in India as early as 3500 B.C. In the sixth century B.C. King Bimbisara constructed a pucca road in Rajgir in Patna district. During the regime of Ashoka (about 270 B.C.) there was a good network of roads in India.

Mughal Roads. Sher Shah Suri (1540—1545 A.D.) constructed the longest road from Lahore to Calcutta on which the present G.T. Road (National Highway No. N.H. 1) has been constructed.

Roads in British Period. The first systematic road organisation in the form of central and state P.W.Ds. were formed during the regime of Lord Dalhousie (1855). At the same time the first Indian Railways organisation was set up prior to that roads in India were built by the British Military Engineers. In the year 1919 because of growing importance of railways, roads became a provincial subject under Montague Chelmsford Reform. This resulted in a great setback to the road activity both in regard to quality and the extent.

In the year 1927, the Indian Roads and Transport Development Association (I.R.T.D.A.) was set up having head office at Bombay and branch offices at Delhi, Gauhati and Madras with a view to study the transport problems of the country. A committee known as Jayakar Committee was formed by the Central Government on the recommendation of I.R.T.D.A. in 1927. Jayakar Committee gave its recommendations in 1928 and according to these recommendations a Central Road Fund was created in 1929 by additional taxation of two annas (12 Paise) per gallon of petrol. 20% of the revenue thus raised was kept by the Central Government as reserve for administration of the fund, research, collection and dissemination of technical information and for giving grants for promotion of communication facilities between the states. The remaining 80% was allotted to the state in proportion to the collection from the sale of petrol. In 1930 Central Road Organisation was set up.

In December 1934 a semi-Government body named as Indian Road Congress (I.R.C.) was founded and constituted, with its

headquarters at New Delhi to provide forum for regular pooling up the information, knowledge and experience for all matters affecting the construction and maintenance of roads in India ; to recommend standard specifications and to provide a platform for the expression of professional opinion on matters relating to road engineering.

In the year 1939 Motor Vehicle Act was enacted for the administration of road transport.

Since the roads had become provincial subject after 1918, there was very little of standardisation and uniformity in the design, construction and development of roads in the country. To overcome this difficulty, in Dec. 1943 the Chief Engineers Conference was held at Nagpur and resulted in the nationalisation and classification of roads in the country. The road system was divided into the following four categories :

1. National Highways,
2. Provincial Highways.
3. Major District Roads and Other District Roads.
4. Village Roads.

The conference also recommended that the planning, construction and maintenance of National Highways should be the responsibility of the centre. This resulted in the Government of India taking over National Highways in 1947, though it was in 1956 that they became central subject under the Highway Act.

Roads in Free India. To look after interests of road transport in particular the Motor Vehicle Taxation Enquiry Committee was constituted in 1950 and a major step in the production of roads in general was taken in 1952 with the establishment of Central Road Research Institution by the Council of Scientific and Industrial Research (C.S.I.R.).

The outlays for first four Five-Year Plans for roads were respectively as follows : Rs. 109 crores, Rs. 269·5 crores, Rs. 440 crores and Rs. 871 crores. The Fifth Five-Year Plan provides for an investment of Rs. 1800 crores. The total length of roads in India is approximately 13 lakh km, two-third of which has been constructed during the last twenty five years. Approximately one-third of these roads are surfaced, one-third all weather motor roads and remaining kutcha village roads.

The working of the First Five-Year Plan showed that the planning of road construction for a five year is not satisfactory. The spade work required in the form of finalising alignment, acquiring land etc. is considerable and time consuming. In a number of cases the planned projects remained incomplete at the end of the period and accordingly a long term plan for roads in India known as Bombay Plan (Aug. 1958) was formulated for a period of 20 years (1961—81) which holds the field at present.

The basis of the 1958 Bombay Plan was that no village in developed agricultural area should remain more than 6·4 km from metallic road or 2·4 km for any type of road. In the Nagpur plan

16 km of road per 100 sq km was proposed, this was to be doubled by 1981, *i.e.* 32 km for 100 sq km.

To give special emphasis to the rural roads, government set up a committee in 1968 which laid down specifications and recommended setting up of a high level Rural Road Board in each state.

