MECHANISTIC APPROACH FOR FIBRE-REINFORCED FLEXIBLE PAVEMENT

Submitted in partial fulfilment of the requirements

for the degree of

Bachelor of Engineering

by

Sufiyan Imtiyaz Dandekar (16DCES64)

Ammar Iqbal Darji (14CES09)

Kiran Appaso Dongare (13CES16)

Under the guidance of

Prof. Tehsin A. Kazi

Department of Civil Engineering

School of Engineering and Technology

Anjuman-I-Islam's Kalsekar Technical Campus

New Panvel, Navi Mumbai-410206

2018-2019

A Project Report on

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CERTIFICATE

This is to certify that the project entitled **"MECHANISTIC APPROACH FOR FIBRE-REINFORCED FLEXIBLE PAVEMENT"**is a bonafide work of **"SUFIYAN DANDEKAR, AMMAR DARJI AND KIRAN DONGARE"** submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Undergraduate" in "Civil Engineering"

Prof. Tehsin A. Kazi

(Guided By)

Dr. R. B. Magar

(Head of Department)

Dr. Abdul RazakHonnutagi

(Director, AIKTC)

APPROVAL SHEET

This dissertation report entitled **"MECHANISTIC APPROACH FOR FIBRE-REINFORCED FLEXIBLE PAVEMENT"** by **"SUFIYAN DANDEKAR, AMMAR DARJI AND KIRAN DONGARE"** is approved for the degree of "Civil Engineering"

Examiners

1. ………………………….
2. ………………………….

Supervisors:

1. ………………………….
2. ………………………….

Date:

Place: Panvel

DECLARATION

We declare that this written submission represents my ideas in our own words and where others ideas or words have been included,we have adequately cited and referenced the original sources. We also declare that,we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Sufiyan Imtiyaz Dandekar (16DCES64)

Ammar Iqbal Darji (14CES09)

Kiran Appaso Dongare (13CES16)

Date:

ABSTRACT

Soil stabilization is the technique used to increase the strength and stability of soil. It is done by reinforcing the soil with various reinforcing materials, such as geotextiles, geo strips, geonets and fibers. The fibers used in the previous studies for increasing stability are carbon steel, saw dust, wheat husk, polypropylene, etc. Soil stabilization is done by reducing the layer thickness and extending the service life of the pavement. From the previous study, soil stabilization is done mainly by mechanical stabilization, physical stabilization, and by using polymers. Physical and chemical properties of the fibers also plays an important role in soil stabilization such as specific gravity, optimum moisture content (OMC), maximum dry density (MDD), etc. Various tests were performed to decide the optimum quantity of fibers on reinforced and unreinforced such as compaction tests, unconfined compression (UCC) strength tests, CBR tests, etc. Soil stabilization is the better option in terms of economy as well as energy rather going for deep foundation or raft foundation, which depends on designer.

Keywords— Soil; PP Fibers; Specific Gravity; UCC; MDD; OMC; CBR.

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ABBREVIATION NOTATION AND NOMENCLATURE

PP	Polypropylene
OMC	Optimum Moisture Content
MDD	Maximum Dry Density
UCC	Unconfined Compression Test
ASTM	American Society for Testing and Materials
WL	Liquid Limit
Wp	Plastic Limit
Ip	Plasticity Index

Chapter 1

INTRODUCTION

1.1 GENERAL

The intention of this assess is to bring in and summaries journalism pertaining to the application of waste PP fibres as fortification in the soil by examining the performance of experimental soil test samples. The inspection is restricted to published research reports, journal articles, and conference proceedings. This review is structured to illustrate the value added to foundations by the use of geosynthetic reinforcement. In especial, the review is designed to illustrate the benefits derived from waste PP fiber reinforcement, the conditions under which reinforcement is good, the PP properties that are most influential for this application, and the mechanisms responsible for reinforcement. The ends of this unit are used subsequently to evaluate existing design procedures, to comment on developing application specifications.

1.2 RATIONALE FOR TAKING UP THE PROPOSED PROJECT WORK

The safety of any geotechnical structure is dependent on the strength of soil. If the soil fails, the structure founded on it can collapse. Therefore, stabilizing the soil by reinforcing it with fibers and geosynthetic materials. While constructing any structure of any form, it directly depends upon the relation between soil, structure and its loading. There are various methods to improve the stability of the soil but most of them are very costly. Therefore it is necessary to find low cost alternative for the same. Polypropylene fibers are hydrophobic, that is they do not absorb water. Therefore, when placed in a concrete matrix they need only be mixed long enough to insure dispersion in the concrete mixture. The mixing time of fibrillated or tape fibers should be kept to a minimum to avoid possible shredding of the fibers. The type of PP fiber recommended by manufacturers for paving applications is the collated fibrillated fiber. Manufacturers recommend that the length of the fiber be greater than twice the diameter of the aggregate. This would be consistent with past experiences with steel fibers and also with current theories on fiber dispersion and bonding".

