CHAPTER 1 :

INTERNSHIP

An **internship** is a period of work experience offered by an organization for a limited period of time. Once confined to medical graduates, internship is used for a wide range of placements in businesses, non-profit organizations and government agencies. They are typically undertaken by students and graduates looking to gain relevant skills and experience in a particular field. Employers benefit from these placements because they often recruit employees from their best interns, who have known capabilities, thus saving time and money in the long run. Internships are usually arranged by third-party organizations that recruit interns on behalf of industry groups. Rules vary from country to country about when interns should be regarded as employees. The system can be open to exploitation by unscrupulous employers.Internships for professional careers are similar in some ways. Similar to internships, apprenticeships transition students from vocational school into the workforce. The lack of standardization and oversight leaves the term "internship" open to broad interpretation. Interns may be high school students, college and university students, or post-graduate adults. These positions may be paid or unpaid and are temporary. Many large corporations, particularly investment banks, have "insights" programs that serve as a pre-internship event numbering a day to a week, either in person or virtually.

Typically, an internship consists of an exchange of services for experience between the intern and the organization. Internships are used to determine whether the intern still has an interest in that field after the real-life experience. In addition, an internship can be used to build a professional network that can assist with letters of recommendation or lead to future employment opportunities. The benefit of bringing an intern into full-time employment is that they are already familiar with the company, therefore needing little to no training. Internships provide current college students with the ability to participate in a field of their choice to receive hands-on learning about a particular future career, preparing them for full-time work following graduation.

Employers too benefit from an internship arrangement as it gives access to interns with some skills to execute relevant tasks for the employer. Many interns end up with permanent service with the same organization in which they are interned. Their worth to the organization may be greater than before by the fact that they require modest or less training.

An internship may be compensated, non-compensated or some time to some extent paid. Paid internships are usually the norm in fields like medical and health science, engineering, laws and politics, business, graphic design accounting, banking and finance, information technology, media, journalisms, hospitality and tourisms whereas unpaid Internships are common.

Internships may be part-time or full-time; in general, they are part-time during the academy year and full-time in the summer vacations. They usually last for four weeks to two months, its tenure varies from organization to organization, it may be shortening or long based on the organization for which they intern.

Since the 1990’s economic reforms in India, that’s bought a sea change in business and academic culture, internships have found a prominent place in the life of a business and management studies.

CHAPTER 2

PUBLIC WORKS DEPARTMENT (PWD): AN OVERVIEW

Public works department (PWD), under the Ministry of public works department, is the pioneer in construction arena of Karnataka. Over about four centuries, PWD could successfully set the trend and standards in the state's infrastructure development. It plays a pivotal role in the implementation of government construction projects. It also undertakes projects for autonomous bodies as deposit works. Public works department has highly qualified and experienced professionals forming a multi-disciplinary team of civil, electrical and mechanical engineers who work alongside Architects from the Department of Architecture. With its strong base of standards and professionalism developed over the years, PWD is the repository of expertise and hence the first choices among discerning clients for any type of construction project in Karnataka. Besides being the construction agency of the government, it performs regulatory function in setting the pace and managing projects for the country's construction industry under the close supervision of Ministry of Housing and Public Works. It is recognized as a leader and pace setter in the construction industry because of its consistently superior performance.

Successful operation of various schemes for the Public Works Department engineers and supervisory boards in different districts of the engineer's office has been settled by activities of planning, execution, quality control etc. remove impediments find joy in relation to the supervision over the activities are focused. Various schemes operated by the department are the Office of the regional Chief Engineers and Chief Engineers Office.

Public works in India, such as the construction of roads, water tank, etc. was originally conducted by the military. This started with the pioneers and then by the public works department of the town major's list (Bengal and Bombay) or the Effective Supernumeraries (Madras). Much of the responsibility about the public works was then passed over to a special section of the Indian Civil Service in the mid-19th century. Later, the military once more took responsibility for much of the public works.

Drawing attention of the Government to the unsatisfactory management and in public works, the Court of Directors of the East India Company, in early 1850, instituted a Commission in each presidency for investigation. The members of the Commission were unanimous on the inability of the Military Board in the management of public works. Lord Dalhousie founded the Public Works Department (PWD) through which roads, railways, bridges, irrigation and other public utility works were undertaken.

The Commission proposal, which was implemented in 1854, set out the following basic features:

- The control of PWD was removed from under the Military Board and placed under the Chief Engineers.
- The PWD came under the control of respective provincial Government.
- Chief Engineers to be assisted by the Superintending Engineer and Executive Engineer.

CHAPTER 3 : INTRODUCTION

A road is a thoroughfare, route or way on land between two places, which has been paved or otherwise improved to allow travel by some conveyance, including a horse, cart or motor vehicle. Roads consist of one, or sometimes two, roadways (carriageways) each with one or more lanes and any associated sidewalks and road verges. Roads that are available for the use by the public may be referred to as public roads or highways. Everyone is aware about the benefits and advantages of a good constructed road. Roads play very crucial role in modern society providing services and goods for modern people. Today a clear majority of roads are constructed using Asphalt. Now question arises in your mind is “What is Asphalt”? Asphalt is the sticky dark brown viscous liquid present in some natural deposits like crude petroleum. It is the name given to technically or natural mixture used in road construction for road surfacing and compaction.

Development of country depends on the connectivity of various places with adequate road network. Roads are the major channel of transportation for carrying goods and passengers. They play a significant role in the development of socio-economic standards of a region. Roads constitute the most important mode of communication in areas where railways have not developed much and from the basic infrastructure for the development and economic growth of the country. The benefits from the investment in road sector are indirect, long term and not immediately visible. Roads are important assets for any nation. However, merely creating these assets is not enough, it has to be planned carefully and a pavement which is not designed properly deteriorates fast. India is a large country having huge resources of material. If these local materials are used properly, the cost of the construction can be reduced. There are various type of pavements which differ in the suitability in different environments.

We see many roads daily and when we talk about the road construction, all are equally constructed but there is a difference arising in the finishing of the road or the surface material used for finishing. Asphalt, also known as bitumen concrete in engineering language is used to give flexible surface to roads. Asphalt roads offers many benefits such as smooth and flexible surface including cost efficiency, improved safety and comfort , durability, recyclability and reduction in noise pollution. Sometimes asphalt or bitumen are confused with tar. Although they are same in colour, they have distinct chemical properties. Tar was early used in road asphalt, but now has been refined bitumen or asphalt. Today asphalt is more commonly produced as the by-product of the refining process in the petroleum industry.

Road construction is not as easy as it seems to be, it includes various steps and it starts with its designing and structure including the traffic volume consideration. Then base layer is done by bulldozers and levellers and after base surface coating must be done. For giving the road a smooth surface with flexibility, asphalt concrete is used. Asphalt requires an aggregate sub base material layer, and then a base layer to be put into first place. Asphalt road construction is formulated to support the heavy traffic road and climatic conditions. It is 100% recyclable and saving non-renewable natural resources. With the advancement of technology, asphalt technology gives assurance about the good drainage system and with skid resistance it can be used where safety is necessary such as outside the schools. The largest use of concrete is for making asphalt concrete for road surfaces. It is widely used in airports around the world due to the sturdiness and ability to be repaired quickly, it is widely used in runways dedicated to aircraft landing and taking off. Asphalt is normally stored and transported at 150 degree Celcius temperature.

3.1 ROAD AND ITS TYPE

Roadways in India are the thread binding the topographical variations in India. The road network of India has proven its efficiency by providing its infrastructural contribution to the growth of Indian economy. India is a land of diversities and the Indian roads act as a national integration force providing the necessary adhesive for bringing the people from all corners together as easily as possible.

The road transport system in India is one of the widespread network. It spans the entire nation in the form of ring roads, flyovers, highways, expressways and freeways. The roadways travel has developed into an infrastructure strength that has given the Indian economy the necessary backbone support.

The road network in India especially in the more remote areas helps in the development of these regions by connecting them to nearby cities making the modern day facilities more accessible to them. Roadways of India has helped to enhance the productivity of certain areas and contributed to the evolving of a more competitive infrastructure and economy on the world level.

Road transport in India or roadways transport contributes to 60% freight or cargo transport and 80% passenger transport of India. These includes roadways buses, roadways express services, transport both public and commercial systems and others.

The various modes of transportation in India and the road infrastructure in India are under the management and administration of the respective state governments or respective union territory governments. The exemption is the national highways that is the central government responsibility and managed by National Highway Authority of India (NHAI).

3.2 CLASSIFICATION OF ROADS

Classification based on weather

- All weather roads: These roads are negotiable during all weather, except at major river crossings where interruption of traffic is permissible up to certain limit extent, the road pavement should be negotiable during all weathers.
- Fair weather roads: On these roads, the traffic may be interrupted during monsoon season at causeways where streams may overflow across the roads.

Classification based on the carriage way

- Paved roads: These are the roads which have a hard pavement surface on the carriage way.
- Unpaved roads: These are the roads without the hard pavement surface on the carriage way, usually they are earthen or gravel roads.

Classification based on the surface pavement provided

- Surface roads: These roads are provided with any type of bituminous or cement concrete surfacing.

- Un-surfaced roads: These roads are not provided with any type of bituminous or cement concreting surfacing.

Classification based on location and function

According to Nagpur plan, five different categories of roads are as follows.

- **NATIONAL HIGHWAYS (NH)**:
  National highways are the main highways running through the length and breadth of the country, connecting major ports, foreign highways, capitals of large states and large industrial and tourist centres including roads required for strategic movements of troops.
- **STATE HIGHWAYS (SH):**
  State highways are the arterial roads of a state, connecting with the national highways, capitals of adjacent states, district headquarters and important cities within the state. A state highway serves as a connecting link for traffic to and from district roads.
- **MAJOR DISTRIC ROADS (MDR):**
  Major district roads are the important roads within a district, serving areas of production and market and connecting them with each other or with main highways of a district.
- **OTHER DISTRICT ROAD (ODR):**
  Other district roads are the roads serving the rural areas of production and providing them with an outlet to market centres, Taluk headquarters.
- **VILLAGE ROADS (VR):**
  Village roads are the roads connecting villages or the groups of villages with each other to the nearest road of higher category.

CHAPTER 4 :

PAVEMENTS

A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favourable light reflecting characteristics and low noise pollution.

REQUIREMENTS OF A PAVEMENT

The pavements should meet the following requirements:

- Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil.
- Structurally strong to withstand all types of stresses imposed upon it.
- Adequate coefficient of friction to prevent skidding of vehicles.
- Smooth surface to provide comfort to road users even at high speed .

4.1 TYPES OF PAVEMENTS

FLEXIBLE PAVEMENTS

Flexible pavements will transmit wheel load stresses to the lower layers by grain to grain transfer through the points of contact in the granular structure. The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Taking advantage of these stress distribution characteristics, the lower layers will experience lesser magnitude of stress and less quality material can be used. Flexible pavements are constructed using bituminous materials. These can be either in the form of surface treatments (such as bituminous surface treatments generally found on low volume roads) or, asphalt concrete surface courses (generally used on high volume roads such as national highways).

Bitumen has been widely used in the construction of flexible pavements for a long time. This is the most convenient and simple type of construction. The cost of construction of single lane of bituminous pavements varies from 20 to 30 lakhs per km in plane areas. In some applications the performance of conventional bitumen may not be considered satisfactory because of the following reasons:

- In summer season, due to high temperature, bitumen becomes soft resulting in bleeding, rutting and segregation, finally leading to failure of pavement.
- In winter season, due to low temperature, the bitumen becomes brittle resulting in cracking and unevenness which makes the pavement unsuitable for use.
- In rainy season, water enters the pavement resulting into pot holes and sometimes total removal of bituminous layer.
- In hilly areas due to sub-zero temperature, the freeze thaw and heavy cycle takes place. Due to freezing and melting of ice in bituminous voids, volume extraction and contraction occurs.
- The cost of bitumen has been rising continuously. In near future there will be scarcity of bitumen and it will be impossible to procure bitumen at very high costs

4.2 TYPES OF FLEXIBLE PAVEMENTS

The following types of construction have been used in flexible pavement:

- Conventional layered flexible pavement
- Full depth asphalt pavement
- Contained rock asphalt mat (CRAM)

Conventional flexible pavements are layered systems with high quality expensive materials placed in the top where stresses are high, and low quality cheap materials are placed in lower layers.

Full depth asphalt pavements are constructed by placing bituminous layers directly on the soil sub grade. This is more suitable when there is high traffic and local materials are not available.

Contained rock asphalt mats are constructed by placing dense/open graded aggregate layers in between two asphalt layers.

4.2.1 RIGID PAVEMENTS

Rigid pavements have sufficient flexural strength to transmit the wheel load stresses to a wider area below. Compared to flexible pavements, rigid pavements are placed either directly on the prepared sub grade on a single layer of granular or stabilized material.

Since there is only one layer of material between the concrete and the sub grade, this layer can be called as base or sub base course. In rigid pavements, load is distributed by the slab action, and the pavement behaves like an elastic plate resting on a viscous medium. Rigid pavements are constructed by Portland cement concrete (PCC) and should be analysed based on plate theory instead of layer theory.

Rigid pavements though costly in initial investment, are cheap in long run because of low maintenance costs. There are various merits in the use of rigid pavements (concrete pavements) are summarized below:

- Bitumen is derived from petroleum crude, which is short supply globally and the price of which has been rising steeply. India imports nearly 70% of the petroleum crude. The demand for bitumen in the coming years is likely to grow steeply, far out stripping the availability. Hence it will be in India's interest to explore alternative binders. Cement is available in sufficient quantity in India, and its availability in the future is also assured. Thus cement concrete roads should be the obvious choice in the future road programmes.
- Besides the easy availability of cement, concrete roads have a long life and are practically maintenance free.
- Another major advantage of concrete roads is the savings in fuel by commercial vehicle to an extent of 14 to 20%. The fuel savings themselves can support a large programme of concreting.
- Cement concrete roads save a substantial quantity of stone aggregates and this factor must be considered when a choice of pavements is made.

- Concrete roads can withstands extreme weather conditions, wide ranging temperatures, heavy rainfall and water logging.
- Though cement concrete roads may cost slightly more than a flexible pavement initially they are economical when whole life costing is considered.
- Reduction in the cost of concrete pavements can be brought about by developing semi self compacting concrete techniques and the use of closely placed thin joints. R&D efforts should be initiated in this area.

TYPES OF RIGID PAVEMENTS

Rigid pavements can be classified into 4 types:

- Jointed plain concrete pavement (JPCP)
- Jointed reinforced concrete pavement (JRCP)
- Continuous reinforced concrete pavement (CRCP)
- Pre stressed concrete pavement (PCP)
- Jointed plain concrete pavement is plain cement concrete pavements constructed with closely spaced contraction joints. Dowel bars or aggregate interlocks are normally used for load transfer across joints. They normally has a joint spacing of 5 to 10 m.
- Jointed reinforced concrete pavements can drastically increase the joint spacing to 10 to 30m although reinforcements do not improve the structural capacity significantly. Dowel bars are required for load transfer. Reinforcement help to keep the slab together even after cracks.
- In continuous reinforced concrete pavement, complete elimination of joints can be achieved by reinforcement.

Factors affecting pavement design

Traffic and loading:
Traffic is the most important factor in the pavement design. The key factors include contact pressure, wheel load, axle configuration, moving loads, load, and load repetitions.

Contact pressure:
The tire pressure is an important factor, as it determines the contact area and the contact pressure between the wheel and the pavement surface. Even though the shape of the contact area is elliptical, for sake of simplicity in analysis, a circular area is often considered.

Wheel load:
The next important factor is the wheel load which determines the depth of the pavement required to ensure that the sub grade soil is not failed. Wheel configuration affects the stress distribution and deflection within a pavement. Many commercial vehicles have dual rear wheels which ensure that the contact pressure is within the limits. The normal practice is to convert dual wheel into an equivalent single wheel load so that the analysis is made simpler.

Axle configuration:

The load carrying capacity of the commercial vehicle is further enhanced by the introduction of multiple axles.

Moving loads:

The damage to the pavement is much higher if the vehicle is moving at creep speed. Many studies show that when the speed is increased from 2 km/hr to 24 km/hr, the stresses and deflection reduced by 40 per cent.