The volume of traffic has considerably grown up and at the same time the size, capacity and carrying capacity of vehicles has increased. It is, therefore, necessary to modernise the existing system on scientific lines. The main difficulty in the way of reducing transit time is the existence of numerous tax posts which takes away as much as 50% of transit time. This is because of absence of all India permits for goods vehicles. Recently all India permit system of goods and other vehicles in limited cases has been introduced. This will lessen the transit time and improve the transportation.

On 24th Oct, 1973 the Highway Research Board of Indian Roads Congress was inaugurated. This board is to advise the government about the research programme and recommend priorities about various road research problems.

Experience has shown that the road development activity of the nation had a setback due to the various administrative hold-ups. The Indian Roads and Transport Development Associations have advocated autonomous "Road Board" at various state levels on the lines of the Railway Board. Such a board would channalise road revenues and eliminate uncertainty of funds. This board would also undertake survey on traffic data, information about new roads etc. The National Seminar on Transportation organised by the Institute of Engineers India in Feb. 1975 (17—19 Feb.) at Lucknow has also recommended the formation of Road Boards.

3. **Shipping**. India has been a shipping nation for a long time. India was pioneer in sea trade with foreign countries long before the rise of European maritime countries. However, under the British Rule, the country got a setback. In 1945 Shipping Policy Committee recommended, that the shipping tonnage be increased and that coastal trade be reserved for Indian Ships.

As compared to total Indian shipping tonnage of 2·5 lacs in 1947 it increased to 1 million tonnes in 1963 and 3 million tonnes at the end of the forth plan and would increase to 8·6 million tonnes at the end of the Fifth Five-Year Plan. At the end of the Fifth Five-Year Plan we would be handling over 20% of our over-seas trade.

The total investment on major ports during the first three five year plans was Rs. 141 crores and that in the fourth five year plan was Rs. 299 crores. As a result of this the existing 60 million tonnes capacity of the ports would be increased to 100 million tonnes. At the end of the Fifth Five-Year Plan which envisages an expenditure of Rs. 350 crores, the capacity of the ports would further increase to 115 million tonnes.

4. **Inland Water Transport.** The inland water transport in India is confined mostly to North-eastern region, the Ganga river system, and in the South Kerala. Out of a total length of about 13,500 km, only about 20% is navigable. The Committee on Transport Policy and Coordination recommended the development of inland transport in each area within the framework of the transport plan of each region. During the first two Five-Year Plans an expenditure of Rs. one crore was made whereas Rs. four crores were spent in the three five year plans against an outlay of Rs. 7·5 crores. The Fouth Five-Year Plan had an outlay of Rs. 12 crores for investment on Inland Water Transport to provide terminal facilities and road training works and river conservancy. An allocation of Rs. 47 crores has been made in the Fifth Five-Year Plan, for improving the existing routes and opening new routes, modernization of barges and conservancy of rivers.

5. **Air Transport.** In the sphere of Air Transport, spectacular progress has been achieved during the post independence period. In 1953, a number of companies operating various types of aircrafts were merged and Indian Airlines Corporation was formed. In 1966 the corporation had 5 Caravelles, 12 Viscounts, 10 Fokker Friendship, 3 Skymasters and 34 Dakotas. It could carry 1·4 million passengers and 479 tonne-kilometre of freight. During the same period, Air India, the other corporation operating foreign air services, registered a six fold increase. The capacity of Air India became double during the Third Five-Year Plan itself. The outlay during the first three Five-Year Plans was Rs. 126 crores, whereas the Fourth Five-Year Plan provided an outlay of rupees 203 crores. The Fifth Five-Year Plan provides for an outlay of Rs. 3,915 crores for Indian Airlines and Rs. 110 crores for Air India.

Because of the comparatively high operational costs, coordination of air services with other modes of transport is very limited but with the advancement in the air transport technology by way of introduction of large commercial planes, co-ordinated operation may become a reality.

6. **Pipelines and Ropeways.** This mode of transportation has appeared in the transport scene rather recently. Pipe line is useful for transportation of liquids and gases over difficult train. They are being used for the transport of petrol, oil and lubricants (POL)

Ropeways are useful for comparatively short hauls where other modes of transport are very expensive or not feasible.

The total annual carrying capacity of ropeways, mostly in eastern region, is about 34 million tonnes.

Having dealt with the various transport systems it would be desirable to study the efforts made in the direction of coordination of the various modes of transportation so that each system develops in its own field without being hindered by the development of another system.

