INTERNSHIP REPORT ON

ANALYSIS AND DESIGN
OF A FLEXIBLE PAVEMENT FOR AN EXISTING COLONY

Submitted by

HARSHIT SONI

(17CE11L)

in partial fulfillment for the award of the degree of

***BACHELOR OF TECHNOLOGY** IN*

CIVIL ENGINEERING

With specialization in

Transportation Engineering

***Under the Supervision of** Dr. R. K. SINGH*

Assistant Professor

DEPARTMENT OF CIVIL ENGINEERING LINGAYA'S VIDYAPEETH

Faridabad – 121002, Haryana (India)

Department of Civil Engineering

Lingaya's Vidyapeeth

Faridabad – 121002, Haryana (India)

CERTIFICATE

*his is to certify that the Thesis entitled "**ANALYSIS AND DESIGN OF A FLEXIBLE PAVEMENT FOR N EXISTING COLONY** ", submitted by Harshit Soni **(17ce11L)** in partial fulfillment of the requirements for e award of **Bachelor of Technology in Civil Engineering** during session 2020-2021 at Lingaya's Vidyapeeth, aridabad, Haryana is an authentic work carried out by him under my supervision and guidance. To the best of y knowledge, the matter embodied in the report has not been submitted to any other university/institute for the ward of any Degree or Diploma.*

Approved by

Dr. R. K. Singh Assistant Professor

SUPERVISOR
Department of Civil Engineering
LINGAYA'S VIDYAPEETH

Faridabad – 121002, Haryana (India) Department of Civil Engineering

DECLARATION

*I Harshit Soni 17CE11L, a student of BACHELOR **of Technology in Civil Engineering** with specialization in "**Structure Engineering**" during session 2020-2021 at Lingaya's Vidyapeeth, Faridabad, Haryana, hereby declare that the work presented in this report entitled "**ANALYSIS AND DESIGN OF A FLEXIBLE PAVEMENT FOR AN EXISTING COLONY** " is the outcome of my own bonafide work and is correct to the best of my knowledge and this work has been undertaken taking care of Engineering Ethics.*

It contains no material previously published without referring to or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

Name : Harshit Soni
Reg. No.: 17ce11L

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Lastly, I would thank my parents and the almighty God for giving me support and courage throughout this study.

Student Name : Harshit Soni   Reg.No.: 17CE11L
B. TECH. – CIVIL Engineering

To,
Executive engineer

CENTRAL VISTA PROJECT,
A-203, I.P Bhawan
C.P.W.D, New DELHI

Date: 01.03.2021

Respected Sir,

I am Harshit Soni , pursuing Civil Engineering from Lingaya's Vidyapeeth, Faridabad. This is to request you that in our course structure we have to attend a compulsory Internship of (01.03.2021-01.06.2021) 3-6 months, for which I would like to cite my application to your prestigious organization based at Janpath, Central Delhi. The project is about 'Relocation of Indira Gandhi National Centre for the Arts (IGNCA) to Janpath Hotel'.I would like to participate in this Project as this opportunity will help me to have some real world applications in my domain and will support deeper understanding about concepts in my chosen project. Kindly accept my application for the project, I will be really grateful to you

Yours sincerely

Harshit Soni
Roll no. 17CE11L,
LINGAYA'S VIDYAPEETH
DEPARTMENT OF CIVIL ENGINEERING

Approved for doing training in Janpath GPRA project for above mentioned period

Executive Engineer 01/03/21
Central Vista Project
Div.-II, New Delhi

INTERNSHIP LETTER

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ABSTRACT

Pavements are required for the smooth, safe and systematic passage of traffic. Pavements are generally classified as flexible and rigid pavements. Flexible pavements are those which have low flexural strength and are flexible in their structural action under loads. Rigid pavements are those which possess note worthy flexural strength and flexural rigidity.

The profound development in automobile technology has resulted in heavy moving loads on the existing highways for optimization of the transport cost. The existing roads which are designed based on the thumb rules are not able to cater to the heavy wheel loads resulting in the deterioration of the existing roads.

In the project report, an attempt is made to design a road at P.M.Palem, based on the principles of pavement design. On the existing alignment of the road, soil samples are collected for the determination of soil characteristics like consistency limits, sieve analysis, C.B.R. values etc.., Based on this the thickness of the pavement (flexible) is designed. The alignment of the road is also designed and fixed by surveying and leveling. The total road length being 497 meters of which, one section is 247m, other is 200m and the third section is 50m.

CHAPTER 1 INTRODUCTION

For economic and efficient construction of highways, correct design of the thickness of pavements for different conditions of traffic and sub-grades is essential. The science of pavement design is relatively new.

In India, previously road crust was designed on some rational data but more on the experience of the road engineer. Some arbitrary thicknesses of the pavements were used which lead to costly failures and wastage as in some cases, the thickness of pavements was insufficient and in the other cases expensive. As there are no proper design criteria, the construction of roads was more or less uneconomical in almost all cases.

Hence judicious method of designing and calculating the crust thickness on the basis of estimation of traffic loads and bearing capacity of sub-grade etc.., will lead to economical construction of roads.

1. OBJECTIVES AND REQUIREMENTS OF PAVEMENTS:

- The surface of a pavement should be stable and non-yielding, to allow the heavy wheel loads of the road traffic to move with least possible rolling resistance.
- The road should be even along the longitudinal profile to enable the fast vehicles to move safely and comfortably at the design speed.
- A pavement layer is considered more effective or superior, if it is able to distribute the wheel load stress through a larger area per unit depth of the layer.
- The elastic deformation of the pavement should be within the permissible limits, so that the pavement can sustain a large number of repeated load applications during the design life.
- It is always desirable to construct the pavement well above the maximum level of the groundwater to keep the sub-grade relatively dry even during monsoons. At high moisture contents, the soil becomes weaker and soft and starts yielding under heavy wheel loads, thus increasing the tractive resistance.

3. TYPES OF PAVEMENTS:

Based on the structural behavior, pavements are generally classified into the following three categories:

1. Flexible pavement
2. Rigid pavement
3. Semi-rigid pavement.

1. FLEXIBLE PAVEMENT:

Flexible pavements are those which are flexible in their structural action under the loads. Some important features of these pavements are:

- It has no flexural strength,
- It reflects the deformation of lower layers,
- It will transmit the vertical compressive stress to bottom layers by grain to grain transfer,
- The lower layers have to take up only lesser magnitudes of stress and there is no direct wearing action due to traffic loads, therefore inferior materials with low cost can be used in the lower layers.

Flexible pavements consist of the following components:

i. Soil subgrade
ii. Sub base course
iii. Base course
iv. Surface course

Bituminous concrete, granular materials with or without bituminous binders, WBM, soil aggregate mixes etc.., are common examples of flexible pavements.

Flexible pavements are commonly designed using empirical charts or equations. There are also semi-empirical and theoretical methods for the design of flexible pavements.

2. RIGID PAVEMENT:

Rigid pavements are those which possess note worthy flexural rigidity.

- It possesses flexural strength
- Load transfer is by the way of slab action and it distributes the wheel load to a wider area below
- Flexural stresses will be developed due to wheel load temperature changes
- Tensile stresses will be developed due to bending action of the slab under the wheel load
- It does not deform to the shape of the lower layer, but it bridges the minor variations of the lower layer.

Rigid pavement consists of the following components:

i. Cement Concrete slab
ii. Base course
iii. Soil subgrade

Rigid pavements are made of Portland cement concrete either plain, reinforced or prestressed. The plain cement concrete is expected to take up about 40kg/cm^2 flexural stress. These are designed using elastic theory, assuming the pavement as an elastic plate resting over an elastic or viscous foundation.

3. SEMI-RIGID PAVEMENT:

When bonded materials like pozzolanic concrete, lean concrete or soil cement are used, then the pavement layer has considerably higher flexural strength than the common flexible pavement is called a semi-rigid pavement.