Repetition of Loads:

The influence of traffic on pavement not only depends on the magnitude of the wheel load, but also on the frequency of the load applications. Each load application causes some deformation and the total deformation is the summation of all these.

Environmental factors:

Environmental factors affect the performance of the pavement materials and cause various damages. Environmental factors that affect pavement are of two types, temperature and precipitation.

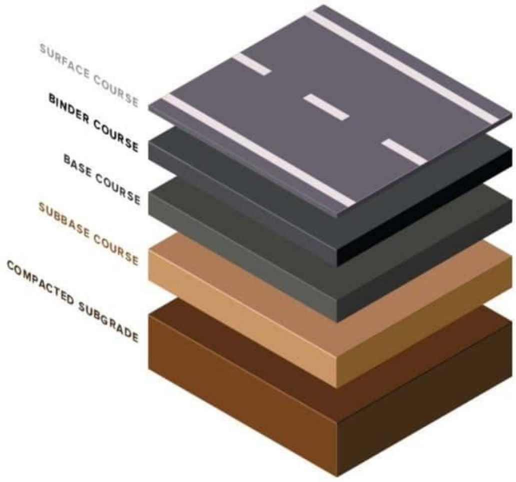
Equivalent single wheel load:

To carry maximum load within the specified limit and to carry greater load, dual wheel, or dual tandem assembly is often used. Equivalent single wheel load (ESWL) is the single wheel load having the same contact pressure, which produces same value of maximum stress, deflection, tensile stress or contact pressure at the desired depth.

Equivalent axle load factor:

An equivalent axle load factor (EALF) defines the damage per pass to a pavement by the ith type of axle relative to the damage per pass of a standard axle load. While _finding the EALF, the failure criterion is important. Two types of failure criteria's are commonly adopted: fatigue cracking and rutting.

4.2.1 Components of flexible pavement layer



Typical cross section of a flexible pavement

Surface course: Surface course or wearing course is the topmost layer of flexible pavement which has direct contact with the vehicular loads. Since it is directly in contact with traffic, good quality aggregates and high dense bitumen or asphalt is recommended for the construction of surface course. The main function of surface course is to provide skid resistance surface, friction and drainage for the pavement. It should be water tight against surface water infiltration. The thickness of the surface course generally provided is 25 to 50mm.

- **Binder course:** This layer provides the bulk of the asphalt concrete. It is also constructed using aggregates and bitumen but with less quality than materials used for surface course. In general its thickness is about 50 to 100 mm. If economy is not a problem, binder course and surface course can be constructed monotonically using good quality materials with 100 to 150mm thickness. The function of binder course is to transfer the loads coming from surface course to the base course.

- **Base course:** The base course is important layer of the pavement structure and it distributes the loads from top layers to the underneath sub base and sub grade layers. It provides structural supports for the pavement for the pavement surface. It is constructed with hard and durable aggregates which may be either stabilized or granular or both. The thickness of the base course must be great enough to reduce the load capacity on sub grade and sub base courses. The minimum base course thickness recommended is 100mm. Sub surface drainage system can be provided within the base course.

- **Sub base course:** The sub base course is provided beneath the base course and it also functions as same as base course and the primary function is to provide structural support and to improve drainage. If the sub grade soil is strong and stiff, then there is no need of sub base course. Granular aggregates are used to construct sub base course. If sub grade is weak, minimum 100mm thick sub base course should be provided.

- **Sub grade:** Sub grade is the bottom most layer which is nothing but natural soil layer compacted up to required depth generally about 150 to 300mm to receive the loads coming from the top layers. This layer is termed as the foundation for the pavement system. The sub grade should be strong enough to take the stresses and also it is important to keep the stresses coming from top layers should be within the limit of sub grade capacity. To reduce the amount of stress on soil sub grade, thick layers of base course, sub base course and surface course should be provided.

Apart from the above layers, 3 types of coats or finishes are provided in flexible pavement system which are as follows,

- **Seal coat:** Seal coat is provided directly on the top of the surface course to make it watertight and to provide skid resistance to the structure. Mixture of emulsified asphalt, mineral filler and water is used as seal coat material.

- **Tack coat:** Tack coat is a very light application of asphalt. It is provided on the top of binder courseto develop strong bond between the binder course and the surface course. Asphalt emulsion diluted with water is used as tack coat material.

- **Prime coat:** Prime coat is provided between base course and binder course to develop strong and water tight bond between them. Low viscous cutback bitumen is sprayed at the top of the base course as a prime material.

CHAPTER 5 :

IRC METHOD OF DESIGN OF FLEXIBLE PAVEMENTS

Flexible pavements are so named because of total pavement structure deflects, or flexes under loading. A flexible pavement structure is typically composed of several layers of materials. Each layer receives load from the above layer, spreads them out and passes on these loads to the next layer below. Thus the stresses will be reduced, which are maximum at the top layer and minimum on the top of sub grade. In order to take maximum advantage of this property, layers are usually arranged in the order of descending load bearing capacity with the highest load bearing capacity material (and most expensive) on the top and the lowest load bearing capacity material (and least expensive) on the bottom.

OVERVIEW:

IRC has specified the design procedure for flexible pavements based on CBR values. The pavement design given in the previous edition IRC: 37-1984 were applicable to design traffic up to only 30 million standard axles (msa). The earlier code is empirical in nature which has limitations regarding applicability and extrapolation. The guideline follows analytical designs and developed new set of designs u to 150 msa.

SCOPE:

These guidelines will apply to design of flexible pavements for Expressway, National highways, State highways, Major district roads and other categories of roads. Flexible pavements are considered to include the pavements which have bituminous surfacing and granular base and sub base courses confirming to IRC/MOST standards. These guidelines apply to new pavements.

The flexible pavements has been modelled as a three layer structure and stresses and strains at critical locations have been computed using linear elastic model. To give proper consideration to the aspects of performance, the following 3 types of pavement distress resulting from repeated (cyclic) application of traffic loads are considered.

- Vertical compressive strain at the top of the sub grade which can cause sub grade deformation resulting in permanent deformation at the pavement surface.
- Horizontal tensile strain or stress at the bottom of the bituminous layer which can cause fracture of the bituminous layer.
- Pavement deformation within the bituminous layer.

While the permanent deformation within the bituminous layer can be controlled by meeting the mix design requirements, thickness of granular and bituminous layers are selected using the analytical design approach so that strains at the critical points are within the allowable limits. For calculating tensile strains at the bottom of the bituminous layer, the stiffness of dense bituminous macadam (DBM) layer with 60/70 bitumen has been used in the analysis.

Design traffic

The method considers traffic in terms of the cumulative number of standard axles (8160 kg) to be carried by the pavement during the design life. This requires the following information:

1. Initial traffic in terms of CVPD
2. Traffic growth rate during the design life
3. Design life in number of years
4. Vehicle damage factor (VDF)
5. Distribution of commercial traffic over the carriage way.

Initial traffic

Initial traffic is determined in terms of commercial vehicles per day (CVPD). For the structural design of the pavement only commercial vehicles are considered assuming laden weight of three tonnes or more and their axle loading will be considered. Estimate of the initial daily average traffic flow for any road should normally be based on 7-day 24-hour classified traffic counts (ADT). In case of new roads, traffic estimates can be made on the basis of potential land use and traffic on existing routes in the area.

Traffic growth rate

Traffic growth rates can be estimated

- By studying the past trends of traffic growth, and
- By establishing econometric models. If adequate data is not available, it is recommended that an average annual growth rate of 7.5 percent may be adopted.

Design life

For the purpose of the pavement design, the design life is defined in terms of the cumulative number of standard axles that can be carried before strengthening of the pavement is necessary. It is recommended that pavements for arterial roads like NH, SH should be designed for a life of 15 years, EH and urban roads for 20 years and
other categories of roads for 10 to 15 years.

Vehicle Damage Factor

The vehicle damage factor (VDF) is a multiplier for converting the number of commercial vehicles of different axle loads and axle configurations to the number of standard axle-load repetitions. It is defined as equivalent number of standard axles per commercial vehicle. The VDF varies with the axle configuration, axle loading, terrain, type of road, and from region to region. The axle load equivalency factors are used to convert different axle load repetitions into equivalent standard axle load repetitions. For these equivalency factors refer IRC: 37 2001. The exact VDF values are arrived after extensive field surveys.

Vehicle distribution

A realistic assessment of distribution of commercial traffic by direction and by lane is necessary as it directly affects the total equivalent standard axle load application used in the design. Until reliable data is available, the following distribution may be assumed.

- **Single lane roads**: Traffic tends to be more channelized on single roads than two lane roads and to allow for this concentration of wheel load repetitions, the design should be based on total number of commercial vehicles in both directions.
- **Two-lane single carriageway roads**: The design should be based on 75 % of the commercial vehicles in both directions.
- **Four-lane single carriageway roads:** The design should be based on 40 % of the total number of commercial vehicles in both directions.
- **Dual carriageway roads**: For the design of dual two-lane carriageway roads should be based on 75 % of the number of commercial vehicles in each direction. For dual three-lane carriageway and dual four-lane carriageway the distribution factor will be 60 % and 45 % respectively.

CHAPTER 6 :

HIGHWAY ALLIGNMENT AND SURVEYS

Introduction

The position or the layout of the central line of the highway on the ground is called the alignment. Highway Alignment includes both

- Horizontal alignment includes straight and curved paths, the deviations and horizontal curves.
- Vertical alignment includes changes in level, gradients and vertical curves.

A new road should be aligned very carefully as improper alignment will lead to increase in construction, maintenance and vehicle operation cost. Once the road is aligned and constructed, it is not easy to change it due to increase in cost of adjoining land and construction of costly structures by the roadside

Requirements

The requirements of an ideal alignment are
a) Short: The alignment between two terminal stations should be short and as far as possible be straight, but due to some practical considerations deviations may be needed.

b) Easy: The alignment should be easy to construct and maintain. It should be easy for the operation of vehicles. So, to the maximum extend easy gradients and curves should be provided.

c) Safe: It should be safe both from the construction and operating point of view especially at slopes, embankments, and cutting. It should be safe for traffic operation with safe geometric features.

Factors Controlling Alignment

For an alignment to be shortest, it should be straight between the two terminal stations, but this is not always possible due to various practical difficulties such as intermediate obstructions or topography. A road which is economical with low initial investment may not be the most economical in terms of maintenance or vehicle operation cost (VOC). Thus, is may be seen that an alignment can fulfil all the requirements simultaneously, hence a judicial choice is made considering all the factors.
The various factors that control the alignment are as follows:
a) Obligatory Points

b) Traffic

c) Geometric Design

d) Economics

e) Other Considerations

Obligatory Points

These are the control points governing the highway alignment. These points are classified into two categories.

1) Points through Which the Alignment Should Pass

2) Points through Which the Alignment Should Not Pass.

Points through Which the Alignment Should Pass

a) Bridge site: The bridge can be located only where the river has straight and permanent path and also where the abutment and pier can be strongly founded. The road approach to the bridge should not be curved and skew crossing should be avoided as possible. Thus, to locate a bridge the highway alignment may be changed.

b) Mountain: While the alignment passes through a mountain, the various alternatives are to either

c) Construct a tunnel or to go around the hills: The suitability of the alternative depends on factors like topography, site conditions and construction and operation cost.

d) Intermediate town: The alignment may be slightly deviated to connect an intermediate town or village nearby. These were some of the obligatory points through which the alignment should pass.

Points through Which the Alignment Should Not Pass

a) Religious places: These have been protected by the law from being acquired for any purpose. Therefore, these points should be avoided while aligning.

b) Very costly structures: Acquiring such structures means heavy compensation which would result in an increase in initial cost. So, the alignment may be deviated not to pass through that point.

c) Lakes/ponds etc.: The presence of a lake or pond on the alignment path would also necessitate deviation of the alignment.

Traffic

The alignment should suit the traffic requirements. Based on the origin- destination data of the area, the desire lines should be drawn. The new alignment should be drawn keeping in view the desire lines, traffic flow pattern etc.

Geometric design

Geometric design factors such as gradient, radius of curve, sight distance etc. also governs the alignment of the highway. To keep the radius of curve minimum, it may be required to change the alignment of the highway. The alignments should be finalized such that the obstructions to visibility do not restrict the minimum requirements of sight distance. The design standards vary with the class of road and the terrain and accordingly the highway should be aligned.

Economics

The alignment finalized should be economical. All the three costs i.e. construction, maintenance, and operating cost should be minimum. The construction cost can be decreased much if it is possible to maintain a balance between cutting and filling. Also try to avoid very high embankments and very deep cuttings as the construction cost will be very higher in these cases.

Other Considerations

The various other factors that govern the alignment are drainage considerations, political considerations and monotony. The vertical alignment is often guided by drainage considerations such as sub surface drainage, water level, seepage flow, and high flood levels. A foreign territory coming across the alignment will necessitate the deviation of the horizontal alignment.

CHAPTER 7 :

ENGINEERING SURVEYS FOR HIGHWAY ALIGNMENT

Stages of Engineering Surveys
Before a highway alignment is finalised 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

Map Study
It is possible to suggest the likely routes of the roads if the topographic map of the area is available. 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.

- Alignment avoiding valleys, ponds or lakes
- When the road has to cross a row of hills or mountains, possibility of crossing through a mountain pass.
- Approximate location of bridge site for crossing rivers, avoiding bend of the river, if any
- 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 .

Thus, from the map study alternate routes can be suggested. It may also be possibly from map study to drop a certain route in view of any unavoidable obstructions or undesirable ground and map study gives a rough guidance of the routes to be further surveyed in the field.

Reconnaissance Survey
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, 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,

- Valleys, ponds, lakes, marshy land, ridge, hills, permanent structures and other obstructions alone the route which are not available in the map.
- Approximate values of gradient, length of gradients and radius of curves of alternate alignments.
- Number and type of cross drainage structures, maximum flood level and natural ground water level along the probable routes.

- Soil type along the routes from field identification tests and observation of geological features.
- Sources of construction materials, water and location of stone quarries.
- 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 and it may be done by aerial survey. From the details collected during the survey the alignment proposed may be altered or even changes completed.

Preliminary Survey

- The main objectives of the preliminary survey are To survey the various alternate alignment proposed after the reconnaissance and to collect all the necessary physical information and details of topography, drainage and soil
- To compare the different proposals in view of the requirements of a good alignment.
- To estimate quantity of earthwork materials and other construction aspects and to work out the cost of alternate proposals.

The preliminary survey may be carried out by of 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) Modem techniques by use of Global Positioning System (GPS)

The procedure of the conventional methods of preliminary survey is given in following steps:

a) Primary Traverse

b) Topographical Features

c) Levelling Work

d) Drainage Studies and Hydrological Data

e) Soil Survey

f) Material Survey

g) Traffic Studies Primary Traverse

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.

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 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. 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 metre 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.

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 earned 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 20 year 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.

Rapid method using aerial survey and modern technique using GPS

Aerial photographic surveys and photogrammetric methods are very much suited for preliminary surveys, especially when the distance and area to be covered are vast, The survey may be divided into the following steps:
Taking aerial photographs of the strips of land to be surveyed with the required longitudinal and lateral overlaps. Vertical photographs are necessary for the preparation of mosaics.

- The photographs are examined under stereoscopes and control points are selected for establishing the traverses of the alternate proposals. The control points are located on the maps
- Using stereo-pair observations, the spot levels and subsequently contour details may be noted down on the maps

Final Location and Detailed Survey

The alignment finalised 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.
- The data during the detailed survey should be elaborate and complete for preparing detailed plans, design and estimates of the project.

CHAPTER 8 :

NEW HIGHWAY PROJECT

General

In a new highway project, the engineer has to plan, design and construct either a net-work of new roads or a road link. There are also projects requiring re-design and re-alignment of existing roads of upgrading the geometric design standards.

Once a highway is constructed, development takes place along the adjoining land and subsequent changes in alignment or improvements in geometric standards become very difficult. A badly aligned highway is not only a source of potential traffic hazard, but also causes a considerable increase in transportation cost and strain on the drivers and the passengers. Therefore, proper investigation and planning are most important in a road project, keeping in view the present day needs as well as the future developments of the region.