The Committee on Transport Policy set up in 1966 recommended that the various modes of transport should develop as com-

plementary services so that each system gives the best to the nation. To achieve this, the following points were suggested :

(*i*) Joint rail-road transport for passengers and goods facilities through arrangements arrived at mutually between the Indian Railways and State Road Transport Corporation.

(*ii*) Development of Operation of Central and State Road Corporations with the participation of the Indian Railways.

(*iii*) Existing public enterprises to become Corporation or Companies.

The latest thinking on the co-ordination of the various modes of transport has been given in the reco nmendations of the National Seminar on Transportation organised by the Institution of Engineers India, 17 to 19 Feb. 1975. The recommendation of this Seminar are as below :

1. No individual form of transport can be prescribed universally as being better than the other. Each area and region must be studied in its entirity and a combination of most suitable form of transport adopted.

2. There is an urgent need for an over co-ordinating authority at the national level for implementing the programme approved by the Planning Commission and to ensure that adjustments are made to obtoin maximum benefit from various modes of transport towards overall economic growth.

3. An Institution of Transportation Technology and Economics be set up for undertaking in depth, studies for various transport problems and comparative cost of different modes of transport to guide the Planning Commission in allocation of overall resources so that development of different modes of transport may proceed with correct priorities. To indicate awareness of transportation problem, Transportion Technology be introduced in academic institutes and Engineering Colleges.

4. To ensure that the transportation has a possible influence on the growing economy, 'Transporation' as a whole must be treated as a part of the "CORE SECTOR".

5. For the development of any mode of transport a separate approach should be adopted covering all the elements like the industry, the operating organisation and the Government agencies.

6. Railways play a major-role in movement of bulk materials and long distance freight and passanger traffic. It is in these areas that the development of railways must be accorded priority by introducing "Unit Trains" for bulk traffic containerisation, providing mechanised loading and unloading and creation of dumps and stock yards.

7. There is an urgent need to set a Road Board to co-ordinate all new construction right down to the district level, at centre and state level, to plan development and maintenance of roads from centre to state level.

8. The existing highway need to be improved and strengthened using modern techniques to take projected volume of traffic and should cater for truck-tractor combination and heavy vehicles.

There is need for joint studies of road transport and road problem to arrive at a balance between road construction and improvement programme as well as types and sizes of vehicles to be used.

9. A network of feeder roads for the villages should be developed to take animal transport which will continue in India for a long time. Efforts should be directed to improve their per-performance, safety and economy.

10. Priority should be given on public transport to meet the need of metropolitan cities to avoid congestion by increasing private vehicles.

11. Bulk improvement by use of pipe line should be explored.

12. Inland water transport and coastal transport are an accepted mode of cheap transportation for several commodities in specified regions and should play an effective role in the overall transportation system in the country. To ensure this, necessary financial, technical and managerial inputs must be provided.

13. Ports both major and minor, are essential links in the "Through Transportation Concept" and their ability in fulfilling this concept should be ensured through :

(*a*) Adequate traffic.

(*b*) Development of technical potential particularly modern high speed handling technique.

(*c*) The provision of matching intrafractual facilities like roads, railways and inland water transport to bring traffic from these ports.

(*d*) Result oriented management and stream line operational and commercial procedures.

14. Coastal shipping is an important and low energy consumption mode of transportation for our country having a long coastal line. Every encouragement including reservation of cargo for economical coastal movement is necessary. Technical inputs like suitable ships, proper draughts and handling facilities in the ports should be ensured so that this mode of transport can acquire its rightful place in the country's transportation system.

15. Because of the capital intensive nature of the industry and its higher rate of growth of both passenger and cargo traffic *vis a-vis* other modes, Air Transport requires for its development a viable long term plan and adequate fund for capital projects.

16. In view of the very large investment involved in air field pavement construction, engineering efforts should continue to prepare economical design to the extent possible, consistent with

safe and comfortable operation of all aircrafts expected to use the pavements.

17. Airfield evaluation procedures should be developed which permit a precise assessments of aircraft—airfield compatibility because only then can both the aircraft and airfield be used to the optimum extent without any detrimental effects.

1·3. Roads as a Means of Communication

Transportation of men, material and information can be effeced by air, sea and land. Railways and roads play important part in transportation on land.