These materials have low resistance to impact and abrasion and are therefore used with flexible pavement surface course.

3. FUNCTIONS OF PAVEMENT COMPONENTS:

3.3.1. SOIL SUBGRADE:

- The pavement load is ultimately taken by soil subgrade and hence in no case it should be over stressed and the top 50cm layer of soil subgrade should be well compacted at O.M.C.
- Common strength tests used for evaluation of soil subgrade are :
  i. California Bearing Ratio test
  ii. California resistance value test
  iii. Triaxial compression test

iv. Plate bearing test

2. **SUB BASE AND BASE COURSES:**

- These are broken stone aggregates. It is desirable to use smaller size graded aggregates at sub base course instead of boulder stones.
- Base and sub base courses are used under flexible pavements primarily to improve load supporting capacity by distribution of load through a finite thickness.
- Base courses are used under rigid pavements for :
    i. Preventing pumping
    ii. Protecting the subgrade against frost action.

3. **WEARING COURSE:**

- Purpose of this course is to give a smooth riding surface. It resists pressure exerted by tyres and takes up wear and tear due to traffic. It also offers water tightness.
- The stability of the wearing course is estimated by the Marshalling stability test where the optimum percent of bituminous material is worked out based on stability density, voids in mineral aggregate (V M A) and voids filled with bitumen (V F B). Plate Bearing tests are also sometimes made use for elevating the wearing course and the pavement as a whole.

4. **FACTORS TO BE CONSIDERED IN THE DESIGN OF PAVEMENTS:**

Pavement design consists of two parts:

i. Mix design of material to be used in each pavement component layer
ii. Thickness design of the pavement and the component layer The various factors to be considered for the design of pavement are:
    - Design wheel load
    - Sub grade soil

➢ Climatic factors

Pavement component material

Environmental factors

Special factors in the design of different types of pavements.

1. **DESIGN WHEEL LOAD:**

Following are the important wheel load factors:

A. **MAXIMUM WHEEL LOAD:**

Maximum legal axle load as specified by IRC is 8170kg with a maximum equivalent single wheel load of 4085kg. Total load influences the equality of surface course.

The vertical stress computation under a circular load is based on Boussinesq's theory.

$$\sigma_z = P [1 - (z^3/(a^2 + z^2)^{3/2})]$$

B. **CONTACT PRESSURE**

- Tyre pressures of high magnitudes demand high quality of materials in upper layers in pavements, however the total depth of pavement is not governed by tyre pressure.
- Generally, wheel load is assumed to be distributed in a circular area but it is seen that contact area in many cases is elliptical.
- Commonly used terms with reference of the tyre pressure are:

i. Tyre pressure
ii. Inflation pressure
iii. Contact pressure

- Tyre pressure and inflation pressure mean exactly the same. The contact pressure is found more than tyre pressure when tyre pressure is less than 7 kg/cm^2 and its vice-versa when the tyre pressure exceeds 7 kg/cm^2.

Rigidity factor = (contact pressure) / (tyre pressure)

R.F. =1, for tyre pressure is 7 kg/cm^2

R.F. <1, for tyre pressure >7 kg/cm^2

R.F. >1, for tyre pressure <7 kg/cm^2

rigidity factor depends on the degree of tension developed in the wall of the tyre.

C. **EQUIVALENT SINGLE WHEEL LOAD (ESWL):**

- The effect on the pavement through a dual load assembly is not equal to two times the load on any one wheel. The pressure at a depth below the pavement surface is between the single load and two times load carried by any one wheel.

D. **REPETITION OF LOADS:**

- If the pavement structure fails with N_1 number of repetitions and P_1 kg load and similarly if N_2 number of repetitions of P_2 kg load can also cause failure of the same pavement structure then P_1N_1 and P_2N_2 are equivalent.
- If the thickness required for 10^6 repetitions is 't', then the pavement thickness

required for failure at one repetition is t/4

E. **ELASTIC MODULUS:**

- Elastic modulus of different pavement material can be evaluated. Mainly plate bearing tests are employed for this purpose.
- If Δ is the maximum vertical deflection of the flexible pavement, then

$$\Delta = 1.5pa / E_s$$

- If rigid circular plate is used instead of flexible plate, then:

$$\Delta = 1.8\ pa / E_s$$

Where, a= radius of plate
P = pressure at deflection
E_s= young's modulus of pavement material

2. **SOIL SUBGRADE:**

The properties of soil subgrade are important in deciding the thickness of the pavement to protect it from traffic loads. The variations in stability and volume of sub grade soil with moisture changes are to be studied as these properties are dependent on the soil characteristics. Apart from the design, the pavement performance to great extent depends on the sub grade soil properties and drainage.

The desirable properties of soil as pavement materials are:

I. Stability

ii.Incompressibility

'ermanency of strength

Minimum changes in volume and stability under adverse conditions of weather and groundwater
Good drainage
Ease of compaction

3. CLIMATIC FACTORS:

The climatic variations cause the following major effects:

i. Variation in moisture content,
ii. Frost action,
iii. Variation in temperature.

1. VARIATION IN MOISTURE CONTENT:

The stability of most of the subgrade soils are decreased under adverse moisture conditions. Presence of soil fraction with high plasticity will result in variations in volume (swelling and shrinkage) with variation in water content. As the moisture content of the subgrade below the centre is often different from that of the pavement edges, there can be differential rise or fall of the pavement edges with respect to the centre, due to swelling and shrinkage of the soil subgrade. These effects are likely to cause considerable damage to the pavement and also will be progressive and cumulative.

2. FROST ACTION:

Frost action refers to the adverse effect due to frost heave. Due to continuous supply of water from capillary action at sub freezing temperature leads to the formation of frost heave. The non uniform heaving and thawing leads to undulations.

Factors on which frost actions depends are:

i. Frost susceptible soil,
ii. Depressed temperature below the soil,
iii. Supply of water,
iv. Cover.

To reduce the damage due to frost action, proper surface and subsurface drainage systems should be provided. Capillary cut offs can also be provided to reduce the adverse frost action by soil stabilization.

3. VARIATION IN TEMPERATURE:

Wide variation in temperature due to climatic changes may cause damaging effects in some pavements. Temperature stresses of high magnitude can be induced in cement concrete pavements due to daily variations in temperature and consequent warping of the pavement. Bituminous pavement becomes soft in hot weather and brittle in very cold weather.

4. PAVEMENT COMPONENT MATERIALS:

The stress distribution characteristics of the pavement component layers depend on the characteristics of the materials used. The fatigue behavior of these materials and their durability under adverse conditions of weather should also be given due consideration

5. ENVIRONMENTAL FACTORS:

The environmental factors such as height of embankment and its foundation details, depth of cutting, depth of subsurface water table, etc.., affect the performance of the pavement.

The choice of bituminous binder and performance of bituminous pavements depends on the variations in pavement temperature with seasons in the region. The warping stresses in rigid pavements depend on daily variations in temperature in the region and in the maximum difference in temperature between the top and bottom of the pavement slab.

5. DESIGN OF FLEXIBLE PAVEMENT:

Various approaches for flexible pavement design may be classified into three broad groups:

a. Empirical methods:
   - These are based on physical properties and strength parameters of soil sub grade
   - The group index method, CBR method, Stabilometer method and Mcleod method etc…, are empirical methods.

(b) Semi empirical methods or semi theoretical methods:

These methods are based on stress strain function and experience.

E.g.: Triaxial test method

c. Theoretical methods:These are based on mathematical computations. For example, the Burmister method is based on elastic two layer theory.

1. GROUP INDEX METHOD:

D.J.Steel suggested the thickness requirements with the Highway Research Board method based on the group index values in 1945. Group index value is an arbitrary index assigned to the soil types in numerical equations based on the percent fines, liquid limit and plasticity index. GI values of soil vary in the range of 0 to 20. The higher the GI value, the weaker is the soil subgrade and for a constant value of traffic volume, the greater would be the thickness requirement of the pavement.