The new highway project work may be divided into the following stages:

a) Selection of route, finalisation of highway alignment and geometric design details

b) Collection of materials and testing of sub grade soil and other construction materials, mix design of pavement materials and design details of pavement layers.

c) Construction stages including quality control.

Route Selection

The selection of route is made keeping in view the requirements of alignment and the geological, topographical and other features of the locality. However special care should be taken as regards the geometric design standards of the road for possible upgrading of speed standards in future, without being necessary to realign the road. After the alignment if finalised, the plans and working drawings are prepared.

Materials and Design

The soil samples collected from the selected route during the soil surveys are tested in the laboratory in order to design the required pavement thickness and the design of embankment and cut slopes. The basic construction materials such as selected soil, aggregates etc. are collected from the nearest borrow pits and quarries and stacked along the road alignment after subjecting these materials to the specified laboratory tests. In order to design the mixes for the pavement component layers and to specify quality control test values during road construction, mix design tests are carried out in the laboratory.

The possibility of using low-cost construction material like soil-aggregate mixes, soft aggregates, stabilized soil and pozzolonic concrete mixes, in the sub-base or base course layers of pavement should be fully explored. When high quality pavement materials like bituminous mixes or cement concrete are to be used in the surface course, the mix design specification and construction control tests should be strictly followed. The pavement thickness is designed based on anticipated traffic, stability and drainage conditions of the sub grade and the type and thickness of pavement layers chosen for the construction.

In India, the CBR method has been recommended by the Indian Roads Congress for designing the thickness of flexible pavements.

Construction

The construction of the road may be divided into two stages as follows

1) Earth Work

2) Pavement Construction.

Earth Work

It consists of excavation and construction of the embankments. During the excavation for highway cuts, the earth slopes, their protection and construction of drainage network are taken care of. Highway embankments may be best constructed by rolled-fill method by compacting the soil in layers under controlled moisture and density using suitable rollers. In the case of high embankments, the stability of the embankment foundation and slopes and the possible settlement of the embankment with time are to be investigated.

Pavement Construction

It is subsequently taken up starting with the preparation of sub grade and the construction of sub-base, base and surface courses of the pavement.

Steps in a new project work

The various steps in a new highway project may be summarised as given below:

1. **Map Study:** This is carried out with the help of available topographic maps of the area.
2. **Reconnaissance Survey:** During reconnaissance survey, a general idea of a topography and other features, field identification of soils and survey of construction materials, by an on-the spot inspection of the site.
3. **Preliminary Survey:** Topographic details and soil survey along alternate alignments, consideration of geometric design and other requirements of alignment, preparation of plans and comparison of alternate routes; economic analysis and selection of final alignment.
4. **Location of Final Alignment:** Transfer of the alignment from the drawings to the ground by driving pegs along the centre line of finally chosen alignment, setting out geometric design elements by location of tangent points, apex points, circular and transition curves, elevation of centre line and super elevation details.
5. **Detailed Survey:** Survey of the highway construction work or the preparation of longitudinal and cross sections, computations of earth work quantities and other construction material and checking details of geometric design elements.
6. **Materials Survey**: Survey of construction materials, their collection and testing.
7. **Design:** Design details of embankment and cut slopes, foundation of embankments and bridges, and pavement layers and cross drainage structures.
8. **Earth Work:** Excavations for highway cutting and drainage system, construction of embankments.
9. **Pavement Construction:** Preparation of sub grade, construction of sub-base, base and surface courses.

10. **Construction Controls:** Quality control tests during different stages of construction and check for finished road surface such as unevenness, camber, super elevation and extra widening of pavements at curves.

11. **Construction Planning and Programming:** The construction planning and programming to be carried out taking into accounts all the restraints and existing problems. In order to minimise the construction cost and time, it is essential to resort to appropriate approaches such as use of Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT).

WIDTH OF PAVEMENT OR CARRIAGEWAY

The width of pavement or carriageway depends on

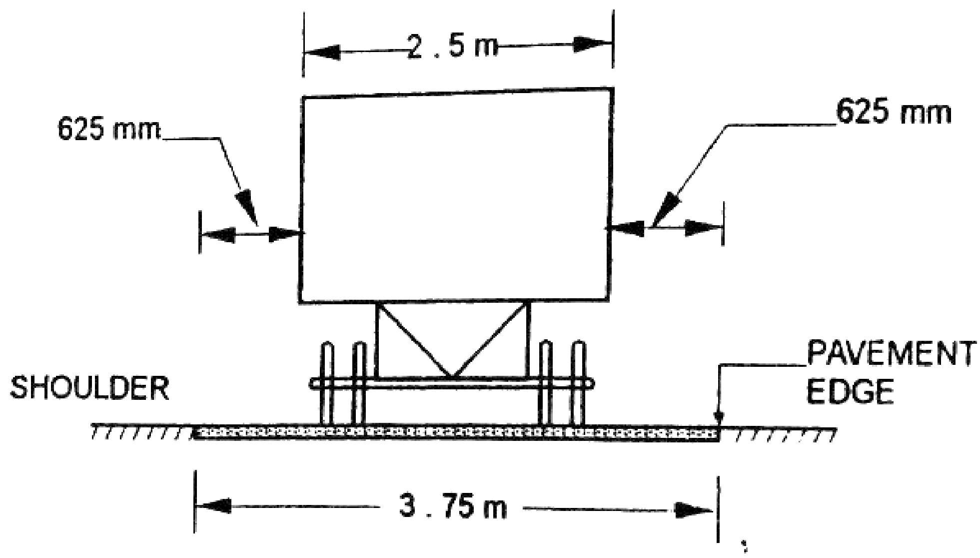
1) Width of Traffic Lane

2) Number of Lanes.

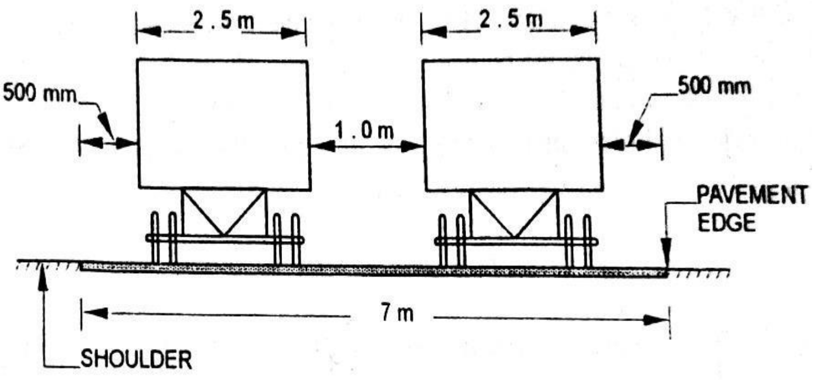
The portion of carriageway width that is intended for one line of traffic movement is called a traffic lane. As different classes of vehicles travel along the same roadway generally the lane width is decided based on a standard vehicle such as the passenger car. However, it is also necessary to consider the maximum width of the largest vehicle class such as the heavy commercial vehicle (HCV) which is legally permitted to use the roadway in the country.

Width of carriageway recommended by IRC

Class of Road	**Width of Carriageway, m**
Single lane roads	3.75
Two lane roads, without raised kerbs	7
Two lane roads, with raised kerbs	.5
Intermediate carriageway	5.5
Multi lane pavements	3.5 per lane



Single lane pavement



Double lane pavement

MEDIANS/TRAFFIC SEPARATORS

In highways with divided carriageway, a median is provided between two sets of traffic lanes intended to divide the traffic moving in opposite directions. The main function of the median is to prevent head-on collision between vehicles moving in opposite directions on adjacent lanes. The median is also called or traffic separator. The traffic separators used may be in the form of pavement markings, physical dividers or area separators. Pavement marking is the simplest of all these, but this will not rule out head-on collision. The mechanical separator may be suitably designed keeping in view safety considerations.

KERBS

Kerb indicates the boundary between the pavement and median or foot path or island or shoulder. It is desirable to provide kerbs on urban roads. Refer Fig. There are a variety of kerb designs. Kerbs may be mainly divided based on their functions.

- **Low or Mountable Kerbs:** These types of kerbs are provided such that they encourage the traffic to remain in the through traffic lanes and also allow the driver to enter the shoulder area with little difficulty.
- **Semi-Barrier Type Kerbs:** When the pedestrian traffic is high, these kerbs are provided. Their height is 15 cm above the pavement edge.
- **Barrier Type Kerbs:** They are designed to discourage vehicles from leaving the pavement. They are provided when there is considerable amount of pedestrian traffic. They are placed at a height of 20 cm above The pavement edge with a steep batter.
- **Submerged Kerbs:** They are used in rural roads. The kerbs are provided at pavement edges between pavement edge and shoulder.

ROAD MARGINS

The portion of the road beyond the carriageway and on the roadway can be generally called road margin. Various elements that form the road margins are given below.

Shoulders

Shoulders are provided on both sides of the pavement all along the road in the case of undivided highway and are provided on the outer edge of the highway in divided carriage way
The important functions of shoulders are:

- Shoulders provide structural stability and support to the edges of the flexible pavements.

- The capacity of the carriageway and the operating speeds of vehicles increase if the shoulders are laid and maintained in good condition.

- Shoulders serve as emergency lanes for vehicle compelled to be taken out of the main carriageway or roadway. Shoulders should have sufficient load bearing capacity to support loaded truck even in wet weather

- Shoulders also act as service lanes for vehicles that are disabled. The width of shoulder should be adequate to accommodate stationary vehicle fairly away from the edge of adjacent lane.

Guard rails
Guard rails are provided at the edge of the shoulder when the road is constructed on a fill so that vehicles are prevented from running off the embankment, especially when the height of the fill exceeds 3 m. Guard stones (painted with black and white strips) are installed at suitable intervals along the outer edge of the formation at horizontal curves of roads running on embankments along rural areas so as to provide better night visibility of the curves under head lights of vehicles.

Footpath or side-walk
In order to provide safe facility to pedestrians to walk along the roadway, foot paths or side-walks are provided in urban areas where the pedestrian traffic is noteworthy and the vehicular traffic is also heavy. By providing good foot path facility, the pedestrians can keep off from the carriageway and they are segregated from the moving vehicular traffic. Thus, the operating speeds of the vehicular traffic increases and there will be marked reduction in accidents involving pedestrians.

Drive ways
Drive ways connect the highway with commercial establishment like fuel-stations, service-stations etc. Drive ways should be properly designed and located, fairly away from an intersection. The radius of the drive way curve should be kept as large as possible, but the width of the drive way should be minimised to reduce the crossing distance for the pedestrians.

Cycle tracks
Cycle tracks are provided in urban areas where the volume of cycle traffic on the road is very high. A minimum width of 2 m is provided for the cycle track and the width may be increased by 1.0 m for each additional cycle lane.

Parking lanes
Parking lanes are provided on urban roads to allow kerb parking. As far as possible only 'parallel parking' should be allowed as it is safer for moving vehicles. For parallel parking, the minimum lane width should be 3.0 m.

Bus bays
Bus bays may be provided by recessing the kerb to avoid conflict with moving traffic. Bus bays should be located at least 75 m away from the intersections.

Lay-byes
Lay-byes are provided near public conveniences with guide maps to enable drivers to stop clear off the carriageway. Lay-byes should normally be of 3.0 width and at least 30 m length with 15 m end tapers on both sides.

Frontage roads

Frontage roads are provided to give access to properties along an important highway with controlled access to express way or freeway. The frontage roads may run parallel to the highway and are isolated by a separator, with approaches to the through facility only at selected points, preferably with grade separation.

WIDTH OF FORMATION OR ROADWAY

Width of formation or roadway is the sum of widths of pavement or carriageway including separators, if any and the shoulders. Formation or roadway width is the top width of the highway embankment or the bottom width of highway cutting excluding the side drains.

RIGHT OF WAY AND LAND WIDTH

Right of way is the area of land acquired for the road, along its alignment. The width of the acquired land for right of way is known as 'land width' and it depends on the importance of the road and possible future development. A minimum land width has been prescribed for each category of road. A desirable range of land width has also been suggested for each category of road. While acquiring land for a highway it is desirable to acquire more width of land as the cost of adjoining land invariably increases as soon as the new highway is constructed.

8.1 MATERIALS FOR FLEXIBLE PAVEMENT LAYER

1. Sub grade soil
2. Stone aggregates
3. Bituminous binder
4. Water

SUB GRADE SOIL : Sub grade soil is an integral part of the road pavement structure which directly receives the traffic load from the pavement layers. The sub grade soil and its properties are important in the design of pavement structure. The main function of the sub grade is to give adequate support to the pavement and for this the sub grade should possess sufficient stability under adverse climate and loading conditions.

The formation of waves, corrugations, rutting and shoving in black top pavements and the phenomena of pumping, blowing and consequent cracking of cement concrete pavements are generally attributed due to the poor sub grade conditions.

The soil used in embankment construction should not undergo excessive settlement due to weather changes and superimposed loads. Differential settlements of embankment may lead to failure of pavements and other structures.

Selected superior quality is borrowed and used for the construction of sub grade of pavements. Well compacted soils and stabilized soils are at times used in the sub base or base course of pavements of low volume roads. The soil is therefore considered as one of the principal highway materials.

Desirable Properties

The desirable properties of soil as a highway material are :

a) Stability

b) Incompressibility

c) Permanency of strength

d) Minimum changes in volume and stability under adverse conditions of weather and ground water.

e) Good drainage

f) Ease of compaction

The soil should possess adequate stability or resistance to permanent deformation under loads, and should possess resistance to weathering, thus retaining the desired sub grade support. Minimum variation in volume will ensure minimum variation in differential strength values of the sub grade. Good drainage is essential to avoid excessive moisture retention and to reduce the potential frost action. Ease of compaction ensures higher dry density and strength under particular type and amount of compaction.

8.2 SOIL CLASSIFICATION

Soil Classification Based on Grain Size
There are several soil classification systems based on grain size of soil, according to which soils have been classified as
a) Gravel

b) Sand

c)Silt and Clay

The most widely accepted grain size classification system is MIT soil classification system. The Bureau of Indian Standards (BIS) has also adopted the same limits as MIT system for the Indian Standard Classification System for soil grains.

Highway Research Board (HRB) classification of soils : The Highway Research Board (HRB) soil classification method is also called Revised Public Roads Administration (PRA) soil classification system. With just three simple laboratory tests namely sieve analysis, liquid limit and plastic limit, it is possible to classify the soils. The HRB soil classification system is generally adopted in highway engineering for the classification of sub grade soils.

Soils are divided into seven groups A-1 to A-7. A-1, A-2 and A-3 soils are granular soils, percentage fines passing 0.075 mm sieve being less than 35. A-4, A-5, A-6 and A-7, soils are fine grained or silt-clay soils, passing 0.075 mm sieve being greater than 35 percent.

- A-1 soils are well graded mixture of stone fragments, gravel coarse sand, fine sand and non-plastic or slightly plastic soil binder. The soils of this group are subdivided into two subgroups, A- 1-a, consisting predominantly of stone fragments or gravel and A-I-b consisting predominantly of coarse sand.
- A-2 group of soils include a wide range of granular soils ranging from A- 1 to A-3 groups, consisting of granular soils and up to 35% fines of A-4, A-5, A-6 or A-7 groups. Based on the fines content, the soils of A-2 groups are subdivided into subgroups A-2-4, A-2- 5, A-2-6 and A-2-7.
- A-3 soils consist mainly, uniformly graded medium or fine sand similar to beach sand or desert blown sand. Stream-deposited mixtures of poorly graded fine sand with some coarse sand and gravel are also included in this group.

CHAPTER 9 : Tests on soil

9.1 CALIFORNIA BEARING RATIO TEST

- **AIM:**
  To determine the California bearing ratio by conducting a load penetration test in the laboratory.
- **DEFNITION:**
  CBR is the ratio expressed in percentage of force per unit area required to penetrate a soil mass with a standard circular plunger of 50 mm diameter at the rate of 1.25 mm/min to that required for corresponding penetration in a standard material. The ratio is usually determined for penetration of 2.5 and 5 mm. When the ratio at 5 mm is consistently higher than that at 2.5 mm, the ratio at 5 mm is used. the test is performed on remoulded specimens which are compacted dynamically. The methodology covers the laboratory method for the determination of C.B.R. of remoulded /compacted soil specimens in soaked state.