In the case of railways the tractive resistance of steel wheel on a steel rail is only 20% of pneumatic tyre on a modern highway. The railway truck can carry high axle loads many times greater than the road. These benefits are there in a flat country having very small gradients. The road gradients can be five times steeper than railway gradients. Hence in such places the road transport is faster.

As the roads can reach the consumer directly, the handling charges at the starting and destination points for roads are much less than those in the case of railways.

It is by roads only, the goods and passengers can be transported from railway stations, harbours and aerodromes.

Roads thus will form an integral system of transportation. from one place to another for light traffic and short distances. It will be also cheaper as handling charges are very low.

For longer distances, transport by rail, water or air becomes convenient and cheaper.

1·4. History of Road Construction

Roads as a primary means of communication in some form or the other came into existence with the creation of mankind. Even when people lived as nomads they used some type of track. Road building as a science however was first started during the Roman Empire. Their roads were classified as

(*i*) Roads made of levelled earth (*Via Eterrenae*)
(*ii*) Roads made of gravel surface (*Via Glareatae*)
(*iii*) Roads paved with rectangular or multifaced stone blocks (*Via Munitae*)

Most of the Roman roads, however, were of very high specifications using various sizes of broken stones and limes as cementing or building material. The lime concrete used by the Roman was a mixture of lime, loose volcanic rock and sand. Typical cross-section of Roman road consisted of foundation stones in lime mortar as soling or foundation course. Over this a layer of lime concrete using broken stones was used. On top of this a layer of compacted loam was used. On the top of compacted loam a variable thickness of lime concrete using gravel as base course was provided and the top layer consisted of stones slabs laid in lime grout. It would thus be seen that the safety and durability of the road surface had

over the cost aspect. Such a road, if constructed at the present time would be laughed at except in the case of very high traffic and extreme climatic conditions. A typical section of such a Roman road is given in Fig. 1·1.

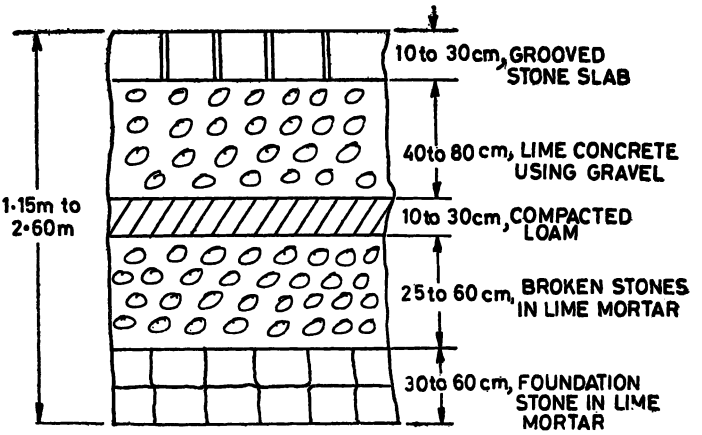

Fig. 1·1. Typical section of Roman Road.

The archaeological findings in India like excavation of *Mohanjodaro* and Harappa indicate that the science of road consrtuction was known in India about 3500 B.C. In Rigveda (5000 B.C.) the highways have been called *Maha Paths*.

Road making as a building science was started by the French. In 1597, French Engineer Sully was the first to use broken stones for road construction work.

Another French Engineer Tresguet laid the foundation for the modern road construction technique. The practice of digging the ground to provide bottom or base course was started by him along with the concept of providing slope at the subgrade stage to drain away the water which got into the bottom of the road for mation through seepage. He also provided top camber for quick and efficient drainage for the top surface. A typical *Tresguet's* section is given in Fig. 1·2.

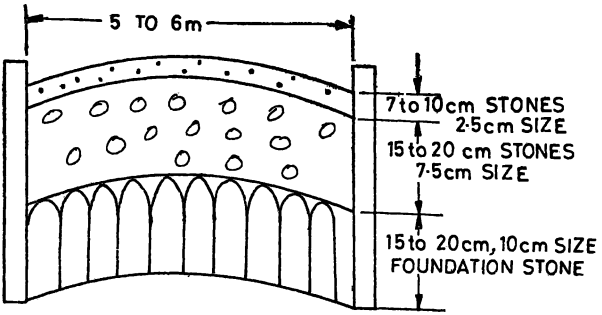

Fig. 1·2. Tresguet's Section.