The traffic volume in this method is divided into three groups:

Traffic volume (commercial vehicles)	No. of vehicles/day
Light	Less than 50
Medium	50 to 300
Heavy	Over 300

DESIGN STEPS:

Initially, the group index value is calculated for the soil sub grade based on the following formula:

$$GI = 0.2a + 0.005ac + 0.01bd$$

Where,

a = percentage of material passing through IS 200 (0.075mm) sieve, is more than 35 and less than 75 (0 to 40)

b = percentage of material passing through IS 200 (0.075mm) sieve, is more than 15 and less than 55 (0 to 40)

c = liquid limit more than 40 and less than 60 (0 to 20)

d = plasticity index more than 10 and less than 30 (0 to 20)

DETERMINATION OF PERCENTAGE FINER THROUGH IS: 200 SIEVE:

- Take 500 gms of the sub grade soil sample
- Sieve it through IS : 200 sieve. While sieving through each sieve, the sieve should be agitated such that the sample rolls in regular motion on the sieve.

- The mass of material retained on the sieve is determined and the value of percentage finer is determined using the formula:

Percentage finer = [(mass of soil passed)/(total mass of soil taken)]*100

DETERMINATION OF LIQUID LIMIT:

- The liquid limit of a soil is the water content at which the soil behaves practically like a liquid, but has smaller shear strength. It flows to close the groove in just 25 blows in Casagrande's liquid limit device. Take 150 gm of air dried soil sample passing through 425μ IS sieve.
- Mix the sample thoroughly with distilled water in an evaporating dish or glass plate to form a uniform paste. Mixing should be continued for about 15 to 30 minutes till a uniform mix is obtained.
- Place the sample in the cup of the device by a spatula and level it to have a minimum depth of soil as 1cm at the point of the maximum thickness. The excess soil, if any, should be transferred to the evaporating dish.
- 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 symmetric axis, along the diameter through the centre line of the cup. Hold the tool perpendicular to the cup.
- Give blows mechanically 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.
- Collect the representative sample and place the specimen in an air tight container for water content determination and determine the water content.

DETERMINATION OF PLASTIC LIMIT AND THUS, PLASTICITY INDEX:

- The plastic limit of the soil is the water content of the soil at which it ceases to be plastic. It begins begins to crumble when rolled into a thread of 3mm diameter/
- Take about 30gm of air dried soil from a thoroughly mixed sample of soil passing 425μ sieve
- Mix the soil with distilled water in an evaporation dish or a glass plate to make it plastic enough to shape into a small bob.
- Leave the plastic soil mass for some time for maturing. Take about 8gms of plastic soil, roll it with your fingers on the glass plate. The rate of rolling should be 80 to 90 strokes per minute to form a thread of 3mm diameter, counting one stroke when the hand moves forward and backward to the starting point.
- Repeat the process of alternate kneading and rolling until the thread crumbles, and the soil can no longer be rolled into thread.
- Collect the pieces of the crumbled soil thread in a moisture container and determine the moisture content.
- Then, obtain the plasticity index of the given soil sample using the formula: PLASTICITY INDEX = LIQUID LIMIT – PLASTIC LIMIT

Based on the group index value, and the assumed traffic volume, the combined thickness of surface, base and sub base courses may be obtained from the design charts. Also, the thickness of surface and base courses may be obtained from the charts.

2. CALIFORNIA BEARING RATIO METHOD:

In 1928, California divisions of highways in the USA developed the CBR method for pavement design. The majority of curves developed later are based on the original curves developed by O.J.Porter. At the beginning of the second world war, the corps engineer of the USA made a survey of the existing method of pavement design and adopted the CBR method for designing military airport pavements. One of the chief advantages of the CBR method is the simplicity of the test procedure.

Most of the road pavements designed in CBR method on the CBR value of sub grade soil determined by conducting CBR test in the laboratory on the sub grade soil disturbed or remoulded depending on whether an existing subgrade is utilized for the pavement without improvement or a new subgrade is to be constructed with proper control over its properties, especially compaction characteristics.

CBR value is defined as the ratio of load required to cause a specified penetration, say 2.5mm or 5mm of a standard plunger into the sample to the load required to produce the same penetration of same plunger into standard stone aggregate sample, expressed as a percentage. CBR value varies from 0 to 100%. More CBR indicates stronger soil. If density is less, CBR is less. The CBR is expressed as the percentage of penetration resistance of a given pavement material to that of a standard value of penetration resistance obtained for a crusher stone aggregate available in California.

The thickness of the pavement is then obtained from the CBR value using the charts provided.

DESIGN OF PAVEMENT USING CBR METHOD: IRC

- CBR test should be performed on remoulded soils in laboratory, in-situ tests are not recommended for design purpose.
- The soil should be compacted at OMC to proctor density.
- Test samples should be soaked in water for 4 days before testing. However in dry zones (<50cm rainfall) it is not necessary to soak.
- At least three samples should be tested on each type of soil at the same density and moisture content. If variation is more than permissible, an average of six samples should be considered.

Permissible variations	CBR(%)
3%	Upto 10%
5%	10 to 30%
10%	30 0to 60%

- The top 50cm of sub grade should be compacted at least up to 95 to 100% of proctor density.
- Following formula may be used in case estimating future heavy vehicles in view of growth rate for design:

$A = P(1+r)^{n+10}$ A = P
A= no. of heavy vehicles/ day for design (weight>3 T) P = no. of vehicles/ day at the last count
R = annual rate of increase of vehicles
n = no. of years between the last count and the year of completion of construction.

- The design thickness is considered applicable for single axle loads up to 8200 kg and tandem axle up to 14500 kg for higher axle loads, the thickness is further increased.

➢ When sub base course material contains a substantial proportion of aggregate size above 20mm, the CBR value of the material would not be valid for the design of subsequent layers above them.

LIMITATION:

The CBR method gives the total thickness requirement of the pavement above a sub grade and this thickness value would remain the same irrespective of the quality of materials used in the component layers. Thus, the component of materials should be judiciously chosen for durability and economy.

6. ESTIMATION:

An estimate is a computation or calculation of the qualities required and expenditure likely to be incurred in the construction of a work. The primary objective of estimate is to enable one to know beforehand the cost of the work.

For all engineering works, it is desirable to know beforehand the probable cost of construction known as estimated cost. If the estimated cost is greater than the money available, then attempts are made to reduce the cost by reducing the work or changing the specifications. In preparing the estimate, the quantities of different items of work are calculated by simple mensuration method and from these quantities, the cost is calculated.

Accuracy in estimate is very important, if an estimate is exceeded, it becomes a very difficult problem for the engineers to explain, to account for and arrange for the additional money. Inaccuracy in preparing of estimate, omission of items, changes in design, improper rates etc.., are the reasons for exceeding the estimate, though increases in rate is also one of the main reasons.

The rate of each item should be reasonable and workable. The rates in the estimate provide for the complete work, which consists the cost of the materials, cost of labour, cost of tools and plants, cost of water, taxes, establishment, supervision cost, reasonable profit of contractor etc..,

CHAPTER 2 LITERATURE REVIEW

Flexible pavements are preferred over cement concrete roads as they have a great advantage that these can be strengthened and improved in stages with the growth of traffic and also their surfaces can be milled and recycled for rehabilitation. The flexible pavements are less expensive also with regard to initial investment and maintenance. Rigid pavement is expensive but has less maintenance and has a good design period. The economic part is carried out for the design pavement of a section by using the results obtained by design method and their corresponding component layer thickness.