- **APPARATUS:**

1. CBR Test Apparatus
2. CBR Mould
3. Collar
4. Weights
5. Compaction Rammer

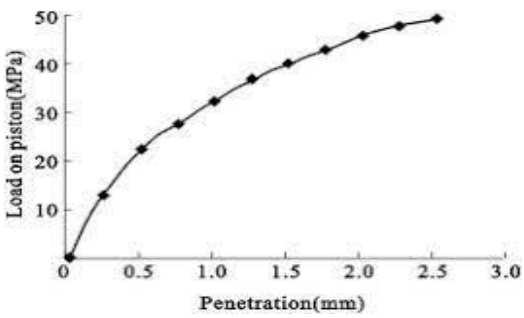
- **PROCEDURE**
  Preparation of Test Specimen**:**

1. Remoulded specimen: The test material should pass 19 mm IS sieve and retained on 4.75 mm IS sieve. The dry density for a remoulding shall be either the field density or the value of the maximum dry density estimated by the compaction test (Heavy Compaction Test as per IS 2720 (Part-8) - 1983, for Railway Formation). The water content used for compaction shall be the optimum water content or the field moisture as the case may be.
2. Dynamic Compaction: A representative sample of the soil weighing approximately 4.5 kg or more for fine grained soil and 5.5 kg or more for granular soil shall be taken and mixed thoroughly with water. If the soil is to be compacted to the maximum dry density at the optimum moisture content, the exact mass of the soil required shall be taken and the necessary quantity of water added so that the water content of the soil sample is equal to the determined optimum moisture content.
3. Fix the extension collar and the base plate to the mould. Insert the spacer disc over the base. Place the filter paper on the top of the spacer disc.
4. Apply Lubricating Oil to the inner side of the mould. Compact the mix soil in the mould using heavy compaction. i.e., compact the soil in 5 layers with 55 blows to each layer by the 4.89 kg rammer.
5. Remove the extension collar and trim the compacted soil carefully at the level of top of mould, by means of a straight edge. Any holes developed on the surface of the compacted soil by removal of the coarse material, shall be patched with the smaller size material. Remove the perforated base plate, Spacer disc and filter paper and record the mass of the mould and compacted soil specimen. Place a disc of coarse filter paper on the perforated base plate, invert the mould and compacted soil and clamp the perforated base plate to the mould with the compacted soil in contact with the filter paper.

6. Place a filter paper over the specimen and place perforated plate on the compacted soil specimen in the mould. Put annular weights to produce a surcharge equal to weight of base material and pavement, to the nearest 2.5 kg.
7. Immerse the mould assembly and weights in a tank of water and soak it for 96 hours. Mount the tripod for expansion measuring device on the edge of the mould and record initial dial gauge reading. Note down the readings every day against time of reading. A constant water level shall be maintained in the tank throughout the period.
8. At the end of soaking period, note down the final reading of the dial gauge and take the mould out of water tank.
9. Remove the free water collected in the mould and allow the specimen to drain for 15 minutes. Remove the perforated plate and the top filter paper. Weigh the soaked soil sample and record the weight.

Procedure for Penetration Test

1. Place the mould assembly with test specimen on the lower plate of penetration testing machine. To prevent upheaval of soil into the hole of the surcharge weights, 2.5 kg annular weight shall be placed on the soil surface prior to seating the penetration plunger after which the remainder of the surcharge weights shall be placed.
2. Seat the penetration piston at the centre of the specimen with the smallest possible load, but in no case in excess of 4 kg so that full contact of the piston on the sample is established.
3. Set the load and deformation gauges to read zero. Apply the load on the piston so that the penetration rate is about 1.25 mm/min.



4. Record the load readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.5, 10 and 12.5 mm.
5. Raise the plunger and detach the mould from the loading equipment. Take about 20 to 50 g of soil from the top 30 mm layer and determine the moisture content.

Observations

Penetration(mm)	Applied Load (kg)
0.5	
1	
1.5	
2	
2.5	
4	
5	
7.5	
10	
12.5	

CALCULATION:

1. If the initial portion of the curve is concave upwards, apply correction by drawing a tangent to the curve at the point of greatest slope and shift the origin. Find and record the correct load reading corresponding to each penetration.
   C.B.R. = (PT/PS) X 100
   where PT = Corrected test load corresponding to the chosen penetration from the load penetration curve. PS = Standard load for the same penetration taken from the table above.
2. C.B.R. of specimen at 2.5 mm penetration =
3. C.B.R. of specimen at 5.0 mm penetration =
4. The C.B.R. values are usually calculated for penetration of 2.5 mm and 5 mm. Generally, the C.B.R. value at 2.5 mm will be greater than at 5 mm and in such a case/the former shall be taken as C.B.R. for design purpose. If C.B.R. for 5 mm exceeds that for 2.5 mm, the test should be repeated. If identical results follow, the C.B.R. corresponding to 5 mm penetration should be taken for design.

9.2 GRADATION/ SAND CONTENT TEST

- **AIM:**
  To find the distribution of sand grains using a set of sieves and to find the average grain fineness number.

- **DEFNITION:**
  The grain size of the sand is expressed by a number called “grain fineness number”.

PROCEDURE:

1. Weigh a 50 gm or 100 gm sample of the sand when it is perfectly dry (free of clay & moisture)
2. Place the sample of the sand into the coarsest (top most) sieve.
3. Place the set of sieves on shaking device to shake Shown in figure above.
4. Shake the sample in set of sieves on shaking device for definite length of time for 15 minutes.
5. After shaking start removing sieves form top sieve to bottom, weigh the quantity of remaining sample on each sieve.
6. The weight collected from each sieve is multiplied with sieve mesh number.
7. Finally divide the total product by the total sample weight & this produces the fineness number, which in the AFS (American Foundry Society). After calculating the number is called AFS number.

- **OBSERVATION:**

Sl. No	Sieve no.(A)	Weight retained (B)	Percentage of sand retained (C)	Multiplier (D)	Product (D*C)	Cummulative % of sand retained
1	1700					
2	850					
3	600					
4	425					
5	300					
6	212					
7	150					
8	106					
9	75					
10	53					
11	pan					
12			P=			

Equipment : Set of sieves with shaker (Indian standard)

9.3 LIQIUD LIMIT TEST

- **AIM:**
  To determine the liquid limit of the given sample.

- **DEFINITION:**
  The liquid limit of a soil is the water content at which the soil behaves practically like a liquid, but has small shear strength.

- **APPARATUS:**

1. Casagrande's liquid limit device
2. Grooving tools of both standard and ASTM types
3. Oven
4. Evaporating dish or glass sheet
5. Spatula
6. 425 microns IS sieve
7. Weighing balance accuracy 0.01g.
8. Wash bottle

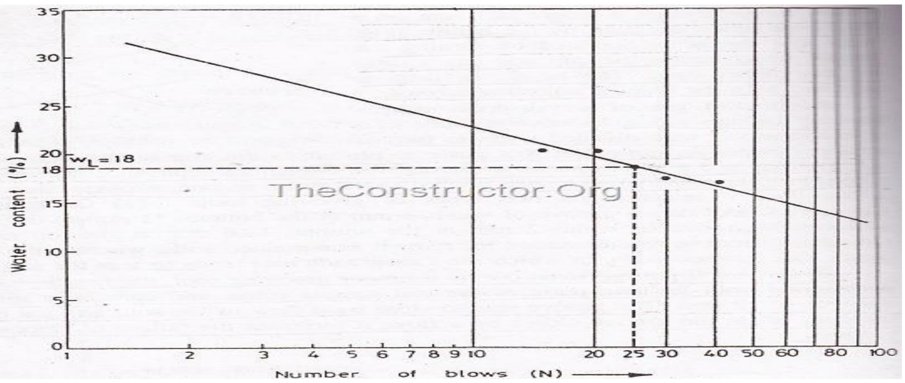
- **PROCEDURE:**

1. Adjust the drop of the cup of the liquid limit device by releasing the two screws at the top and by using the handle of the grooving tool or a gauge. The drop should be exactly 1 cm at the point of contact on the base. Tighten the screw after adjustment.
2. Take about 120g of the air-dried soil sample passing 425 microns IS sieve.
3. Mix the sample thoroughly with distilled water in an evaporating dish or a glass plate to form a uniform paste. Mixing should be continued for about 15 to 30 min, till a uniform mix is obtained.
4. Keep the mix under humid conditions for obtaining uniform moisture distribution for sufficient period. For some fat clays. This maturing time may be up to 24 hours.
5. Take a portion of the matured paste and remix it thoroughly. Place it in the cup of the device by a spatula and level it by a spatula or a straight edge to have a minimum depth of the soil as 1cm at the point of the maximum thickness. The excess soil, if any should be transferred to the evaporating dish.
6. Cut a groove in the sample in the cup by using the appropriate tool. Draw the grooving tool through the paste in the cup along the symmetrical axis, along the diameter through the centre line of the cup. Hold the tool perpendicular to the cup.
7. Turn the handle of the device at a rate of 2 revolutions per second. Count the number of blows until the two halves of the soil specimen come in contact at the bottom of the groove along a distance of 12mm due to flow and not by sliding.
8. Collect a representative sample of the soil by moving spatula width-wise from one edge to the other edge of the soil cake at right angles to the groove. This should include the portion of the groove in which the soil flowed to close the groove.
9. Remove the remaining soil from the cup. Mix it with the soil left in evaporating dish.
10. Change the water content of the mix in the evaporating dish either by adding more water if the water content is to be increased or by kneading the soil, if the water content is to be decreased. In no case the dry soil should be added to reduce the water content.

OBSERVATION:

Description	**1**	**2**	**3**
Number of blows (N)			
Water content can No.			
Mass of empty can (M_1)			
Mass of can + wet soil (M_2)			
Mass of can + dry soil (M_3)			
Mass of water = M_2 - M_3			
Mass of dry soil = M_3 - M_1			
Water content = w = [(6) / (7)] x 100			

Graph:



Equipments:

Casagrande apparatus

9.4 PLASTIC LIMIT TEST

- **AIM:**
  To determine the plastic limit of the given soil sample.

- **DEFNITION:**
  The plastic limit of a soil is the moisture content at which soil begins to behave as a plastic material. At this water content (plastic limit), the soil will crumble when rolled into threads of 3.2mm(1/8in) in diameter. In this article test methods used for determination of soil plastic limit in accordance with ASTM D4148 will be presented.

- **APPARATUS:**

1. Ground Glass Plate: a ground glass plate at least 30 cm (12 in.) square by 1 cm (3?8 in.) thick for rolling plastic limit threads.
2. Plastic Limit-Rolling Device (optional).
3. Spatula or pill knife having a blade about 2 cm wide, and about 10 to 13 cm long.
4. Drying Oven
5. Metallic rod 3.2mm diameter and 100mm long
6. Water Content Containers
7. Balance, conforming to Specification D 4753, Class GP1 (readability of 0.01 g).

- **PROCEDURE:**
  SOIL SAMPLE PREPARATION:

1. Select a 20-g or more portion of soil from the material prepared for the liquid limit test.
2. Reduce the water content of the soil to a consistency at which it can be rolled without sticking to the hands by spreading or mixing continuously on the glass plate or in the mixing/storage dish.
3. The drying process may be accelerated by exposing the soil to the air current from an electric fan.

PLASTIC LIMIT PROCEDURE:

1. select a 1.5 to 2.0 g from the plastic-limit specimen and form the selected portion into an ellipsoidal mass.
2. Roll the soil mass by one of the following methods (hand or rolling device)
3. **Hand Method: r**oll the mass between the palm or fingers and the ground-glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. The thread shall be further deformed on each stroke so that its diameter reaches 3.2 mm, taking no more than 2 min. Normally 80-90 stroke per minute is recommended. count a stroke as one complete motion of the hand forward and back to the starting position. The rate of rolling shall be declined for very fragile soils.
4. When the diameter of the thread becomes 3.2 mm, break the thread into several pieces. Squeeze the pieces together, knead between the thumb and first finger of each hand, reform into an ellipsoidal mass, and re-roll. Continue this alternate rolling to a thread 3.2 mm in diameter, gathering together, kneading and re-rolling, until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a 3.2-mm diameter thread.

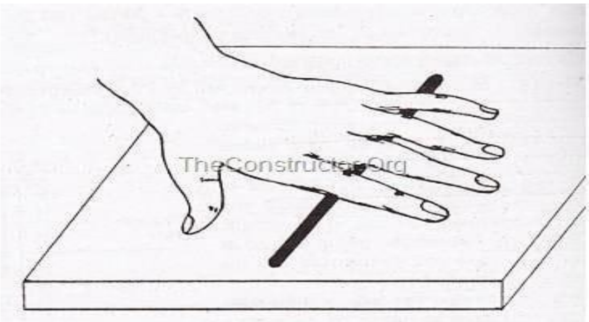
5. Gather the portions of the crumbled thread together and place in a container of known mass. Immediately cover the container.
6. Select another 1.5 to 2.0-g portion of soil from the plastic limit specimen and repeat step 1 and 2 until the container has at least 6 g of soil.
7. Repeat step 1 to 5 to make another container that contains at least 6 g of soil.

- **OBSERVATION:**

Description	**1**	**2**	**3**
Moisture content container number			
Mass of empty container (M_1)			
Mass of container + wet soil (M_2)			
Mass of container + dry soil (M_3)			
Mass of water = $M_2 - M_3$			
Mass of dry soil = $M_3 - M_1$			
Water content = w = [(5) / (6)] x 100			

Equipments:

Plastic limit test apparatus set



Plastic limit test on soil

9.5 PROCTOR TEST

- **AIM:**
  To determine the dry density of the given soil sample.

- **DEFNITION:**
  Compaction is the process of densification of soil by reducing air voids. The degree of compaction of a given soil is measured in terms of its dry density. The dry density is maximum at the optimum water content. A curve is drawn between the water content and the dry density to obtain the maximum dry density and the optimum water content.
  Dry density of soil= (M/V)/(1+W)

- **APPARATUS:**

1. Compaction mould, capacity 1000ml.
2. Rammer, mass 2.6 kg
3. Detachable base plate
4. Collar, 60mm high
5. IS sieve, 4.75 mm
6. Oven
7. Desiccat
8. Spatula
9. Graduated jar
10. Mixing tools, spoons, trowels, etc.

PROCEDURE:

1. Take about 20kg of air-dried soil. Sieve it through 20mm and 4.7mm sieve.
2. Calculate the percentage retained on 20mm sieve and 4.75mm sieve, and the percentage passing 4.75mm sieve.
3. If the percentage retained on 4.75mm sieve is greater than 20, use the large mould of 150mm diameter. If it is less than 20%, the standard mould of 100mm diameter can be used. The following procedure is for the standard mould.
4. Mix the soil retained on 4.75mm sieve and that passing 4.75mm sieve in proportions determined in step (2) to obtain about 16 to 18 kg of soil specimen.
5. Clean and dry the mould and the base plate. Grease them lightly.
6. Weigh the mould with the base plate to the nearest 1 gram.
7. Take about 16 – 18 kg of soil specimen. Add water to it to bring the water content to about 4% if the soil is sandy and to about 8% if the soil is clayey.
8. Keep the soil in an air-tight container for about 18 to 20 hours for maturing. Mix the soil thoroughly. Divide the processed soil into 6 to 8 parts.
9. Attach the collar to the mould. Place the mould on a solid base.
10. Take about 2.5kg of the processed soil, and hence place it in the mould in 3 equal layers. Take about one-third the quantity first, and compact it by giving 25 blows of the rammer. The blows should be uniformly distributed over the surface of each layer.

11. The top surface of the first layer be scratched with spatula before placing the second layer. The second layer should also be compacted by 25 blows of rammer. Likewise, place the third layer and compact it.
12. Remove the collar and trim off the excess soil projecting above the mould using a straight edge.
13. Clean the base plate and the mould from outside. Weigh it to the nearest gram.
14. Remove the soil from the mould. The soil may also be ejected out.
15. Take the soil samples for the water content determination from the top, middle and bottom portions. Determine the water content.
16. Add about 3% of the water to a fresh portion of the processed soil, and repeat the steps 10 to 14.