The road foundation for modern highway construction was developed by *Telford* (1757—1834) and Macadam (1756—1836) almost simultaneously.

(*a*) *Telford Method.* The foundation was dug out and levelled and filled with large size stone such that bigger stones were laid towards the centre and smaller ones towards the edges. The size of the central stone being 15 to 20 cm diminishing to 7 to 10 cm at the edges. The central 5·4 m width of road was covered with two layers of stones 10 cm. and 5 cm thick respectively and the size of stones was 7·5 cm grade. The side portions were made up of only one layer of broken stones and levelled off to give a suitable camber or cross fall upto 1 in 60. On the top formation of the road thus formed 4 cm thick binding layer of gravel was spread, watered and consolidated by traffic. In order to drain of the water which percolated to the bottom cross drains at interval of 30 to 50 metres were provided. A typical Telford section is shown in Fig. 1·3.

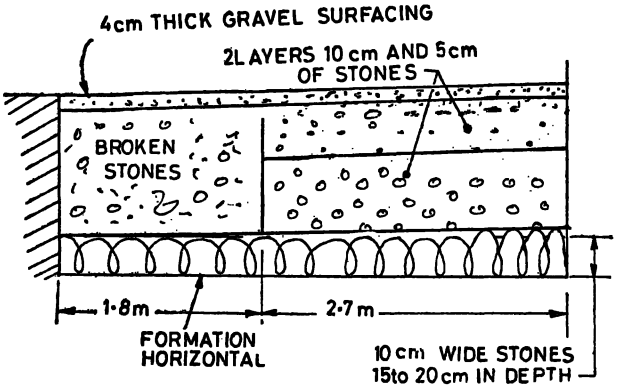

Fig. 1·3. Telford Section.

(*b*) *Macadam construction.* Main difference between Telford and Macadam construction is that whereas the subgrade formation in the case of Telford construction is level thereby making it necessary to have a provision of cross drains, in the case of Macadam type construction the formation at the dug up stage is kept cambered thereby providing normal drainage of the percolated water to the sides.

Broken stones are placed in two or more layers such that they could be properly compacted. The voids between the stones are filled up by the powder formed by the attrition of stones under traffic. The finising coat of 5 cm thickness consists of angular fragmentes of stones upto 2 5 cm size. Smaller sized stones are used at the wearing surface level at the top, the reason having been explained by Mr. Macadam himself as "The size of a stone used on a road must be in due proportion to the space occupied by a wheel of ordinary dimensions on a smooth level surface. This point of contact will be found to be longitudinal about 1″ (2·5 cm) and every piece of stone put into the road which exceeds 1″ (2·5 cm) in any of its dimension is mischievious."

The modern water bound Macadam road consists of broken stones consoliated under a roller in layers so as to provide effective consolidation. The binder material which holds the stones in position is the stone dust formed during rolling of the stones. In practice the most effective binding material has been found to be the quarry dust formed during the crushing of the boulders and stones in crushers at the quarry site. Water is used to form the slurry or the paste which helps in the binding and hence the term water bound macadam.

For Indian conditions the WBM roads are quite suitable upto 2000 tonnes of daily traffic. For higher traffic and for longer life of the pavement bitumen treatment by way of surface treatment, semi greuting, bitumen road mixes, plain mixes, hot mixes and cold mixes are provided.

(*c*) *Concrete pavements.* For excessive loads and stresses cement concrete, plain or reinforced is used as a pavement. Its main advantage is its long comparatively maintenance free life which provides a smooth finished surface with low resistance to traffic flow. In this jet aircraft age this the only surface which can withstand the extreme heavy stresses.

Initial cost of concrete roads is comparatively high. Secondly cutting of the slab after construction for laying the underground cables and sewers is difficult as well as costly. However, because of the dominating advantages, in the developing and developed countries, for important highways, as far as possible perference is always given to concrete pavement.

(*d*) *Earth Roads.* This is a low cost road recommended for traffic upto 500 tonnes/day consisting of one-third of low traffic and remaining truck loads below 5 tonnes. The bridges and culverts are designed for 10 tonne road roller. In the Seminar on low cost roads and soil stabilisation organised by the Economic Commission for Asia and the Far East held in New Delhi in January 1958 (ECAFE) the low cost roads have been defined as "rods constructed at low cost and capable of being maintained at low cost".