Saurabh Jain, Dr. Y. P. Joshi, S. S. Goliya: This paper discusses about the design methods that are traditionally being followed and examines the "Design of rigid and flexible pavements by various methods & their cost analysis by each method"

D. S. V. Prasad and G. V. R. Prasada Raju : This paper investigates the performance of flexible pavement on expansive soil subgrade using gravel/fly ash as sub base course with waste tyre rubber as a reinforcing material. It was observed that from the laboratory test results of direct shear and CBR, the gravel sub base shows better performance as compared to flyash sub base with different percentages of waste tyre rubber as reinforcing material. Cyclic load tests are also carried out in the laboratory by placing a circular metal plate on the model flexible pavements. It was observed that the maximum load carrying capacity associated with less value of rebound deflection is obtained for gravel reinforced sub base compared to fly ash reinforced sub base.

A B.Tech project on "Proposal of alignment and pavement design for a newly built up colony": by J.B.S. Bharathi et al In this project an attempt is made to design a model road for a newly built up colony based on the modern principles of pavement design. On the existing alignment of the road, soil samples are collected for the determination of soil characteristics like consistency limits, sieve analysis, C.B.R values, etc. Based on this, the thickness of the pavement (flexible) is designed. The alignment of the road is also designed and fixed by surveying and levelling.

CHAPTER 3 METHODOLOGY AND ANALYSIS

1. **COLLECTION OF SAMPLES:** Three samples of soils had been collected in the location of the site (work).

   2. **TYPES OF TESTS:** The different types of tests conducted on the samples are;

   a. **Index Properties**

      1. Liquid limit
      2. Plastic limit
      3. Specific gravity
      4. Sieve analysis

   b. **Engineering Properties**

      1. Standard Proctor test

1. **LIQUID LIMIT OF SOIL:**

DEFINITION

Liquid limit is the moisture content at which 25 blows in standard liquid limit apparatus will just close a groove of standardized dimensions cut in the sample by the grooving tool by a specified amount.

FIG.3.1: Liquid Limit Apparatus

PROCEDURE

- A sample weighing about 150 gm shall be taken from the thoroughly mixed portion of material passing 425μ and mixed thoroughly with distilled water in the evaporating dish to form a uniform thick paste.
- The liquid limit device is adjusted to have a free fall of the cup through 10mm. A portion of the paste is placed in the cup above the lowest spot, and squeezed down with the spatula to have a horizontal surface
- The specimen is trimmed by firm strokes of spatula in such a way that the maximum depth of the soil sample in the cup is 10mm. the soil in the cup is divided along the diameter through the centre line followed by the firm strokes of the grooving tool to get a clean sharp curve
- The crank is rotated till two halves of the soil cake come into contact at the bottom of the groove along a distance of about 10mm, and the number of blows given is recorded.
- A representative soil is taken, placed in the moisture container, lid placed over it and weighed. The container is placed in the oven and dry weight is determined the next day for finding the moisture content of the soil.
- The operations are repeated for at least three more trails with slightly increased moisture content each time, noting the number of blows so that at least four uniformly distributed readings of number of blows 10 and 60
- The flow curve is plotted by taking the number of blows in the logarithmic scale on the X- axis, and the water content in the arithmetic scale on Y-axis.

OBSERVATIONS & CALCULATIONS (Sample 1):

Weight of soil sample taken=150gm Table 3.1: Liquid limit of soil (sample 1)

S.No.	DESCRIPTION	Sample 1	Sample 2	Sample 3	Sample 4
1	Weightof empty can, W_1	10	10.5	11	11
2	Weight of the can + weight of wet soil, W_2(g)	24	29.5	30	28

3	Weight of can + weight of dry soil, W_3(g)	21	26	27	26
4	Water content, w(%)	27.27	22.1	18.75	13.33
5	No. of blows as observed, n	18	30	42	65

FIG. 3.2: Graphical Representation of Liquid Limit Test (Sample 1) From graph,

Water content corresponding to 25 blows = 24% Therefore, the liquid limit of the soil sample 1 is 24%

OBSERVATIONS & CALCULATIONS (Sample 2):

Weight of soil sample taken=150gm Table 3.2: Liquid limit of soil (sample 2)

S.No	DESCRIPTION	Sample 1	Sample 2	Sample 3	Sample 4
1	Weight of empty can, W_1	11	11	17	17
2	Weight of the can + weight of wet soil, W_2(g)	31	34.6	29	47
3	Weight of can + weight of dry soil, W_3(g)	28	31	27	41
4	Water content, w(%)	17.64	18	20	25
5	No. of blows as observed, n	70	50	22	16

FIG. 3.3: Graphical Representation of Liquid Limit Test (Sample 2) From graph,

Water content corresponding to 25 blows=22.5% Therefore, the liquid limit of the soil sample 2 is 22.5%

OBSERVATIONS & CALCULATIONS (Sample 3):

Weight of sample taken= 150gm

Table 3.3: Liquid limit of soil (sample 3)

S.No	DESCRIPTION	Sample 1	Sample 2	Sample 3	Sample 4
1	Weightof empty can, W_1	16	17	16	17
2	Weight of the can + weight of wet soil, W_2(g)	25	33.6	30	37
3	Weightof can + weight of dry soil, W_3(g)	24	31	28	33
4	Water content, w(%)	12.5	18.6	16.6	25
5	No. of blows as observed, n	55	30	17	14

FIG. 3.4: Graphical Representation of Liquid Limit Test (Sample 3) From graph,
Water content corresponding to 25 blows=20% Therefore, the liquid limit of the soil sample 3 is 20%

2. PLASTIC LIMIT OF SOIL:

DEFINITION

Plastic limit is the moisture content at which a soil when rolled into thread of small diameter possible starts crumbling and has a diameter of 3mm

FIG.3.5: Representation of plastic limit test

PROCEDURE

- A sample weighing about 20gm from the thoroughly mixed portion of the material passing 425μ IS sieve. The soil is mixed thoroughly with distilled water in the evaporating dish till the soil is plastic enough to be easily molded with fingers.

- A small ball is formed with the fingers and this is rolled between the fingers and the ground glass plate to a thread. The rolling is done till the diameter of the thread is 3mm. Then, the soil is kneaded together to a ball and rolled again to form a thread.
- This process of alternate rolling and kneading is continued until the thread crumbles under pressure required for rolling and the soil can no longer be rolled into a thread.
- If the crumbling starts at a diameter less than 3mm, then moisture content is more than plastic limit and if the diameter is greater while crumbling starts, the moisture content is lower. By trial, the thread which starts crumbling at 3mm diameter under normal rolling should be obtained and this should be immediately transferred to the moisture container, lid placed and weighed to find the wet weight of the thread.
- The container is kept in the oven for about a day and dry weight is found to determine the moisture content of the thread. The above process is repeated for at least three consistent values of the plastic limit.

FORMULA:

Plasticity Index (P.I) is calculated as the difference between liquid limit and plastic limit Plasticity Index (I_P) = liquid limit – plastic limit

$= W_L - W_P$

OBSERVATIONS & CALCULATIONS (Sample 1):

Weight of empty can, W_1 = 11gm

Weight of can + weight of wet soil, W_2 = 15gm Weight of can + weight of dry soil, W_3 = 14.5gm Weight of water, $W_2 - W_3$ = 0.5gm

Water content, w = 14.28%

Plasticity index of soil, I_P = 24-14.28%

= 9.72%

Plastic limit of the soil sample = 14.28% Plasticity index of the soil sample = 9.72%

OBSERVATIONS & CALCULATIONS (Sample 2):

Weight of empty can, W_1 = 10gm

Weight of can + weight of wet soil, W_2 =16 gm Weight of can + weight of dry soil, W_3 = 15.4gm Weight of water, $W_2 - W_3$ = 0.6

Water content, w =11.11 %

Plasticity index of soil, I_P = 22.5 - 11.11%

=11.39%

Plastic limit of the soil sample = 11.11 % Plasticity index of the soil sample =11.39 %

OBSERVATIONS & CALCULATIONS (Sample 3):

Weight of empty can, W_1 = 11gm

Weight of can + weight of wet soil, W_2 =17.5 gm Weight of can + weight of dry soil, W_3 =16.9 gm Weight of water, $W_2 - W_3$ =0.6 gm

Water content, w =10.16 %

Plasticity index of soil, I_P = 20 – 10.16 %

= 9.84%

Plastic limit of the soil sample =10.16 % Plasticity index of the soil sample = 9.84%

3. SIEVE ANALYSIS OF SOIL:

PROCEDURE

- A 500gm of oven dried sample is taken
- The sieves are arranged in the order 4.75mm, 2.36mm, 1.18mm, 600μ, 425μ, 300μ, 150μ and 75μ.
- The soil is agitated such that the sample rolls in irregular motion over the sieves. However, no particles should be pushed.
- The soil fractions retained on each sieve were collected in a separate container and weighed accurately.
- The percentage retained on each sieve, cumulative percentage retained and the percentage finer than the particle sieve size is calculated based on the total mass.