OBSERVATION:

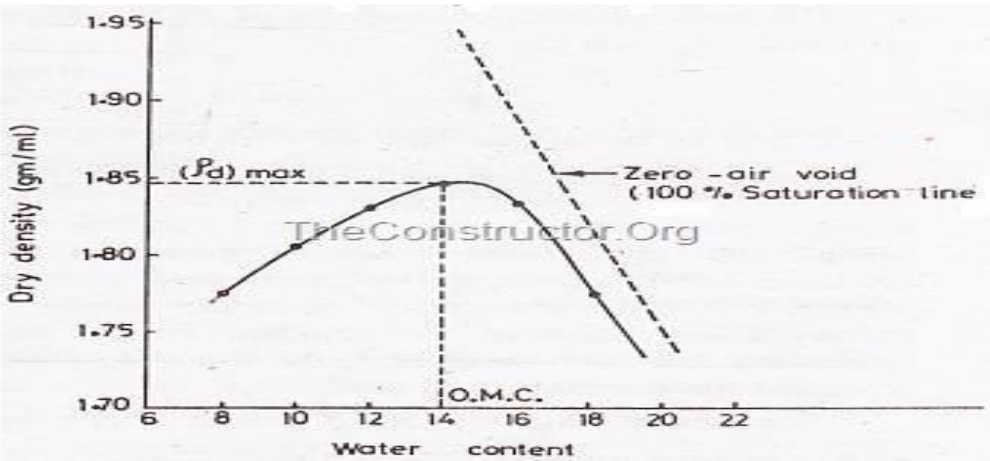
Sl. No.	**Discription**	**Sample 1**	**Sample 2**	**Sample 3**
1	Mass of empty mould with base plate			
2	Mass of mould, compacted soil and base plate			

Calculations:

Particulars	**Sample 1**	**Sample 2**	**Sample 3**
Mass of compacted soil M = (2) – (1)			
Bulk Density $\rho = \frac{Mass}{Volume}$			
Water content, w			
Dry density $\rho_d = \frac{\rho}{1+w}$			
1Void ratio $e = \frac{\rho_w G}{\rho_d} - 1$			
Dry density at 100% saturation (theoretical) $\rho_{d,\max} = \frac{G\rho_w}{1+wG}$			
Degree of saturation $S = \frac{wG}{e} \times 100$			

GRAPH:

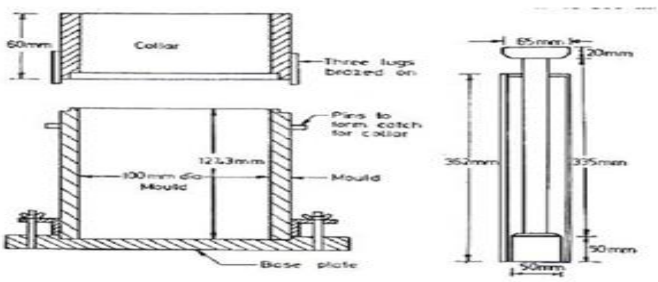
Plot a curve between was abscissa and ρ_d as ordinate



SOIL COMPACTION CURVE

Equipments:

Proctor test apparatus



Compaction mould and rammer details

CHAPTER 10 :

STONE AGGREGATES

Stone aggregates form the major portion of pavement structures and they form the prime materials used in the construction of different pavement layers. Aggregates used in various pavement layers have to bear the different magnitudes of stresses due to the wheel loads. The aggregates of the pavement surface course has to resist,

- Wear due to abrasive action of the traffic.
- Deterioration due to weathering.
- The highest magnitude of wheel load stresses.

The stone aggregates are used in the construction of various pavement layers such as,

- Bituminous pavement layers of flexible pavements.
- Cement concrete mixes used for CC pavement slab and also for the other cross drainage structures.
- Granular base course.
- Granular sub base course or lean cement concrete sub base.
- Drainage layer.

Thus stone aggregates form one of the important components of highway materials and therefore the properties of aggregates are of considerable significance to the highway engineers.

Most of the road aggregates are prepared by crushing the natural rock. Gravel aggregates are small rounded stones of different sizes which are generally obtained as such from river beds. Sand due to weathering of rock obtained from river bed is used as fine aggregate." Manufactured sand" obtained by crushing of hard rocks are also made use of fine aggregates. The properties of the rock from which the aggregates are formed depends on the properties of constituent materials and the nature of bond between them. Based on the origin, natural rocks are classified as igneous, sedimentary and metamorphic. Texture is the important factor affecting the property of the rock and the fragments of aggregates.

The aggregates are specified based on the grain size, shape, texture and its gradation. The crushed aggregates of different sizes are separated by sieving through square sieves of successively decreasing sizes. The required aggregate sizes are chosen to fulfil the desired gradation. The grading, tests and specifications of stone aggregates for different road making purposes have been specified by various agencies like the IRC, BIS, ASTM and BSI.

Based on the strength property, the coarse aggregates may be divided as "hard aggregates" and "soft aggregates". Generally for the wearing course of superior pavement types, hard aggregates are preferred to resist the abrading and crushing effects of heavy traffic loads and to resist adverse weather condition.

Desirable properties

The desirable properties of aggregates are summarised as follows,

- Resistance to impact or toughness.
- Resistance to abrasion or hardness.
- Resistance from getting polished or smooth/slippery.
- Resistance to crushing or crushing strength.
- Good shape factors to avoid too flaky and elongated particles of coarse aggregates
- Resistance to weathering or durability.

10.1 Tests on aggregates

10.1.1 AGGREGATE IMPACT VALUE TEST

- **AIM:**
  Determination of Aggregate Impact Value - Impact Test on Aggregates is done to carry out toDetermine the impact value of the road aggregates,Assess their suitability in road construction on the basis of impact value.

- **DEFNITION:**
  The property of a material to resist impact is known as toughness. Due to movement of vehicles on the road the aggregates are subjected to impact resulting in their breaking down into smaller pieces. The aggregates should therefore have sufficient toughness to resist their disintegration due to impact. This characteristic is measured by impact value test. The aggregate impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.

- **APPARATUS:**

1. A testing machine weighing 45 to 60 kg and having a metal base with a painted lower surface of not less than 30 cm in diameter.
2. A cylindrical steel cup of internal diameter 102 mm, depth 50 mm and minimum thickness 6.3 mm.
3. A metal hammers
4. A cylindrical metal measure having internal diameter 75 mm and depth 50 mm for measuring aggregates.
5. Tamping rod 10 mm in diameter and 230 mm long, rounded at one end.
6. A balance of capacity not less than 500g, readable and accurate up to 0.1 g.

- **PROCEDURE:**

1. The test sample consists of aggregates sized 10.0 mm 12.5 mm. Aggregates may be dried by heating at 100-110° C for a period of 4 hours and cooled.
2. Sieve the material through 12.5 mm and 10.0mm IS sieves. The aggregates passing through 12.5mm sieve and retained on 10.0mm sieve comprises the test material.
3. Pour the aggregates to fill about just 1/3 rd. depth of measuring cylinder.

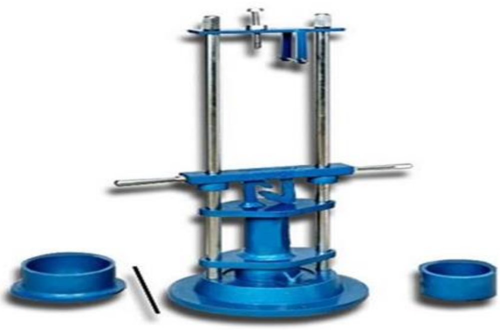
4. Compact the material by giving 25 gentle blows with the rounded end of the tamping rod.
5. Add two more layers in similar manner, so that cylinder is full.
6. Strike off the surplus aggregates.
7. Determine the net weight of the aggregates to the nearest gram(W).
8. Bring the impact machine to rest without wedging or packing up on the level plate, block or floor, so that it is rigid and the hammer guide columns are vertical.
9. Fix the cup firmly in position on the base of machine and place whole of the test sample in it and compact by giving 25 gentle strokes with tamping rod.
10. Raise the hammer until its lower face is 380 mm above the surface of aggregate sample in the cup and allow it to fall freely on the aggregate sample. Give 15 such blows at an interval of not less than one second between successive falls.
11. Remove the crushed aggregate from the cup and sieve it through 2.36 mm IS sieves until no further significant amount passes in one minute.
12. Weigh the fraction passing the sieve to an accuracy of 1 gm. Also, weigh the fraction retained in the sieve. Compute the aggregate impact value. The mean of two observations, rounded to nearest whole number is reported as the Aggregate Impact Value.

- **OBSERVATION AND RECORDING:**

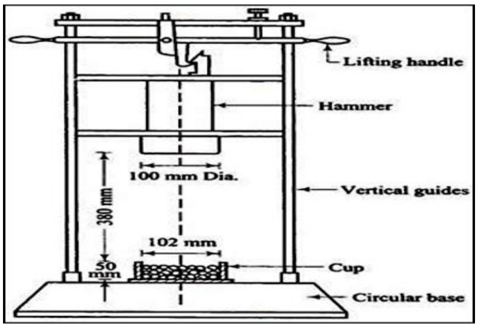
Observations	**Sample 1**	**Sample 2**
Total weight of dry sample (W_1 gm)		
Weight of portion passing 2.36 mm sieve (W_2 gm)		
Aggregate Impact Value (percent) = W_2 / W_1 X 100		

- **CALCULATION:**
  IMPACT VALUE= (SAMPLE 1+SAMPLE 2)/2

Equipments:



Impact value testing apparatus



Impact value testing apparatus details

10.1.2 FLAKINESS INDEX AND ELONGATION INDEXTEST (SHAPE TEST)

- **AIM:**

  To determine the flakiness index and elongation index of the given sample.

- **DEFNITION:**

  The particle shape of aggregates is determined by the percentages of flaky and elongated particles contained in it. For base course and construction of bituminous and cement concrete types, the presence of flaky and elongated particles is considered undesirable as these causes inherent weakness with possibilities of breaking down under heavy loads. Thus, evaluation of shape of the particles, particularly with reference to flakiness and elongation is necessary.

- **APPARATUS:**

1. A standard thickness gauges
2. A standard length gauges
3. IS sieves of sizes 63, 50 40, 31.5, 25, 20, 16, 12.5,10 and 6.3mm
4. A balance of capacity 5kg, readable and accurate up to 1 gm.

- **PROCEDURE:**

1. Sieve the sample through the IS sieves (as specified in the table).
2. Take a minimum of 200 pieces of each fraction to be tested and weigh them.
3. To separate the flaky materials, gauge each fraction for thickness on a thickness gauge. The width of the slot used should be of the dimensions specified in column (4) of the table for the appropriate size of the material.
4. Weigh the flaky material passing the gauge to an accuracy of at least 0.1 per cent of the test sample.
5. Weigh the elongated material retained on the gauge to an accuracy of at least 0.1 per cent of the test sample.

OBERVATION:

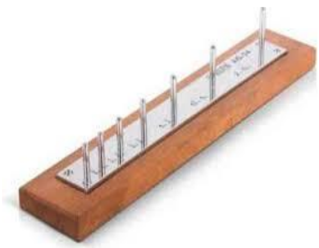
Size of aggregate passing through IS sieve (mm)	**Size of aggregate retained on IS sieve (mm)**	**Weight of fraction consisting of at least 200 pieces**	**Thickness gauge size, mm**	**Weight of aggregates in each fraction passing thickness gauge, mm**	**Length gauge size, mm**	**Weight of aggregates in each fraction retained on length gauge, mm**
1	2	3	4	5	6	7
63	50	W1	23.90	X1	-	-
50	40	W2	27.00	X2	81.0	Y1
40	31.5	W3	19.50	X3	58.O	Y2
31.5	25	W4	16.95	X4	-	-
25	20	W5	13.50	X5	40.5	Y3
20	16	W6	10.80	X6	32.4	Y4
16	12.5	W7	8.55	X7	25.5	Y5
12.5	10	W8	6.75	X8	20.2	Y6
10	6.3	W9	4.89	X9	14.7	Y7
Total	W=		X=		Y=	

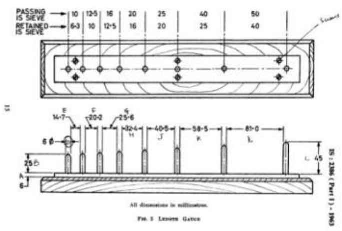
Calculations:

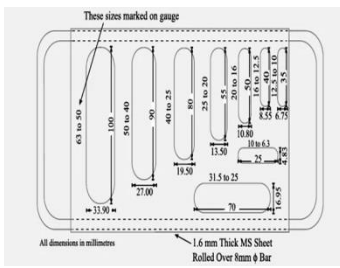
Flakiness Index = $(X_1 + X_2 + \ldots..) / (W_1 + W_2 + \ldots.) \times 100$

Elongation Index = $(Y_1 + Y_2 + \ldots) / (W_1 + W_2 + \ldots.) \times 100$

Equipments:







10.1.3 CRUSHING STRENGTH TEST

- **AIM:**
  To determine the crushing strength value of the given aggregate sample.

  DEFNITION:
  Aggregate crushing value test on coarse aggregates gives a relative measure of the resistance of an aggregate crushing under gradually applied compressive load. Coarse aggregate crushing value is the percentage by weight of the crushed material obtained when test aggregates are subjected to a specified load under standardized conditions.

- **APPARATUS:**

1. A steel cylinder 15 cm diameter with plunger and base plate.
2. A straight metal tamping rod 16mm diameter and 45 to 60cm long rounded at one end.
3. A balance of capacity 3 kg readable and accurate to one gram.
4. IS sieves of sizes 12.5mm, 10mm and 2.36mm
5. A compression testing machine.
6. Cylindrical metal measure of sufficient rigidity to retain its from under rough usage and of 11.5cm diameter and 18cm height.
7. Dial gauge

- **PROCEDURE:**

1. Put the cylinder in position on the base plate and weigh it **(W)**.
2. Put the sample in 3 layers, each layer being subjected to 25 strokes using the tamping rod. Care being taken in the case of weak materials not to break the particles and weigh it **(W1)**.
3. Level the surface of aggregate carefully and insert the plunger so that it rests horizontally on the surface. Care being taken to ensure that the plunger does not jam in the cylinder.
4. Place the cylinder with plunger on the loading platform of the compression testing machine.
5. Apply load at a uniform rate so that a total load of 40T is applied in 10 minutes.
6. Release the load and remove the material from the cylinder.
7. Sieve the material with 2.36mm IS sieve, care being taken to avoid loss of fines.
8. Weigh the fraction passing through the IS sieve **(W2)**.

- **OBSERVATION AND CALCULATION:**

1. The ratio of weight of fines formed to the weight of total sample in each test shall be expressed as a percentage, the result being recorded to the first decimal place.

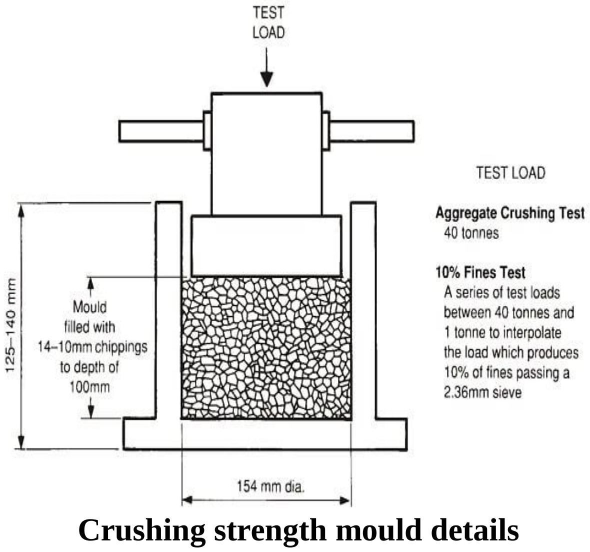
   Aggregate crushing value = (W2 x 100) / (W1-W)

2. W2 =Weight of fraction passing through the appropriate sieve W1-W =Weight of surface dry sample. The mean of two result to nearest whole number is the aggregate crushing value.

Equipments:

Crushing strength testing apparatus

Crushing strength mould



Crushing strength mould details

CHAPTER 11 :

COARSE AGGREGATE

11.1 SPECIFIC GRAVITY TEST ON COARSE AGGREGATE

- **AIM:**

  Determine the specific gravity of soil fraction passing 4.75 mm I.S sieve by density bottle.