Width of the road between edge of one shoulder to the edge of another shoulder, varies for 6 to 7·2 m. For quick and effective draining of water a cross slope or camber of 1 in 18 to 1 in 24 is provided. To reduce dust nuisance use of oils has proved effective provided the soil is not sandy.

For cheap all-weather road a coarse well graded gravel has been found very satisfactory, for upto 4000 tonnes traffic per day.

(*e*) *Traffic Bound Macadam Roads.* Basic material of road construction consists of crushed stones gravel or slag and instead of using rollers, consolidation is left to be done under traffic. On account of natural cementing properties, lime stone has been found to give most satisfactory results.

(*f*) *Water-Bound Macadam Roads.* Strictly speaking this category of road does not fall under the classification of low coat road. The base course consists of bigger stones or boulders or

bricks and only the wearing coat consists of broken stones of irregular shape keyed together by consolidation under a roller, the stones themselves get wedged in position. The smaller stones prevent the dislocation of their position. In such cases the cost of construction is comparatively less and can be termed as a low cost construction. As compared to the cost, the load carrying capacity is fairly large upto 2000 tonnes per day. This capacity can further be improved by bituminous surfacing.

(*g*) *Gravel Roads.* It is a road constructed of graded gravel from fines to pebbles containing binding material such as clay, in two courses, mainly foundation or base course and wearing coat. For higher traffic 15 cm is adequate whereas for heavy traffic 30 cm would be adequate. Size of gravel may vary from 5 to 1 cm. Presence of 10 to 15 per cent of fines passing 200 mesh ASTM (75 micron I.S.) sieve is considered adequate to fill the voids. Normally admixture of fine clay is done with twice its quantity of sand. Consolidation, if done with road roller should be such that the consolidated thickness does not exceed 10 cm layer at a time. Sometimes, for comparatively light traffic, consolidation is left to be done by traffic alone.

(*h*) *Kankar Road.* This is another cheap road material which may be used for construction of complete road where the traffic intensity is comparatively less such as village road. District roads and other district roads or it may serve as a subgrade for cement concrete or water bound pavements. Its usefulness is limited to locality where suitable kankar stone quarries are available. The size of kankar useful for road work is from 7·5 to 2 cm gauge.

(*i*) *Brick Pavements.* For light traffic such as in town streets brick flooring laid over 5 to 8 cm of consolidated stone or lime concrete or lean concrete has also been found be quite economical and satisfactory. If previously laid hard surface is available, a 5 cm coarse sand cushion may be provided below the brick.

(*j*) *Soil Stabilised Roads.* Soil stabilisation is either a physical process or physio-chemical or chemical or a combination of these processes by means of which the load bearing property of the soil may be improved and it becomes more stable. Soil stabilisation may be done with a view to reducing the cost of the road building material or in the case of comparatively light traffic the natural surface improved by stabilisation may itself form the road surface. These types of roads are specially suitable for developing countries like India where locally available material is used for stabilisation with the ultimate arm of effecting reduction in the initial construction cost of the highway pavement.

The stabilisation may be done by one of the following methods :

(*i*) Mechanical stabilisation
(*ii*) Cement stabilisation
(*iii*) Lime stabilisation
(*iv*) Bitumen stabilisation.

Three main constituents of soil are sand, silt and clay. In natural soil they combine in limitless forms but very rarely is the combination such as to give load bearing and weather resistance properties. The process of adjusting proportion of these basic constituents by compaction under optimum moisture content conditions or by addition of suitable admixtures is known as soil stabilisation.

QUESTIONS

1. Briefly describe the historical developments of roads in India. (*I.R.S.E., 1960*)

2. (*a*) What factors were responsible for the suppression of road activities in the latter half of the nineteenth century ?

What is 20-year Road Development Plan ? When was it formulated ? What are its mileage targets ?

(*b*. Name the various associations that are promoting highway research in India. (*Punjab University, 1958*)

3. Describe briefly the poineer contribution by Tresaguet Telford and Macadam to road improvement a scientific nature. (*Punjab University, 1950*)

4. Roads are the red carpets on which prosperity and civilization spread. 'Comment'. (*U.P.S.C., 1975*)

5. Give the names of the different categories of roads constructed in India. (*A.M.I.E., Nov. 1968*)

6. Dintinguish between water boun d Macadam and Telford roads. (*A.M.I.E. Nvo. 1975*)