FIG.3.6: Sieve Shaker

FORMULA:

Uniformity coefficient, $C_u = D_{60} / D_{10}$

Coefficient of curvature, $C_c = (D_{30})^2 / (D_{60} * D_{10})$ D_{10} = particle size corresponding to 10% finer D_{30} = particle size corresponding to 30% finer D_{60} = particle size corresponding to 60% finer

OBSERVATIONS & CALCULATIONS (Sample 1):

Table 3.4: Sieve analysis (sample 1) Weight of sample taken = 500gm

S.No	Sieve size	Weightof soil retained, g	Percentage weight retained, %	Cumulative percentage retained,%	Percentage finer,%
1	4.75mm	1	0.2	0.2	99.8

2	2.36mm	25	5	5.2	94.8
3	1.18mm	116	23.2	28.4	71.6
4	600µ	72	14.4	42.8	57.2
5	425µ	104	20.8	63.6	36.4
6	300µ	81	16.8	79.8	20.2
7	150µ	64	12.8	92.6	7.4
8	75µ	20	4.0	96.6	3.4
9	PAN	6	1.2	97.8	2.2

FIG.3.7: Graphical representation of Sieve analysis (Sample 1)

From graph, $D_{10} = 0.18$

$D_{30} = 0.4$

$D_{60} = 0.65$

Uniformity coefficient, $C_u = D_{60}/D_{10}$

$= 3.61$

Coefficient of curvature, $C_c = (D_{30})^2/(D_{60}*D_{10})$

$= 1.367$

OBSERVATIONS & CALCULATIONS (Sample 2):

Table 3.5: Sieve analysis (sample 2) Weight of the sample taken= 500gm

S.No	Sieve size	Weight of soil retained, g	Percentage weight retained, %	Cumulative percentage retained,%	Percentage finer,%
1	4.75mm	1	0.2	0.2	99.8
2	2.36mm	36	7.2	7.4	92.6
3	1.18mm	118.4	23.68	31.08	68.92
4	600µ	52.4	10.48	41.56	58.44
5	425µ	105.6	21.12	62.68	37.32
6	300µ	62.25	12.45	75.13	24.87
7	150µ	43.8	8.76	83.89	16.11

8	75µ	27	5.4	89.29	10.71
9	PAN	48	9.6	98.89	1.11

FIG.3.8: Graphical representation of Sieve analysis (Sample 2)

From graph, $D_{10} = 0.075$

$D_{30} = 0.22$

$D_{60} = 0.89$

Uniformity coefficient, $C_u = D_{60}/D_{10}$

$=11.86$

Coefficient of curvature, $C_c = (D_{30})^2/(D_{60} * D_{10})$

$= 0.725$

OBSERVATIONS & CALCULATIONS (Sample 3):

Table 3.6: Sieve analysis (sample 3) Weight of the sample taken= 500gm

S.No	Sieve size	Weight of soil retained, g	Percentage weight retained, %	Cumulative percentage retained,%	Percentage finer,%
1	4.75mm	30	6	6	94
2	2.36mm	48	9.6	15.6	84.4
3	1.18mm	116	23.2	38.8	61.2
4	600µ	57	11.4	50.2	49.8
5	425µ	60	12	62.2	37.8
6	300µ	60	12	74.2	25.8
7	150µ	48	9.6	83.8	16.2
8	75µ	47	9.4	93.2	6.8
9	PAN	31	6.2	99.4	0.6

FIG.3.9: Graphical representation of Sieve analysis (Sample 3)

From graph, $D_{10} = 0.09$

$D_{30} = 0.26$

$D_{60} = 0.9$

Uniformity coefficient, $C_u = D_{60}/D_{10}$

$=10$

Coefficient of curvature, $C_c = (D_{30})^2 /(D_{60}*D_{10})$

$= 0.834$

4. **PROCTOR COMPACTION TEST:**

PROCEDURE

- The test consists of compaction of soil at various water contents in the mould in three equal layers, each being given 25 blows with the 2.6 kg hammer dropped from a height of 31cm
- The dry density of the soil sample can be obtained by finding the bulk density of compacted soil and its water content

- About 5kg of air dried, pulverized soil passing through 4.75mm sieve is taken and mixed thoroughly with an arbitrary water content say,6%

The mixed soil sample in the mould and compacted by giving blows with the hammer uniformly over the surface such that the compacted height of the soil is about 1/3rd of the height of the mould. The second and third layers are similarly impacted each being given 25 blows

The last compacted layer should not project more than 6mm into the collar. The collar is removed and the excess soil is trimmed off to make it level with the top of the mould.

The weight of the mould with base plate and the compacted soil is taken. A representative sample is taken from the centre of the compacted specimen and is kept in the oven for water content determination.

The compacted soil is taken out of the mould, broken by hand and remixed with increased water content. Again the soil is compacted in a mould in three equal layers as described above and the corresponding dry density (γ_d) and the water content (w) are thus determined.

The test is repeated on soil samples with increasing water content and the corresponding dry densities as determined.

A compaction curve is plotted between water content as the abscissa and the corresponding dry densities are ordinates.

The dry density goes on increasing as the water content is increased till the maximum dry density is reached. The water content corresponding to the maximum dry density is called optimum moisture content(w).

FIG.3.10: Proctor Compaction Test Apparatus

FORMULA

The bulk density and the corresponding dry density for compacted soil are calculated from the following relations

Wet density, $\gamma = W/V$ g/cc Dry density, $\gamma_d = \gamma/(1+w)$ g/cc

Where, W = weight of compacted specimen w = water content
V = volume of the mould

γ = wet density of soil in g/cc γ_d = dry density of soil in g/cc

OBSERVATIONS & CALCULATIONS (Sample 1):

Mould diameter = 10cm Mould height = 12cm Mould volume = 942.47 cc

Table 3.7: Proctor Compaction test (sample 1)

Details	Sample 1	Sample 2	Sample 3	Sample 4
Weight of empty mould(w_1) g	4385	4385	4385	4385
Weight of mould + compacted soil(w_2) g	5962	6058	6134	6146
Bulk density(γ) g/cc	1.67	1.77	1.855	1.868
Weightof can (W_1) g	21	28	29	28
Weightof wet soil (W_2) g	65	70	65.4	69.4
Weightof soil(W_3) g	62.4	66.9	61.9	65.2
Water content(w) %	6.28	7.96	10.63	11.29
Dry density (γ_d) g/cc	1.571	1.639	1.678	1.676

FIG.3.11: Graphical representation of proctor compaction test (Sample 1) The optimum moisture content of the soil sample = 10.63%

Maximum dry density of the soil sample = 1.678 g/cc

OBSERVATIONS & CALCULATIONS (Sample 2):

Mould diameter = 10cm Mould height = 12cm Mould volume = 942.47 cc

able 3.8: Proctor Compaction test (Sample 2)