- **DEFNITION:**

  Specific gravity G is defined as the ratio of the weight of an equal volume of distilled water at that temperature both weights taken in air.

- **APPARATUS:**

1. Density bottle of 50 ml with stopper having capillary hole.
2. Balance to weigh the materials (accuracy 10gm).
3. Wash bottle with distilled water, Alcohol and ether.

- **PROCEDURE:**

1. Clean and dry the density bottle, wash the bottle with water and allow it to drain, wash it with alcohol and drain it to remove water, wash it with ether, to remove alcohol and drain ether.
2. Weigh the empty bottle with stopper (W_1)
3. Take about 10 to 20 gm of oven soil sample which is cooled in a desiccator. Transfer it to the bottle. Find the weight of the bottle and soil (W_2).
4. Put 10ml of distilled water in the bottle to allow the soil to soak completely. Leave it for about 2 hours.
5. Again, fill the bottle completely with distilled water put the stopper and keep the bottleunder constant temperature water baths (T_x^0).
6. Take the bottle outside and wipe it clean and dry note. Now determine the weight of the bottle and the contents (W_3).
7. Now empty the bottle and thoroughly clean it. Fill the bottle with only distilled water and weigh it. Let it be W_4 at temperature (T_x^0 C).
8. Repeat the same process for 2 to 3 times, to take the average reading of it.

Observation:

Observation Number	**1**	**2**	**3**
Weight of density bottle (W_1 g)			
Weight of density bottle + dry soil (W_2 g)			
Weight of bottle + dry soil + water at temperature $T_x{}^0$ C (W_3 g)			
Weight of bottle + water (W_4 g) at temperature $T_x{}^0$ C			
Specific gravity G at Tx^0 C			
Average specific gravity at $T_x{}^0$ C			

- **CALCULATION:**
  Unless or otherwise specified specific gravity values reported shall be based on water at 27^0C. So, the specific gravity at 27^0C = K Sp. gravity at $T_x{}^0$C.
  Specific gravity = W_3 **/ (**W_3**– (**W_1**–** W_2**))**

Equipments:

Apparatus for testing specific gravity and water absorption test

11.2 WATER ABSORPTION TEST

- **AIM:**
  Water absorption gives an idea on the internal structure of aggregate. Aggregates having more absorption are more porous in nature and are generally considered unsuitable, unless found to be acceptable based on strength, impact and hardness tests.

- **DEFNITION:**
  Specific gravity test of aggregates is done to measure the strength or quality of the material while water absorption test determines the water holding capacity of the coarse and fine aggregates.

- **APPARATUS:**

1. A balance of capacity about 3kg, to weigh accurate 0.5g, and of such a type and shape as to permit weighing of the sample container when suspended in water.
2. A thermostatically controlled oven to maintain temperature at 100-110° C.
3. A wire **basket of not** more than 6.3 mm mesh or a perforated container of convenient size with thin wire hangers for suspending it from the balance.
4. A container for filling water and suspending the basket
5. An air tight container of capacity similar to that of the basket
6. A shallow tray and two absorbent clothes, each not less than 75x45cm

- **PROCEDURE:**

1. About 2 kg of aggregate sample is washed thoroughly to remove fines, drained and placed in wire basket and immersed in distilled water at a temperature between 22- 32º C and a cover of at least 5cm of water above the top of basket.
2. Immediately after immersion the entrapped air is removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop at the rate of about one drop per second. The basket and aggregate should remain completely immersed in water for a period of 24 hour afterwards.
3. The basket and the sample are weighed while suspended in water at a temperature of 22° – 32°C. The weight while suspended in water is noted **= W_1g.**
4. The basket and aggregates are removed from water and allowed to drain for a few minutes, after which the aggregates are transferred to the dry absorbent clothes. The empty basket is then returned to the tank of water jolted 25 times and weighed in water= **W_2 g.**
5. The aggregates placed on the absorbent clothes are surface dried till no further moisture could be removed by this cloth. Then the aggregates are transferred to the second dry cloth spread in single layer and allowed to dry for at least 10 minutes until the aggregates are completely surface dry. The surface dried aggregate is then weighed = **W_3 g**
6. The aggregate is placed in a shallow tray and kept in an oven maintained at a temperature of 110° C for 24 hrs. It is then removed from the oven, cooled in an air tight container and weighted=**W_4 g**

- **OBSERVATION:**
  - Weight of saturated aggregate suspended in water with basket = $\mathbf{W_1 g}$
  - Weight of basket suspended in water = $\mathbf{W_2\ g}$ Weight of saturated surface dry aggregate in air = $\mathbf{W_3}$g
  - Weight of oven dry aggregate = $\mathbf{W_4\ g}$
  - Weight of saturated aggregate in water = $\mathbf{W_1 - W_2\ g}$
  - Weight of water equal to the volume of the aggregate = $\mathbf{W_3 - (W_1 - W_2)\ g}$

- **CALCULATION:**
  Water Absorption = (($W_3 - W_4$**)** / W_4) X 100

Equipments:

Apparatus for testing specific gravity test and water absorption test

CHAPTER 12 :

BITUMINOUS BINDERS

Bituminous binders used in pavement construction works are bitumen and tar. Bitumen is a petroleum product obtained by the distillation of petroleum crude. Coal tar is produced from coal as a by product of coke. Both bitumen and tar have similar appearances as both are black in colour. Though both these binders were used for pavement works, they have widely different characteristics. Tar is no longer used for paving applications because of its undesirable characteristics including high temperature susceptibility and harmful effects of its fumes during heating.

Bitumen is hydrocarbon material of either natural or pyrogenous origin found in gaseous, liquid, semisolid or solid form and is completely soluble in carbon disulphide and in carbon tetra chloride. Bitumen is a complex organic material and occurs either naturally or may be obtained artificially during the distillation of petroleum. Bituminous materials are very commonly used in highway construction because of their binding and water proofing properties. The different grades of bitumen used for pavement construction work of roads and airfields are called paving grade bitumen and those used for water proofing of structures and industrial floors etc are called industrial grade bitumen.

Paving grade bitumen which is obtained from the distillation process of petroleum crude is extensively used in the construction of flexible pavement layers, particularly the surface and binder courses. At normal range of atmospheric temperature, bitumen is in semi solid state and remains highly viscous and sticky.

When the paving grade bitumen is heated, it softens at a rapid rate and attains fluid consistency and the viscosity decreases with further increase in temperature. For the construction of bituminous pavements, the paving grade bitumen is heated to temperatures in the range of 130 to 175 degree celcius or even higher, depending upon the type and grade of bitumen selected and the type of construction works. Mixing of the bitumen with the aggregates is done in a hot mix plant to obtain “hot bituminous mix”.

In order to achieve fluid consistency of the bitumen at relatively low temperatures with nominal heating, ‘cut back bitumen’ has been developed. Cutback bitumen is prepared by diluting the paving grade bitumen with a volatile solvent such as alight fuel oil or kerosene.

Another entirely different approach of achieving fluid consistency of bitumen for use in road works without the need to heat the binder is the ‘bitumen emulsion’. Bitumen emulsion or emulsified bitumen is prepared by dispersing bitumen in the form of fine globules suspended in water with the help of a suitable emulsifier. The properties of bituminous emulsions vary depending upon the properties of the bituminous binder, its proportion with respect to water and properties of the emulsifier. Appropriate type and grade of bitumen emulsion may be selected for being directly sprayed as prime coat or tack coat and for being mixed with aggregates to prepare ‘cold bituminous mix’.

The viscosity of ordinary paving grade bitumen varies considerably with temperature resulting in bituminous pavement surface course being susceptible to temperature changes. During hot weather, the bituminous pavement surface course becomes soft and during cold weather it becomes too stiff and brittle with the possibility of early cracking. Bituminous modifiers reduces the temperature susceptibility of the bituminous binder and that of the bituminous mix. Bituminous mixes prepared using suitable type of modified binders offer better resistance to deformation at higher temperatures and remains relatively more flexible and classic at low temperatures.

Thus the types of bituminous binders that are used in flexible pavement construction are:

- Paving grade bitumen
- Modified bituminous binders
- Cut back bitumen
- Bitumen emulsion

Of the above binders, the paving grade bitumen and modified bituminous binders need heating before being used for paving applications. Cut back bitumen may or may not need slight heating depending on the selected grade of the binder and the site temperature during mixing. When bitumen emulsion is used in pavement construction, no heating is required. Bituminous emulsions are also available with modifiers.

Functions of the binders as pavement materials

Bituminous binders are most commonly used in surface course of pavements. They are also used in the binder and base courses of flexible pavements to withstand relatively adverse conditions of traffic and climate. Bituminous binders are used for preparation of bituminous mixes by mixing the selected aggregates, either in the form of hot bituminous mix or cold mix. Bituminous binders are also used in other techniques of constructions such as ‘surface dressing’ to be used as a thin surfacing course or in ‘penetration macadem’ for use in the base course.

Bituminous binder is used in the form of bitumen emulsion, as a ‘prime coat’ over granular base course of flexible pavement. The binder in the form of emulsion is also used as a tack coat to be sprayed over the primed base course or over an existing bituminous surface, before laying a bituminous pavement layer.

The bituminous binder (in the form of cutback or emulsion) may be used in soil bitumen stabilisation. The bituminous binder may also be used for the preparation of sealer materials for filling the joints and cracks in cement concrete pavements.

Desirable properties

The desirable properties of the bitumen depend on the type of bituminous construction. In general bitumen should possess the following desirable properties:

- The viscosity of the bitumen at the time of mixing with aggregates and compaction of the pre mix should be adequate. This is achieved either by heating the bitumen prior to mixing or by using in the form of cut back or by using in the form of emulsion of suitable grade.

- The bituminous binder should become sufficiently viscous on cooling (or on evaporation of the volatile solvent of the cut back or the water of the emulsion) that the compacted bituminous pavement layer can gain stability and resist deformation under traffic loads.
- It is desirable that the bituminous binder used in the bituminous mixes form ductile thin films around the aggregates to serve as a satisfactory binder in improving the physical interlocking of the aggregates. The binder material which does not possess sufficient ductility would crack and thus provide pervious pavement surface.
- The bituminous binder used should not be highly temperature susceptible. During the hottest weather of the region the bituminous surface should not become too soft or unstable. During cold weather the mix should not become too hard and brittle, causing cracking of surface. The material should also be durable to sustain adverse weathering effects.
- The bitumen binder should have sufficient adhesion with the aggregates in the mix in the presence of water.
- There has to be adequate affinity and adhesion between the bitumen and aggregates used in the mix. The coated binder should not strip off from the stone aggregate under stagnant water.

Comparison between tar and bitumen

BITUMEN	TAR
It has black to dark brown colour.	It also has black to dark brown in colour.
It is natural petroleum product.	Tar is produced by the destructive distillation of coal or wood.
It is soluble in Carbon disulphide & in Carbon tetrachloride.	Tar is soluble only in toluene.
It has better weather resisting property.	It has inferior weather resisting property.
Bitumen is less temperature susceptible.	Tar is more temp susceptible.
Free carbon content is less.	Free carbon content is more.
It neither binds the aggregate well nor retains the presence of water.	It binds aggregate more easily & retain it better in the presence of water.

12.1 Tests for bitumen

12.1.1 SPECIFIC GRAVITY TEST FOR BITUMEN

- **AIM:**
  To determine the specific gravity of bitumen, asphalt, coal tar, road tar, and other bituminous products.

- **DEFNITION:**
  Specific Gravity Test of Bitumen is determining the specific gravity of bitumen which one of the fundamental properties of bitumen. It can therefore be used in the classification of bitumen binders used for pavement construction.

- **APPARATUS:**

1. Specific gravity bottle of 50 ml capacity, ordinary capillary type with 6 mm diameter neck or wide mouthed capillary type bottle with 25 mm diameter neck.
2. Balance having least count of 1g.
3. Thermometer.
4. Water bath.

- **PROCEDURE:**

1. The specific gravity bottle is cleaned, dried and weighed along with the stopper.
2. It is filled with fresh distilled water, stopper placed and the same is kept in water container for at least half an hour at temperature 27^0C.
3. The bottle is then removed and cleaned from outside. The specific gravity bottle containing distilled water is now weighed.
4. The bituminous material is heated to a pouring temperature and is poured in the above empty bottle taking all the precautions that it is clean and dry before filling sample materials. The material is filled up to the half taking care to prevent entry of air bubbles.
5. To permit an escape of air bubbles, the sample bottle is allowed to stand for half an hour at suitable temperature cooled to 27^0C and then weighed.
6. The remaining space in the specific gravity bottle is filled with distilled water at 27^0C, stopper placed and is placed in water container at 27^0C.
7. The bottle containing bituminous material and containing water is removed, cleaned from outside and is again weighed.
8. From the weights taken, the specific gravity of bitumen can be found out.

- **OBSERVATION:**

Description	**1**	**2**	**3**
Weight of Empty Bottle (a)			
Weight of Bottle filled + Weight of Distilled Water (b)			
Weight of bottle + Weight of Bitumen filled till half (c)			
Weight of bottle + Weight of Bitumen filled till half + Weight of Distilled Water filled till half (d)			
Specific gravity = (c-a) / (b-a) – (d-c)			
Specific gravity of the sample = Average value of specific gravity of 1, 2, 3.			

- **CALCULATION:**
  Specific gravity of the specimen can be determined by:
  SPECIFIC GRAVITY= (c-a)/((b-a)-(d-c))

  1. a = weight of the specific gravity bottle
  2. b = weight of the specific gravity bottle + weight of distilled water
  3. c = weight of the specific gravity bottle + weight of the specimen half-filled in the bottle
  4. d = weight of the specific gravity bottle + weight of the specimen half-filled in the bottle + weight of the water filled in the remaining half of the bottle.

Equipments: Specific gravity bottles

12.1.2 PENETRATION VALUE TEST

- **AIM:**
  Penetration test on bitumen is carried to determine Consistency of bituminous material, Suitability of bitumen for use under different climatic conditions and various types of construction.

- **DEFNITION:**
  Penetration value test on bitumen is a measure of hardness or consistency of bituminous material. An 80/100 grade bitumen indicates that its penetration value lies between 80 & 100. Penetration value is the vertical distance traversed or penetrated by the point of a standard needle into the bituminous material under specific conditions of load, time and temperature.

- **APPARATUS:**

1. Penetration apparatus
2. Balance
3. Measuring cylinder
4. Stop watch
5. Glass plate
6. Enamel tray
7. Trowel
8. Thermometer

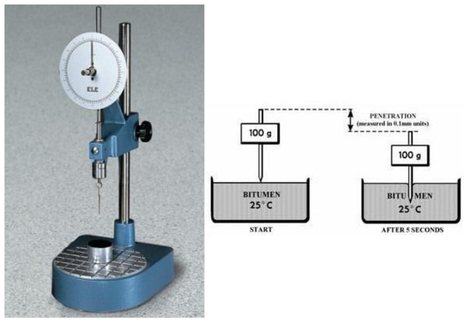
- **PROCEDURE:**

1. Soften the material to a pouring consistency at a temperature not more than 60°C for tars and 90°C for bitumen above the approximate softening point and stir it thoroughly until it is homogeneous and is free from air bubbles and water.
2. Pour the melt into the container to a depth at least 10mm in excess of the expected penetration. Protect the sample from dust and allow it to cool in an atmosphere at a temperature between 15° to 30° C for one hour.

3. Then place it along with the transfer dish in the water bath at 25° ± 0.1 °C, unless otherwise stated.
4. Fill the transfer dish with water from the water bath to depth sufficient to cover the container completely, place the sample in it and put it upon the stand of the penetration apparatus.
5. Clean the needle with benzene, dry it and load with the weight. The total moving load required is 100 ± 0.25 gms, including the weight of the needle, carrier and super-imposed weights.
6. Adjust the needle to make contact with the surface of the sample. This may be done by placing the needlepoint in contact with its image reflected by the surface of the bituminous material.
7. Make the pointer of the dial to read zero or note the initial dial reading.
8. Release the needle for exactly five seconds.
9. Adjust the penetration machine to measure the distance penetrated.
10. Make at least 3 readings at points on the surface of the sample not less than 10 mm apart and not less than l0mm from the side of the dish.
11. After each test return the sample and transfer dish to the water bath and wash the needle clean with benzene and dry it.
12. In case of material of penetration greater than 225, three determinations on each of the two identical test specimens using a separate needle for each determination should be made, leaving the needle in the sample on completion of each determination to avoid disturbance of the specimen.