Details	Sample 1	Sample 2	Sample 3	Sample 4
Weight of empty mould(w_1) g	4385	4385	4385	4385
Weight of mould + compacted soil(w_2) g	6103	6154	6222	6286
Bulk density(γ) g/cc	1.823	1.877	2.09	2.16
Weightof can (W_1) g	17.2	17.2	19.4	16.2
Weightof wet soil (W_2) g	52.2	46	71	71
Weightof soil(W_3) g	50	43.9	66.3	65.8
Water content(w) %	6.02	6.7	7.86	10.02
Dry density (γ_d) g/cc	1.72	1.76	1.9	1.89

Graphical Representation of Proctor Compaction Test (Sample 2)

From graph,

The optimum moisture content of the soil sample =8.1% The maximum dry density of the soil sample = 1.91g/cc

OBSERVATIONS & CALCULATIONS (Sample 3):

Mould diameter = 10cm Mould height = 12cm Mould volume = 942.47 cc

Table 3.9: Proctor Compaction test (sample 3)

Details	Sample 1	Sample 2	Sample 3	Sample 4
Weight of empty mould(w_1) g	4385	4385	4385	4385
Weight of mould + compacted soil(w_2) g	6340	6419	6547	6557
Bulk density(γ) g/cc	2.07	2.15	2.29	2.30
Weightof can (W_1) g	31.8	11.4	11	11.6
Weightof wet soil (W_2) g	63	41	38	51.8
Weightof soil(W_3) g	60.4	38.6	35.2	47.2
Water content(w) %	9.09	9.62	11.5	12.9
Dry density (γ_d) g/cc	1.897	1.929	2.05	2.03

FIG.3.13: Graphical Representation of Proctor Compaction Test (Sample 3) The optimum moisture content of the soil sample = 11.5%

The maximum dry density of the soil sample = 2.05g/cc

1. DETERMINATION OF SPECIFIC GRAVITY OF SOIL: PROCEDURE

- The pycnometer is cleaned, dried and weighed (W_1)
- The pycnometer is filled upto 1/3rd its height with the oven dried sample and weighed (W_2)
- The pycnometer is filled with distilled water and is kept aside for a few minutes to let the soil soak completely and is weighed (W_3)
- the pycnometer is emptied and is filled with water and is weighed (W_4)
- The experiment was repeated at least twice and the results were tabulated.

FORMULA:

Specific gravity $(G_s)=(W_2-W_1)/(W_2-W_1)-(W_3-W_4)$ Where,

W_1 = weight of pycnometer

W_2= weight of pycnometer +dry soil

W_3 = weight of pycnometer + soil + water W_4 = weight of pycnometer + water

Table 3.10. Specific gravity test observations and calculations

Details	Sample 1	Sample 2	Sample 3
Weight of pycnometer (W_1)g	627	627	627
Weight of pycnometer + dry soil (W_2) g	999	1046	999
Weight of pycnometer +soil & water (W_3) g	1725	1752	1730
Weight of pycnometer + water (W_4) g	1517	1517	1517
Specific gravity (G_s)	2.26	2.27	2.339

6. CALIFORNIA BEARING RATIO (CBR) TEST:

GENERAL

The CBR test is a penetration test developed by the California division of highways, as a method evaluating the stability of soil subgrade and other flexible highway materials. The test results have been correlated with the pavement thickness requirements for highways and airfields. The CBR test may be conducted in the laboratory on a prepared specimen in a mould or in-situ in the field.

FIG.3.14: CBR Test apparatus

PROCEDURE

- About 5kg of oven dried soil sample is taken and is mixed with optimum moisture content. The soil is then compacted either by IS light compaction (3 layers, 55 blows, each by 2.6 kg hammer) or IS heavy compaction (5 layers, 55 blows, each by 4.89 kg hammer).
- The mould with the base plate is placed under the penetration plunger of the loading machine and a surcharge weight of 2.5 kg is applied
- The dial gauge for measuring the penetration values of the plunger is fitted in position. The dial gauge of the proving ring and the penetration dial gauge are set. The load readings are recorded at penetration readings of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0 etc.,

- The proving ring calibration factor is noted. The load penetration curve is the plot. The unit load values corresponding to 2.5mm and 5.0mm penetration values are found from the graph.

This load is expressed as a percentage of standard load values at the respective deformation level to obtain the CBR value. The CBR for 2.5mm penetration is taken

The Standard Load Values

Penetration (mm)	Standard Load (kg)	Unit Standard Load (kg/sq.cm)
2.5	1370	70
5.0	2055	105
7.5	2630	134
10.0	3180	162
12.5	3600	183

CBR value is calculated by the formula,

CBR = [(Load sustained by specimen at defined penetration level)/(Load sustained by sustained crushed stone at same penetration level)]*100

OBSERVATIONS & CALCULATIONS (SAMPLE 1):

Table 3.11: CBR test (Sample 1)

S.No	Penetration (mm)	Proving Ring Reading	Load on plunger(kg)
1	0.5	0.8	42.56
2	1.0	1.6	85.12
3	1.5	2.4	127.68
4	2.0	3.2	170.24
5	2.5	3.7	196.84
6	3.0	3.8	202.16
7	3.5	3.9	207.48
8	4.0	4.0	212.8
9	4.5	4.2	223.44
10	5.0	4.3	228.76
11	5.5	4.4	234.08
12	6.0	4.6	244.72
13	6.5	4.8	255.36
14	7.0	5.0	266.0
15	7.5	5.1	271.32
16	8.0	5.2	276.64
17	8.5	5.3	281.96
18	9.0	5.4	287.28

$CBR_{2.5}$ = (196.84/1370)*100 = 14.36% $CBR_{5.0}$ = (228.76/2055)*100 = 11.13%

FIG.3.15: Graphical representation of CBR Test (Sample 1) The CBR value of soil sample = 14.36%

OBSERVATIONS & CALCULATIONS (SAMPLE 2):

Table 3.12: CBR test (Sample 2)

S.No	Penetration	Proving Ring Reading	Load on plunger(kg)

1	0.5	0.2	37.242
2	1.0	1.4	74.48
3	1.5	2.1	111.72
4	2.0	2.8	148.96
5	2.5	3.5	186.2
6	3.0	3.7	196.84
7	3.5	3.9	207.48
8	4.0	4.2	213.44
9	4.5	4.5	239.4
10	5.0	4.8	255.36
11	5.5	5.0	266.0
12	6.0	5.1	271.32
13	6.5	5.1	271.32
14	7.0	5.2	276.64
15	7.5	5.3	281.96
16	8.0	5.4	287.28
17	8.5	5.4	287.28
18	9.0	5.5	292.6
19	9.5	5.6	297.92
20	10	5.8	308.56

$CBR_{2.5}$ = (186.2/1370)*100 = 13.59% $CBR_{5.0}$ = (255.36/2055)*100 = 12.426

FIG 3.16: Graphical Representation of CBR test (Sample 2) The CBR value of the soil sample is 12.426%

OBSERVATIONS & CALCULATIONS (SAMPLE 3):

Table 3.13: CBR test (Sample 3)

S.No	Penetration (mm)	Proving Ring Reading	Load on plunger(kg)
1	0.5	1.0	53.2
2	1.0	1.8	95.76
3	1.5	2.4	127.68

4	2.0	3.0	159.6
5	2.5	3.8	202.16
6	3.0	3.9	207.48
7	3.5	4.0	212.48
8	4.0	4.1	218.12
9	4.5	4.2	223.44
10	5.0	4.3	228.76
11	5.5	4.4	234.08
12	6.0	4.5	239.4

$CBR_{2.5}$ = (202.16/1370)*100 = 14.756% $CBR_{5.0}$ = (228.76/2055)*100 = 11.12%

FIG.3.17: Graphical representation of CBR test (Sample 3) The CBR value of given sample is 14.756%

SAMPLE -1 (SOAKING)

Table 3.14: CBR test for sample 1 (soaking)

S.No	Penetration (mm)	Proving Ring Reading	Load on plunger(kg)
1	0.5	0.8	42.56
2	1.0	1.1	58.52
3	1.5	1.2	63.84
4	2.0	1.3	69.84
5	2.5	1.4	74.48
6	3.0	1.5	79.8
7	3.5	1.6	85.12
8	4.0	1.7	90.44
9	4.5	1.9	101.08
10	5.0	2.0	106.4
11	5.5	2.1	111.72
12	6.0	2.2	117.04

13	6.5	2.3	122.36
14	7.0	2.5	133
15	7.5	2.5	133
16	8.0	2.6	138.32
17	8.5	2.8	148.96
18	9.0	2.9	154.28
19	9.5	3.0	159.6
20	10	3.0	159.6

The CBR value at 2.5mm penetration = (74.48*1370)*100 = 5.436% The CBR value at 5 mm penetration = (106.4/2055)*100 = 5.177

The CBR value of the sample is 5.436%

SAMPLE -2 (SOAKING)

Table 3.15: CBR test for sample 2 (soaking)

S.No	Penetration (mm)	Proving Ring Reading	Load on plunger(kg)
1	0.5	0.2	10.64
2	1.0	0.5	26.6
3	1.5	0.8	42.56
4	2.0	1.0	53.2
5	2.5	1.2	63.84
6	3.0	1.4	74.48
7	3.5	1.2	85.12
8	4.0	1.7	90.44
9	4.5	1.8	95.76
10	5.0	1.9	101.08
11	5.5	2.1	110.656
12	6.0	2.2	115.976
13	6.5	2.2	117.04
14	7.0	2.3	122.36

15	7.5	2.4	127.68
16	8.0	2.5	133
17	8.5	2.6	138.32
18	9.0	2.6	138.32
19	9.5	2.7	143.64
20	10	2.7	143.64

The CBR value at 2.5mm penetration is (63.84/1370)*100 = 4.65% The CBR value at 5mm penetration is (101.08/2055)*100 = 4.91%

The CBR value of the sample is 4.91%

SAMPLE -3 (SOAKING)

Table 3.16: CBR test for sample 3 (soaking)

S.No	Penetration (mm)	Proving Ring Reading	Load on plunger(kg)
1	0.5	0.3	15.96
2	1.0	0.6	31.92
3	1.5	0.9	47.88
4	2.0	1.2	63.84
5	2.5	1.5	79.8
6	3.0	1.6	85.12
7	3.5	1.7	90.44
8	4.0	1.8	95.76
9	4.5	1.9	101.08
10	5.0	2.0	106.4
11	5.5	2.1	111.72
12	6.0	2.2	117.04
13	6.5	2.2	117.04
14	7.0	2.3	122.36
15	7.5	2.4	127.68
16	8.0	2.5	133

17	8.5	2.6	138.32
18	9.0	2.7	143.64
19	9.5	2.8	148.96
20	10	3.0	159.6

The CBR value at 2.5mm penetration = (79.8/1370)*100 = 5.8% The CBR value at 5mm penetration = (106.4/2055)*100 = 5.17%

DESIGN OF PAVEMENT THICKNESS BY GROUP INDEX METHOD: SAMPLE 1:

Sieve analysis:

Mass of soil taken =500gm

Mass of soil passing through 75µ sieve = 6gm

Percentage finer = (mass of soil passing through 75µ sieve) × 100

= (6) × 100 = 1.2%

Liquid limit =24%

Plastic limit =14.28%

GI =0.2a + 0.005ac + 0.01bd

Where,

a = percentage of material passing through IS 200(75 µ) sieve more than 35 and less than 75 b = percentage of material passing through IS 200(75 µ) sieve more than 15 and less than 55 c = liquid limit more than 40 and less than 60

d = plastic limit more than 10 and less than 30 Here, a = 1.2 – 35 = 0

b = 1.2 – 15 = 0

c = 24 – 40 = 0

d = 14.28 – 10 = 4.28

GI = (0.2 × 0) + (0.005 × 0 × 0) + (0.01 × 0 × 0)

= 0

Assuming the traffic to be medium, 50 to 300 vehicles per day.

Mass of soil passing through 75μ sieve = 31gm

Percentage finer = (mass of soil passing through 75μ sieve) × 100

= (31) × 100 = 6.2%

Liquid limit =20%

Plastic limit =10.16%

GI =0.2a + 0.005ac + 0.01bd

Where,

a = percentage of material passing through IS 200(75 μ) sieve more than 35 and less than 75 b = percentage of material passing through IS 200(75 μ) sieve more than 15 and less than 55 c = liquid limit more than 40 and less than 60

d = plastic limit more than 10 and less than 30 Here, a = 6.2 – 35 = 0

b = 6.2 – 15 = 0

c = 20 – 40 = 0

d = 10.16 – 10 = 1.11

GI = (0.2 × 0) + (0.005 × 0 × 0) + (0.01 × 0 × 1.11)

= 0

Assuming the traffic to be medium, 50 to 300 vehicles per day.

From the design charts, the combined thickness, of surface, base and sub-base course = 23cm The thickness of base and sub- base courses = 20cm

FIG: 3.21: Design chart by group index values

DESIGN OF PAVEMENT THICKNESS BY CBR METHOD:

1. The soil samples are taken and their optimum moisture content is determined by

   Proctor's density test for light compaction.

2. The soil sample is then compacted in CBR mould for optimum density and the mould is soaked for 3 days.

3.

Therefore, Design Curve E is to be used for design as the design traffic volume is in the range 450 to 1500 vehicles/day.

Using the design chart, the total pavement thickness over subgrade having CBR of 4.9% is obtained as 45cm for curve E.

Thus 45cm of pavement materials is required to cover the natural soil subgrade having 4.9% CBR value. Therefore, the thickness of base and sub base courses are 13cm and 25cm having CBR value 50% and 25% using the design chart.

The CBR values for the gravel and road metal are assumed as follows:

Type of material	Suggested CBR values(%)
Gravel	25
Road metal	50

SAMPLE 3:

CBR corresponding to 2.5mm penetration = $\left(\underline{79.8}\right) \times 100 = 5.8\%$ Assume, Average Daily Traffic (ADT) = 300

Annual rate of growth of traffic (r) = 8%

Time taken for pavement construction (n) = 1 year No. of vehicles for design (A) = $P(1 + r)^{(n + 10)}$

$$= 300(1 + \underline{8})^{(1 + 10)}$$

= 699.49 vehicles/day

= 700 vehicles/day

Therefore, Design Curve E is to be used for design as the design traffic volume is in the range 450 to 1500 vehicles/day.

Using the design chart, the total pavement thickness over subgrade having CBR of 5.8% is obtained as 38cm for curve E.

Thus 38cm of pavement materials is required to cover the natural soil subgrade having 5.8% CBR value.

Therefore, the thickness of base and sub base courses are 11cm and 22cm having CBR value 47% and 25% using the design chart.

The CBR values for the gravel and road metal are assumed as follows:

Type of material	Suggested CBR values (%)
Gravel	25
Road metal	47

5cm

15cm

25cm

Wearing Course Base Course

Sub-Base Course

CONCLUSION:

Provide the greater of the two values obtained in each case for safety. Hence, provide a sub base of 25 cm thickness, base course of 15 cm thickness and wearing course of 7 cm thickness (as obtained from the curves recommended by IRC) .

CHAPTER 4 SURVEY AND ESTIMATION

SURVEY DATA:

In the design of a pavement, the earthwork estimation plays a major role. In order to obtain the total quantity of earthwork estimation, the longitudinal profile of the proposed road section is determined.