- **OBSERVATION:**
  Actual test temperature = °C

Penetratiodial reading	**Trial 1**	**Trial 2**	**Trial 3**
Initial reading			
Final reading			
Penetration value			



Equipment: Penetration equipment

12.1.3 SOFTENING POINT TEST

- **AIM:**
  The determination of softening point helps to know the temperature up to which a bituminous binder should be heated for various road use applications. Softening point is determined by ring and ball apparatus.

- **DEFNITION:**
  The softening point of bitumen or tar is the temperature at which the substance attains particular degree of softening. As per IS: 334-1982, ASTM E28-67 or ASTM D36 or ASTM D6493 - 11, it is the temperature in ºC at which a standard ball passes through a sample of bitumen in a mould and falls through a height of 2.5 cm, when heated under water or glycerine at specified conditions of test. The binder should have sufficient fluidity before its applications in road uses.

- **APPARATUS:**

1. Steel balls-two numbers each of 9.5 mm diameter weighing 3.5 ± 0.05 g.
2. Brass rings-two numbers each having depth of 6.4 mm
3. Ball guides to guide the movement of steel balls centrally.
4. Support -that can hold rings in position
5. Thermometer
6. Bath-heat resistant glass beaker
7. Stirrer

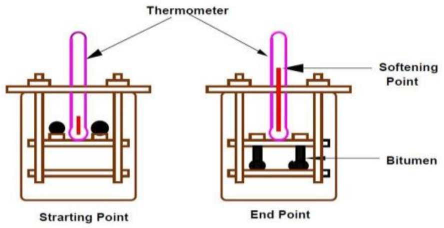
- **PROCEDURE:**

1. Heat the material to a temperature between 75-100° C above its softening point; stir until, it is completely fluid and free from air bubbles and water.
2. If necessary, filter it through IS sieve 30.
3. Place the rings previously heated to a temperature approximating to that of the molten material, on a metal plate which has been coated with a mixture of equal parts of glycerine and dextrin.
4. After cooling for 30 minutes in air, level the material in the ring by removing the excess material with a warmed, sharp knife.
5. Assemble the apparatus with the rings; thermometer and ball guides in position
6. Fill the bath with distilled water to a height of 50mm above the upper surface of the rings. The starting temperature should be 5° C.
7. **Note**: Use glycerine in place of water if the softening point is expected to be above 80° C; the starting temperature may be kept 35° C.
8. Apply heat to the bath and stir the liquid so that the temperature rises at a uniform rate of 5 ± 0.5 °C per minute.
9. As the temperature increases the bituminous material softens and the balls sink through the rings carrying a portion of the material with it.
10. Note the temperature when any of the steel balls with bituminous coating touches the bottom plate.
11. Record the temperature when the second ball touches the bottom plate. The average of the two readings to the nearest 0.5°C is reported as softening point.

- **OBSERVATION:**

Temperature when the ball touches (degree celcius)=

Equipment:



Softening point test illustration

Softening point test apparatus

12.1.4 DUCTILITY TEST

- **AIM:**
  To determine the ductility of cutback bitumen, blown type bitumen, or any other bituminous products. In this ductility test of bitumen, the amount by which the bitumen will stretch at a temperature below the softening point is determined.

- **DEFNITION:**
  Ductility of bitumen is its property to elongate under traffic load without getting cracked in road construction works. Ductility test on bitumen measures the distance in centimetres to which it elongates before breaking.

- **APPARATUS:**

1. Briquette mould
2. Ductility apparatus
3. Water bath
4. Thermometer

- **PROCEDURE:**

1. Melt the bituminous test material completely at a temperature of 75°C to 100° C above the approximate softening point until it becomes thoroughly fluid.
2. Strain the fluid through IS sieve 30.
3. After stirring the fluid, pour it in the mould assembly and place it on a brass plate. In order to prevent the material under test from sticking, coat the surface of the plate and interior surfaces of the sides of the mould with mercury or by a mixture of equal parts of glycerine and dextrin.
4. After about 30-40 minutes, keep the plate assembly along with the sample in a water bath. Maintain the temperature of the water bath at 27° C for half an hour.
5. Remove the sample and mould assembly from the water bath and trim the specimen by levelling the surface using a hot knife.
6. Replace the mould assembly in water bath for 80 to 90 minutes.
7. Remove the sides of the mould.
8. Hook the clips carefully on the machine without causing any initial strain.
9. Adjust the pointer to read zero.
10. Start the machine and pull clips horizontally at a speed of 50 mm per minute.
11. Note the distance at which the bitumen thread of specimen breaks.
12. Mean of two observations rounded to nearest whole number is ductility value.

- **OBSERVATION:**

1. Bitumen Grade =
2. Pouring Temperature =
3. Test Temperature =
4. Period of cooling in minutes

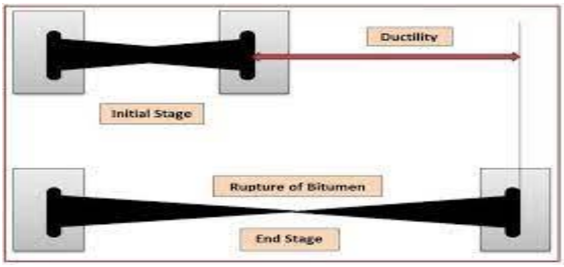
- In air =
- In water bath before trimming =
- In water bath after trimming =

Observations	**1**	**2**	**3**
Initial reading			
Final reading			

Equipments

Ductility testing apparatus

Briquette mould



Ductility test illustration

CHAPTER 13 :

FIELD TESTS

13.1 FDD BY SAND REPLACEMENT METHOD

- **AIM:**
  Determination of field density by sand replacement method.

- **DEFNITION:**
  The dry density of the compacted soil or pavement material is a common measure of the amount of the compaction achieved during the construction. Knowing the field density and field moisture content, the dry density is calculated. Therefore, field density test is importance as a field control test for the compaction of soil or any other pavement layer.

- **APPARATUS:**

1. Sand pouring cylinder equipment
2. Tools for levelling and excavating
3. Containers
4. Balance

- **PROCEDURE:**

1. The determination of volume of the excavated hole is based on the weight of sand filling the hole and the cone and the density of the sand. Calibration of apparatus includes (a) determination of density of test sand used in the experiment under identical height and pouring conditions of the sand into the test hole and (b) determination of the weight of the sand occupying the cone of the sand-pouring cylinder.
2. Clean and dry test sand passing 1.0mm sieve and retained 600-micron sieve is collected in sufficient quantity required for at least three to four sets of tests. The top cap of the sand-pouring cylinder is removed, the shutter is closed, the cylinder is filled with dry test sand up to about 10mm from the top and the cap is replaced. The weight of the cylinder with the sand is determined accurate to one gram and is recorded = WI. In all the subsequent tests for calibration as well as for the field density tests, every time the sand is filled into the cylinder such that the initial weight of the cylinder with sand is exactly WI. The sand pouring cylinder is placed over the calibration cylinder or one of the test holes already excavated, the shutter is opened and the sand equal to the volume of the calibration cylinder or the excavated test hole is allowed to flow out and the shutter is closed.
3. The sand pouring cylinder is now placed on a clean plane surface (glass or Perspex plate), the shutter is kept open till the sand fills up the cone frilly and there is no visible movement of sand as seen from the top of the cylinder by removing the cap. The shutter is closed, the cylinder is removed and the sand which occupied the cone is carefully collected from the plate and weighed = W2.

4. The sand pouring cylinder is refilled with sand such that the initial weight is again WI. Now the cylinder is placed centrally on the top of the calibration container and the shutter is opened. When the sand fills up the calibration container and the cone completely and there is no movement of sand, the shutter is closed and the sand pouring cylinder and the remaining sand is weighed = W3.
5. The above steps are repeated three times and the mean values of W2 and W3 are determined such that the mean value of the weight of sand required to fill the calibration container up to the level top can be determined.
6. The volume of the calibrating container, V is determined either by measuring the internal dimensions or by filling with water and weighing. From the weight of sand WA and its volume V in the calibrating container, the density of sand, is determined.
7. The site where the field density test is to be conducted is cleaned and levelled using a scraper for an area of about 450 mm square. The metal tray central hole is placed on the prepared surface. Using this central hole as pattern, the soil/material is excavated using a dibber or a trowel up to a required depth and the loose material removed is carefully collected in the metal container and is weighed = W. The sand-pouring cylinder is refilled with sand such that its weight is again WI. The metal tray with central hole is removed and the sand-pouring cylinder is placed centrally over the excavated hole. The shutter is opened till the sand fills the excavated hole and the cone completely and there is no further movement of sand in the cylinder. The shutter is closed and the cylinder is weighed again = W4, so that the weight of sand filling the excavated hole alone = WI) can be found.
8. from it in a moisture content dish, weighing, drying in oven at 1 1 OC and re-weighing. Alternatively, the moisture content (w%) is determined by placing the entire excavated soil collected from the hole (of weight W) in the oven and finding its dry weight = Wd.
9. The above steps for the determination of the weights of excavated soil, the weight of the sand filling the hole and the weights of samples for the moisture content determination are repeated at least three times and the average values taken for the determination of field density (wet and dry) values.

- **OBSERVATION:**

DETERMINATION OF WEIGHT OF SAND IN CYLINDER

Tests	1	2	3
Initial weight of container and sand(gms).			
Final weight of container and sand after filling cone.			
Weight of sand in cone = (a) - (b) (gms)			
Average value			

Determination of bulk density of sand

Tests	**1**	**2**	**3**
Weight of sand in cone (gms)			
Weight of sand before pouring.			
Weight of sand after pouring (gms)+Weight of sand in calibration cylinder.			
Volume of calibration cylinder (cc)			
Bulk density of Sand ms/cc			
Average value(gms /cc)			

13.2 FDD BY CORE CUTTER METHOD

- **AIM:**

  By using core cutter method, bulk density of soil can be quickly calculated and by determining the moisture content of the soil the dry density of the fill can be calculated and hence the voids percentage

- **DEFNITION:**

  A high percentage of voids indicates poor compaction of soil. A cylindrical core cutter is a seamless steel tube. For determination of the dry density of the soil, the cutter is pressed into the soil mass so that it is filled with the soil without disturbing the core contents. The cutter filled with the soil is lifted up. The mass of the soil in the cutter is determined.

- **APPARATUS:**

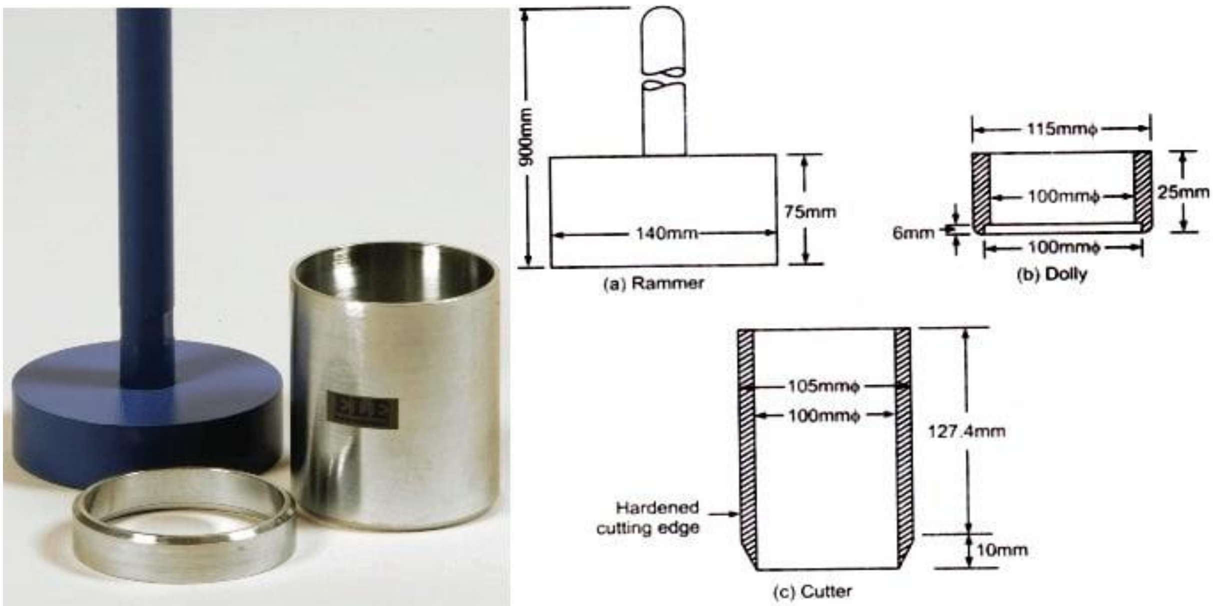
1. Cylindrical core cutter, 100mm internal diameter and 130mm long
2. Steel rammer, mass 9 kg, overall length with the foot and staff about 900mm.
3. Steel dolley, 25mm high and 100 mm internal diameter
4. Weighing balance, accuracy 1g.
5. Palette knife
6. Straight edge, steel rule etc

- **PROCEDURE:**
-

1. Determine the internal diameter and height of the core cutter to the nearest 0.25mm
2. Determine the mass (M_1) of the cutter to the nearest gram.
3. Expose a small area of the soil to be tested. Level the surface, about 300mm square in area.
4. Place the dolley over the top of the core cutter and press the core cutter into the soil mass using the rammer. Stop the pressing when about 15mm of the dolley protrudes above the soil surface.
5. Remove the soil surrounding the core cutter, and take out the core cutter. Soil would project from the lower end of the cutter.
6. Remove the dolley. Trim the top and bottom surface of the core cutter carefully using a straight edge.
7. Weigh the core cutter filled with the soil to the nearest gram (M_2).
8. Remove the core of the soil from the cutter. Take a representative sample for the water content determination.
9. Determine the water content.

- **OBSERVATION:**

Particulars	**1**	**2**	**3**
Core cutter No.			
Internal diameter			
Internal height			
Mass of empty core cutter (M_1)			
Mass of core cutter with soils (M_2)			
$M=M_2 - M_1$			
Volume of cutter V			
Water content			
Drydensityusing formula			



Equipments: Core cutter test apparatus and details

CHAPTER 14 :

PAVEMENT CONSTRUCTION PROCEDURE

During construction of flexible pavement layer, various steps are followed as below,

- Survey of proposed work is done by experienced engineers or by any expert of survey, site survey including geographical details, soil properties and site investigation.
- After survey, a team of experienced engineers and architecture prepare detailed plan of work with the help of various software.
- After that an engineer prepares detailed estimate of proposed work and also prepares an estimate regarding equipments required and labour requirements.
- Now excavation is done with the help of automatic machines and then a equipment is used to cut nearby trees and root removal process.
- After these construction of soil sub grade, base course and then construction of surface course is done.

Sub grade: Sub grade is a layer of natural soil or filled soil, ready to receive the pavement material over it. Traffic load moving on the surface of the road is ultimately transferred to the sub grade through intermediate layer of sub base, base and surface layer. For the successful construction of the road, it is necessary that the soil sub grade should never be over stressed. Stress intensity on the sub grade should not be of the magnitude that may cause excessive deformation in the sub grade. It is this reason that the strength properties of the soil sub grade should be evaluated. The pavement design assumes sub grade strength as the basis for designing the pavement. If strength properties of the sub grade are inferior to the expected ones, it is given suitable treatment to impart improvement in its performance. There are number of tests which can be used to measure strength properties of the soil sub grade. All these tests are useful in their correlation in the design. CBR test and Plate bearing test are some of the standard tests used to evaluate the strength properties of the soil.

Preparation of sub grade layer: Preparation of sub grade layer, it is done after placing the drainage system, piping and electric cable. The sub grade will be compacted and levelled and be cut to make camber as in plan. If the material of a soil did not have a good quality, it will be charged with suitable material. Base formation covered with 50 to 75mm sand layer or quarry dust and will be compacted with 8 to 10 tonnes compactors. This job must be done to prevent the clay from absorbing into the stone layer of sub base.

Granular sub base (GSB):A granular sub base is laid in between the sub grade and the base course of all highway pavements. Sub bases serve a variety of purposes, including reducing the stress applied to the sub grade and providing drainage for the pavement structure. The granular sub base acts as a load bearing layer, and strengthens the pavement structure directly below the pavement surface, providing drainage for the pavement structure on the lowest layer of the pavement system. However, it is critical to note that the sub base layer will not compensate for a weak sub grade. Sub grade with CBR at least 10 will provide adequate support for the sub base.

Preparation of granular sub base: As the granular sub base provides both bearing strength and drainage for the pavement structure, proper size, grading, shape and durability are important attributes to the overall performance of the pavement structure. Granular sub base aggregates consists of durable particles of crushed stone or gravel capable of withstanding the effects of handling, spreading and compacting without generation of deleterious fines. Granular sub base are typically constructed by spreading the materials in thin layers compacting each layer by rolling over it with heavy compaction equipment to achieve a density grater or equal to 70% relative density. Typically the thickness of the sub base is 6 inches with a minimum of 4 inches. Additional thickness beyond 6 inches could allow consolidation of the sub base over time as traffic loads accumulate. Pavement problems may result from this consolidation.

Base course: The base course is the region of the pavement layer that is located directly under the surface course. If there is a sub base course, the base course is constructed directly above this layer. Otherwise it is built directly on top of the sub grade. Typical base course thickness ranges from 4 to 6 inches and is governed y underlying layer properties.

Heavy loads are continuously applied to pavement surfaces, and the base layer absorbs the majority of these stresses. Generally, the base course is constructed with an untreated crushed aggregate such as crushed stone, slag or gravel. The base course material will have stability under the construction traffic and good drainage characteristics.

The base course materials are often treated with cement, bitumen, calcium chloride, sodium chloride, fly ash or lime. These treatments provide improved support for heavy loads, frost susceptibility and serves as a moisture barrier between the base and surface layers. The base course must have sufficient quality and thickness to prevent failure in the sub grade and/or sub base, withstand the stresses produced in the base itself, resists vertical pressures that tend to produce consolidation and result in distortion of the surface course and resists volume changes caused by fluctuations in the moisture content.

The materials composing the base course are select hard and durable aggregates which generally fall into two main classes: stabilized and granular. The stabilized base normally consists of crushed or uncrushed aggregate bound with a stabilizer such as portland cement or bitumen. The quality of base course is a function of its composition, physical properties and compaction of the material.

Prime coat:A prime coat is an application of low viscosity asphalt to a granular base in preparation for an initial layer (or surface course layer) or asphalt. The purpose of the prime coat is to coat and bond loose material particles on the surface of the base, to harden or toughen the base surface to provide a work platform for construction equipment, to plug capillary voids in the base course surface to prevent migration of moisture, and to provide adhesion between the base course and succeeding asphalt course. After applying the prime coat it must cure for a minimum of 48 to 72 hour before asphalt is placed, with no rain in the forecast.

There are 4 primary purposes for the application of prime coat on an aggregate base course,

- Coat and bond loose material particles on the surface of the base.
- Harden or toughen the base surface to provide a work platform for construction equipment.
- Plug capillary voids in the base course to prevent migration of the moisture.

Binder course:

The bituminous surface or wearing course is made up of mixture of various selected aggregates bound together with asphalt or other bituminous binders.

This surface prevents the penetration of surface water to the base course, provides a smooth, well bounded surface free from loose particles, which might endanger aircraft or people, resists the stresses caused by aircraft loads, and supplies a skid resistance surface without causing undue wear on tires.

Tack coat:

The pavement surface receiving the tack coat should be clean and dry to promote maximum bonding. Emulsified tack coat materials can be applied to cool and/or damp pavement. However, the length of time needed for the set to occur may increase. Since existing and milled pavements can be quiet dirty and dusty, their surfaces should cleaned off by sweeping or washing before any tack coat is placed. Otherwise, the tack coat material may bond to the dirt and dust rather than the adjacent pavement layers. This can result in excessive tracking of the tack coat material.

Tack coat application should result in a thin uniform coating of tack coat material covering approximately 90% of the pavement surface. To achieve this result, application rate will vary based on the condition of the pavement receiving the tack coat. Too little tack coat can result in inadequate bonding between layers. Too much tack coat can creates a lubricated slippage plane between layers, or can cause the tack coat material to be drawn into an overlay, negatively affecting mix properties and even creating a potential for bleeding in thin overlays.

Surface course:

The wearing course is the upper layer in roadway, airfield and dockyard construction. The term ‘surface course’ is sometimes used. However this term is slightly used as it can be used to describe very thin surface layers such as chip seal. In grid pavements the upper layer is a Portland cement concrete slab, in flexible pavement, the upper layer consists of asphalt concrete with a bituminous binder. The wearing course is typically placed on the binder course which is then laid on the base course, which is normally placed on the sub base, which rests on the sub grade. There are various different types of flexible pavement wearing course, suitable for different situations. Stone mastic asphalt is a type of flexible pavement wearing course which is typically used for heavily trafficked roads.

The functions and requirements of this layer are,

- It provides characteristics such as friction, smoothness, drainage etc. Also it will prevent the entrance of excessive quantities of surface water into the under lying base, sub base and sub grade.

- It must be tough to resist the distortion under traffic and provides a smooth and skid resistant riding surface.

Seal coat:

Seal coat or pavement sealer s a coating for asphalt based pavements. Seal coating is marketed as a protective coating that extends the life of asphalt pavements. There is no any independent research that proves these claims. Seal coating may also reduce the friction or anti-skid properties associated with the exposed aggregates in asphalt. There are primarily three types of pavement sealers. They are commonly known as refined tar based (coal tar based), asphalt based and petroleum based. All three have their advantages but are typically chosen by the contractor’s preference unless otherwise specified.

Prior to application the surface must be completely clean and dry using sweeping methods and/or blowers. If the surface is not clean and dry, the poor adhesion will result. Pavement sealers are applied either with pressurized spray equipment, or self propelled squeegee machines or by hand with a squeegee. Equipment must have continuous agitation to maintain consistency of the seal coat mix. The process is typically a two coat application which requires 24 to 48 hours of curing before vehicles can be allowed back on the surface. Once the surface is properly prepared, then properly mixed sealer will be applied at about 60 square feet per gallon per coat.

Opening to traffic:

The curing period for bituminous surface course is less and hence the surface can be opened to traffic within 24 hours.

Construction equipment

1. **Excavators:** Excavators are heavy construction equipment consisting of a boom, stick, bucket and cab on a rotating platform (known as the "house"). Excavators are used in many ways: Digging of trenches, holes, foundation, material handling, brush cutting with hydraulic attachments, forestry work, demolition, heavy lift, e.g. lifting and placing of pipes.
2. **Bulldozers:** A bulldozer is a crawler (continuous tracked tractor) equipped with a substantial metal plate (known as a blade) used to push large quantities of soil, sand, rubble, or other such material during construction or conversion work and typically equipped at the rear with a claw-like device (known as a ripper) to loosen densely-compacted materials.
3. **Concrete mixers:** A concrete mixer (also commonly called a cement mixer) is a device that homogeneously combines cement, aggregate such as sand or gravel, and water to form concrete.
4. **Compactors:** A compactor is a machine or mechanism used to reduce the size of waste material or soil through compaction.
5. **Pavers:** A paver (paver finisher, asphalt finisher, paving machine) is an engineering vehicle used to lay asphalt on roadways.
6. **Trailers:** Commonly, the term trailer refers to such vehicles used for transport of goods and materials.
7. **Tippers:** A truck or lorry the rear platform of which can be raised at the front end to enable the load to be discharged by gravity also called tip truck.

8. **Road roller:** A road roller (sometimes called a roller compactor or just roller) is a compactor type engineering vehicle used to compact soil, gravel, concrete, or asphalt in the construction of roads and foundations, similar rollers are used also at landfills or in agriculture.

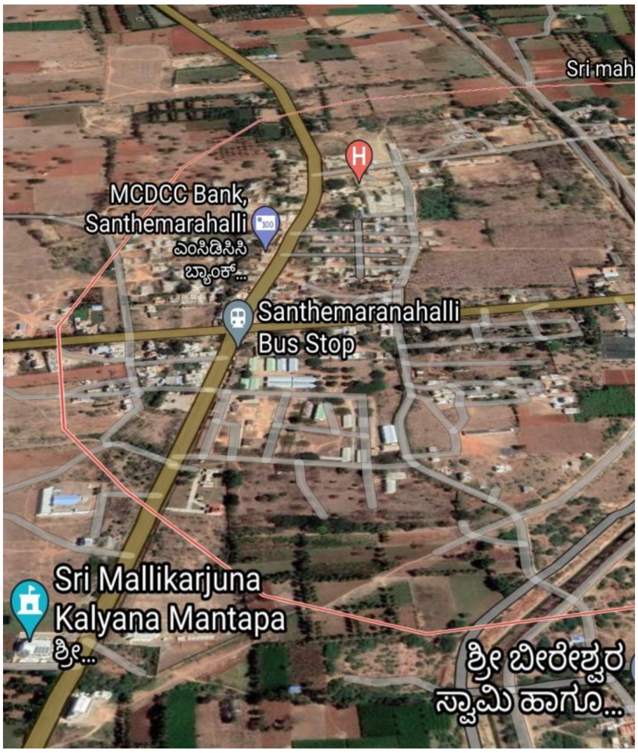
Vehicles that are used for the construction of flexible pavement

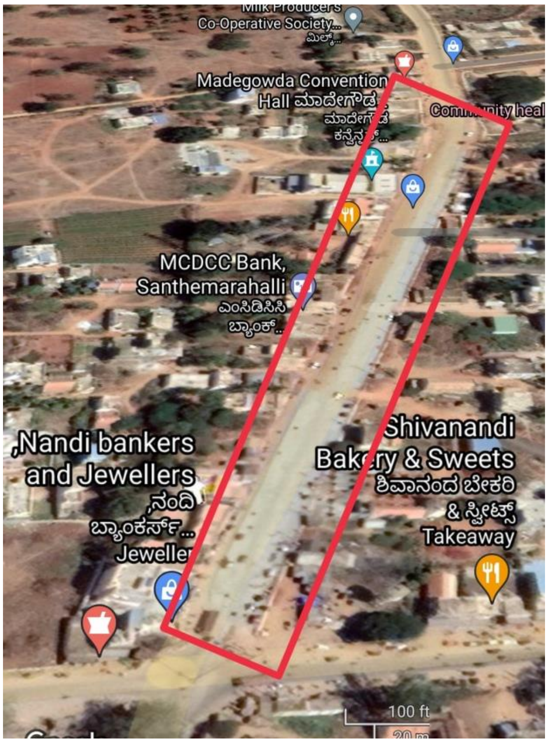
CHAPTER 15 :

INTERNSHIP STUDY AREA

Location :

Santhemararalli ,Chamarajanagar district Karnataka 571115





Pictorial representation of the study area by using google maps satellite images

CHAPTER 16 :

TASK PERFORMED

DETAILED WORDS ABOUT THE UNDERGONE INTERNSHIP PROGRAMME

The internship programme has been conducted in the location "SANTHEMARALLI, CHAMARAJANAGAR DISTRICT, KARNATAKA. From the date of 8th of March to 31ST of March almost a period of month in PUBLIC WORKS DEPARTMENT (PWD) NO.1 SUB DIVISION, CHAMARAJANAGAR. Under the guidance of Sri.Satish (Assistant Engineer)

Picture taken during internship process in the mentioned site location

The above internship process is genuinely conducted in the presence of the Assistant Engineer ,AEE, Junior Engineer and labour workers. The above picture can be recorded as the pictorial evidence for the internship programme using google map camera with mentioning of Latitude, Longitude,Date and Time of the study area that is mentioned above.

During the internship period, I have thoroughly learnt about step-by-step procedure of **"CONSTRUCTION OF FLEXIBLE PAVEMENT"** as well detailed information about the flexible pavement such as :

- **Load Distribution**
- **Layers of Flexible Pavement,**
- **Soil Density Test,**
- **Quality Control Test for both DBM and BC,**
- **Levelling of the road,**
- **Number of Labour Workers required and Daily Expenditure.**
- **Vehicles and Tools That used for laying the material on the road.**
- **Ratio of the DBM and BC mix**
- **Rolling repeats of the roller**

Soil density test of the site as been conducted before the construction process begins.**SAND REPLACEMENT METHOD** has been used to calculate the density of the soil of the site.

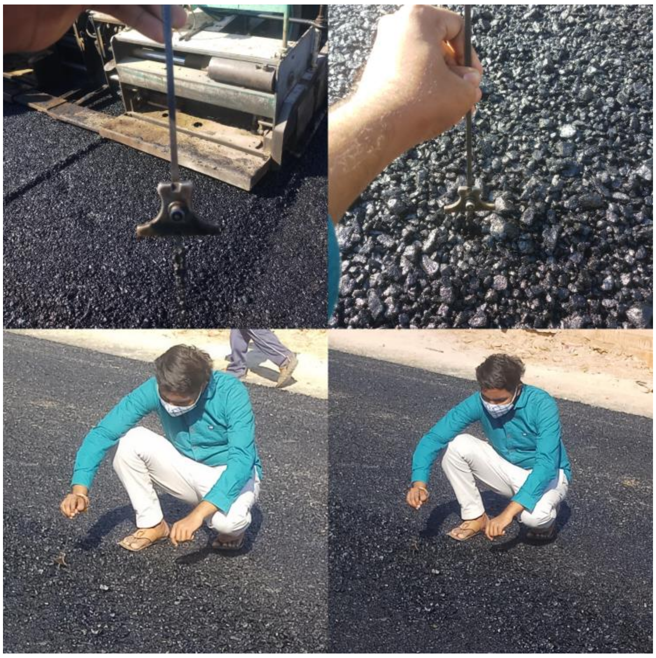
LEVELLING ON THE ROAD

The levelling of the road to be done using levelling instrument to have the proper camber on roads This camber is just nothing but helps not the water on the surface of the road to moves towards the edge/end of the roads.Generally the levelling value in the instrument should be between 2.3 to 2.6 to have proper camber roads so that water may not stands on the road surface without a movement when it falls on the road surface

QUALITY TEST ON MATERIAS USED , DURING CONSTRUCTION

Quality test is done by the quality control unit team persons on the materials that are used for pavement construction like DBM mix,BC mix.This very particular test is done during the middle of the construction itself.And the quality value of 4.5 is suggested for DBM mix and value of 5.6 for BC mix for a sufficient good quality mix.

The load exchange from Truck to Asphalt paver takes place in the way as shown in the above figure. The DBM and BC mix is prepared in the plant and bought to the site from the large truck and carefully transferred to the asphalt paver machine which is already in the site.



Gradual scale that is used to check the DBM or BC mix proportion that is laid down by the asphalt paver and the amount of mix laid down should match pre-set marking in the scale. this usually done during the construction of paver because to check the amount laid down mix fair or not.

The Emulsion oil is sprayed once just after laying the DBM and BC mix to avoid the sticky surface.Usually BITUMEN EMULSION OIL is preferred and used in all the construction of paver.it's helps to rapid setting of the road and mix and also helps to have proper bonding between the road and mix.

M-SAND or DUST that is used to poured after the completion of the road ,as the mix is hot and sticky once it is laid down so there are chances that unwanted materials may fall and stick on the road surface and road surface may get attached to wheels of the vehicle due to its sticky nature.so by using this m-sand or dust we can avoid those circumstances.

CONCLUSION :

The construction of flexible pavement which took place in the study area is about for an around of 1km of 4 lanes road with measurement of 7.5m of each lane.The quantity of ratio of DBM AND BC that was used for the particular road are also known.During the time I was very sincerely happy and enthusiastic about the things that related to the flexible pavement.And mentioned Institute which I completed my internship programme are very supportive and as well as very effective in terms of enlightening me about the detailed terms and aspects of flexible pavement. And I would thank them and institution for providing an opportunity to do the internship and helping me to gain knowledge about the mentioned title.

Pictorial evidence of the internship