For this purpose, the reduced levels along the center-line of the pavement are initially obtained and are tabulated as follows:

Table 4.1: RL's along the centre line of longitudinal profile of the proposed pavement of Road I:

Station	Distance(m)	Back	Intermediate	Fore	Height Of	Reduced	Remarks

III:

Station	Distance (m)	Back Sight (m)	Intermediate Sight (m)	Fore Sight (m)	Height Of Instrument (m)	Reduced Level (m)	Remarks
35 m		1.12			101.48	100.36	BM = 100.36
	5		1.11			100.37	
	10		1.13			100.35	
	15		1.135			100.345	
	20		1.325			100.155	
	25		1.32			100.16	
	30		1.36			100.12	
	35		1.4			100.08	
	40		1.39			100.09	

2. : **EARTHWORK ESTIMATION:**

Table 4.4: Earthwork for filling of Road I

		EARTHWORK FOR FILLING OF ROAD SECTION 1				
S.NO	TOP WIDTH (m)	HEIGHT (m)	BOTTOM WIDTH (m)	AREA (m^2)	INTERVAL (m)	QUANTITY OF EARTHWORK (m^3)
1	5	0.4	5.8	2.16	2.5	5.4

2	5	0.35	5.7	1.872 5	5	9.3625
3	5	0.45	5.9	2.452 5	5	12.2625
4	5	0.4	5.8	2.16	5	10.8
5	5	0.4	5.8	2.16	5	10.8
6	5	0.25	5.5	1.312 5	5	6.5625
7	5	0.25	5.5	12.26 25	5	61.3125
8	5	0.3	5.6	1.59	5	7.95
9	5	0.3	5.6	1.59	5	7.95
10	5	0.25	5.5	1.312 5	5	6.5625
11	5	0.1	5.2	0.51	5	2.55
12	5	0.1	5.2	0.51	5	2.55
13	5	0.1	5.2	0.51	5	2.55
14	5	0.1	5.2	0.51	5	2.55
15	5	0.2	5.4	1.04	5	5.2
16	5	0.3	5.6	1.59	5	7.95
17	5	0.1	5.2	0.51	2.5	1.275
18	5	0.15	5.3	0.772 5	5	3.8625
						167.45

Table 4.5: Earthwork for cutting of Road I

		EARTH WORK FOR CUTTING OF ROAD SECTION 1				
S.NO	TOP WIDTH (m)	HEIGHT (m)	BOTTOM WIDTH(m)	AREA (m2)	INTERVAL (m)	QUANTITY OF EARTHWORK (m^3)
1	5	0.5	6	2.75	2.5	6.875

	5	0.6	6.2	3.36	5	16.8
2	5	0.4	5.8	2.16	5	10.8
3	5	0.4	5.8	2.16	5	10.8
4	5	0.4	5.8	2.16	5	10.8
5	5	0.4	5.8	2.16	5	10.8
6	5	0.3	5.6	1.59	5	7.95
7	5	0.4	5.8	2.16	5	10.8
8	5	0.2	5.4	1.04	5	5.2
9	5	0.1	5.2	0.51	5	2.55
10	5	0.1	5.2	0.51	2.5	1.275
11	5	0.15	5.3	0.772 5	2.5	1.93125
12						
13	5	0.15	5.3	0.772 5	5	3.8625
14	5	0.2	5.4	1.04	5	5.2
15	5	0.3	5.6	1.59	5	7.95
16	5	0.2	5.4	1.04	5	5.2
17	5	0.1	5.2	0.51	5	2.55
18	5	0.05	5.1	0.252 5	5	1.2625
19	5	0.15	5.3	0.772 5	5	3.8625
20	5	0.55	6.1	3.052 5	5	15.2625
21	5	0.8	6.6	4.64	5	23.2
22	5	0.7	6.4	3.99	5	19.95
23	5	0.8	6.6	4.64	5	23.2
						208.08125

Table 4.6: Earthwork for Road II

EARTHWORK FOR CUTTING FOR ROAD SECTION 2						
S.N O	TOP WIDTH (m)	HEIGHT (m)	BOTTO M WIDTH (m)	AREA (m^2)	INTERVA L (m)	QUANTITY OF EARTHWOR K (m^3)

1	5	0.05	5.1	0.2525	2.5	0.63125
2	5	0.1	5.2	0.51	2.5	1.275
						1.90625

EARTHWORK FOR FILLING FOR ROAD SECTION 2						
S.NO	TOP WIDTH (m)	HEIGHT (m)	BOTTOM WIDTH (m)	AREA (m^2)	INTERVAL (m)	QUANTITY OF EARTHWORK (m^3)
1	5	0.1	5.2	0.51	2.5	1.275
2	5	0.05	5.1	0.2525	5	1.2625
3	5	0.05	5.1	0.2525	5	1.2625
4	5	0.05	5.1	0.2525	5	1.2625
5	5	0.2	5.4	1.04	5	5.2
6	5	0.25	5.5	1.3125	5	6.5625
7	5	0.1	5.2	0.51	5	2.55
8	5	0.1	5.2	0.51	2.5	1.275
						20.65

Table 4.7: Earthwork for filling of Road III

EARTHWORK OF FILLING FOR ROAD SECTION 2						
S.NO	TOP WIDTH (m)	HEIGHT (m)	BOTTOM WIDTH (m)	AREA (m^2)	INTERVAL (m)	QUANTITY OF EARTHWORK (m^3)
1	5	0.1	5.2	0.51	2.5	1.275
2	5	0.05	5.1	0.2525	2.5	0.63125
3	5	0.1	5.2	0.51	5	2.55
4	5	0.15	5.3	5.15	5	25.75
5	5	0.35	5.7	1.8725	5	9.3625
6	5	0.25	5.5	2.625	5	13.125
7	5	0.5	6	2.75	5	13.75

8	5	0.5	6	2.75	5	13.75
9	5	0.4	5.8	2.16	5	10.8
10	5	0.35	5.7	1.872 5	5	9.3625
11	5	0.25	5.5	1.312 5	5	6.5625
12	5	0.05	5.1	0.252 5	5	1.2625
						108.18125

Table 4.8: Earthwork for cutting of Road 3

EARTHWORK FOR CUTTING FOR ROAD SECTION 2						
S.N O	TOP WIDT H (m)	HEIG HT (m)	BOTTO M WIDTH (m)	ARE A (m^2)	INTERV AL (m)	QUANTITY OF EARTHWO RK (m^3)
1	5	0.2	5.4	1.04	2.5	2.6
2	5	0.1	5.2	0.51	5	2.55
3	5	0.05	5.1	0.252 5	5	1.2625
4	5	0.05	5.1	0.252 5	2.5	0.63125
5	5	0.1	5.2	0.51	2.5	1.275
6	5	0.2	5.4	1.04	5	5.2
7	5	0.15	5.3	0.772 5	5	3.8625
8	5	0.35	5.7	1.872 5	5	9.3625
9	5	0.25	5.5	1.312 5	5	6.5625
10	5	0.25	5.5	1.312 5	5	6.5625
11	5	0.15	5.3	0.772 5	5	3.8625
12	5	0.1	5.2	0.51	2.5	1.275

13	5	0.2	5.4	1.04	5	5.2
14	5	0.2	5.4	1.04	5	5.2
15	5	0.1	5.2	0.51	5	2.55
16	5	0.1	5.2	0.51	5	2.55
17	5	0.1	5.2	0.51	5	2.55
18	5	0.1	5.2	0.51	5	2.55
19	5	0.1	5.2	0.51	2.5	1.275
						66.88125

CHAPTER 5 CONCLUSION

In this project work, an attempt is made to incorporate latest techniques of geometric design, pavement design for a road for an existing colony which is 2 km away from Car Shed Junction, P.M.Palem. The IRC specifications are based on rational thinking, the proposed road is safe in both geometrics as well as pavement design.

It is also proposed to design a flexible pavement by Group Index method and CBR method. Some more methods are available in the design of flexible pavement, which are much more advanced like the California resisting value method, Mcleod method, Triaxial method and Burnister method. Because of the limitations of time and scope, only the GI method and CBR method are adopted.

To have a practical concept of estimation analysis, an attempt is made to estimate the quantities of earth work of flexible pavement.

CHAPTER 6 REFERENCES

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