Figure 1 (Polypropylene)

1.3 ADVANTAGES OF STABILISATION

- Utilization of local and in situ materials.
- Large number of waste materials can be utilized by increasing their strength.
- Re use of soils considered unsuitable.
- Savings in disposal of unsuitable materials.
- Large savings in aggregate consumption.
- Savings in transportation of material.
- Protection of roads (less truck transport)

1.4 APPLICATIONS

- Road constructions
- Foundations
- Dams and reservoirs

Chapter 2

LITERATURE REVIEW

2.1 GENERAL

For any land based structure, the foundation is very important and has to be strong to support the entire structure. In order for the foundation to be strong, the soil around it plays a very critical role. So, to work with soils, we need to have proper knowledge about their properties and factors which affect their behaviour. The process of soil stabilization helps to achieve the required properties in a soil needed for the construction work. In India, the modern era of soil stabilization began in early 1970's, with a general shortage of petroleum and aggregates, it became necessary for the engineers to look at means to improve soil other than replacing the poor soil at the building site. Soil stabilization was used but due to the use of obsolete methods and also due to the absence of proper technique, soil stabilization lost favour. In recent times, with the increase in the demand for infrastructure, raw materials and fuel, soil stabilization has started to take a new shape. With the availability of better research, materials and equipment, it is emerging as a popular and cost effective method for soil improvement. Here, in this project, soil stabilization has been done with the help of randomly distributed PP fibers obtained from waste materials. The improvement in the shear strength parameters has been stressed upon and comparative studies have been carried out using different methods of shear resistance measurement. It is very expensive to replace the inferior soil entirely soil and hence, soil stabilization is the thing to look for in these cases It improves the strength of the soil, thus, increasing the soil bearing capacity. It is more economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep foundation or raft foundation. It is also used to provide more stability to the soil in slopes or other such places. Sometimes soil stabilization is also used to prevent soil erosion or formation of dust, which is very useful especially in dry and arid weather.

2.2 REVIEW OF LITERATURE

Ayyappan et al. in 2010, studied the influence of PP fibers on engineering behavior of soil−fly Ash mixtures for road construction. The purpose of this investigation was to identify and quantify the influence of fiber variables (content and length) on performance of fiber reinforced soil- fly ash specimens. It was observed that inclusion of randomly distributed fibers significantly improved the unconfined compressive strength of soil fly ash mixtures, increase in fiber length reduced the contribution to peak compressive strength while increased the contribution to strain energy absorption capacity in all soil fly ash mixtures, optimum dosage rate of fibers was identified as 1.00 % by dry weight of soil- fly ash, for all soil fly ash mixtures and maximum performance was achieved with fiber length of 12 mm as reinforcement of soil fly ash specimens.

Malekzadeh and Bilsel in 2012, studied the effect of PP fiber on mechanical behavior of expansive soils. It was concluded that mitigation of expansive soils using PP fiber might be an effective method in enhancing the physical and mechanical properties of sub-soils on which roads and light buildings are constructed.

Satyam Tiwari in 2016, explained the “Soil Stabilization Using Waste Fiber Materials”, and investigated the use of waste fiber materials in geotechnical applications and to evaluate the effects of waste PP fibers on shear strength of unsaturated soil by carrying out direct shear tests and unconfined compression tests on two different soil samples. The percentages of fiber reinforcement added are 0, 0.05, 0.15, and 0.25.Based on Specific gravity of a soil-With mixing of 0.05% fibers (PPF) specific gravity of the soil increases by 0.3%. Strength of the soil is directly proportional to specific gravity, more is the specific gravity more will be the strength of soil. Based on liquid limit of a .Soil without reinforcement and with reinforcement have liquid limit difference of 18.18%.

Pramod S. Patil (Jun-2014), "Innovative techniques of waste plastic used in concrete mixture.''Disposal of plastic waste in an environment is considered to be a big problem due to its very low biodegradability and presence in large quantities, In recent time use of such, Industrial wastes from PP (PP) and polyethylene terephthalate (PET) were studied as alternative replacements of a part of the conventional aggregates of concrete. Plastic recycling was taking position on a significant scale in an India, As much as 60 % of both industrial and urban plastic waste is recycled which obtained from diverse authors, Masses in India have released plastic wastes on a large scale have huge economic value, as a result of this, recycling of waste plastics plays a major function in providing employment.

N. Vijaya Kumar et al; (Jan-2014), "Evaluation of wear properties of industrial waste (Slag) reinforced PP composites." A good deal of waste is produced by industries and they are stacked up on soil which creates state and environmental problems. Government policies and regulations force us to look for choices. Thus, researchers are attempting to utilize these wastes as reinforcement in composites. Slag is an industrial waste reinforced in PP composites. The stick-on disc wear testing machine has been used to study the friction and wear behavior of the polymer composites. The wear loss and coefficient of friction are plotted against the normal loads and sliding speeds. It is noted from the graphical representation of the result that with the increase in load weight loss decreases and increase in sliding velocity weight loss also increases.

.Al-Refeai, 1991; Day et al., 2003; Olaniyan et al., 2011, stated that the capability of synthetic fiber reinforcement for improving the behavior of soil has been demonstrated by using triaxial tests, CBR tests, cyclic triaxial tests, resonant-column and Torsional shear tests.

Hejazi et al., 2012; Ninov et al., 2007, in their studies indicated that fiber inclusions increase the ultimate strength, stiffness, CBR, resistance to liquefaction, and shear modulus and damping of reinforced soil.

Maher and Gray, 1990; Kumar and Singh, 2008, concluded that currently PP fibers are used in soil mass to resist tensile failure, cracking, shrinkage, biological decay, acid and alkali attack.

Puppala and Musenda, 2000; Yetimoglu and Salbas, 2003; Yi et al., 2006; Consoli et al., 2009, observed that an admix of PP fibre into soil have significantly improved its engineering properties (e.g. tensile / compressive / shear strengths, fracture toughness, durability) applied in retrofitting and repairing the covering of structures, carpentries stabilizing, landfill, slope protection, road subgrade etc.

(Li et al., 1995; Zhang et al., 1998), stated the soils reinforced with discrete PP fibre have shown considerable decrease in the stiffness of the soil (hence reduced crack) and enhanced the self-seaming ability of soils.

Gray and Ohashi, 1983; Attom and Tamimi, 2010; Freilich et al., 2010; Malekzadeh and Bilsel, 2012, stated that the soil reinforced with PP fibre exhibits greater toughness and ductility, increases formability and bending strength and lessen loss of post peak strength, as compared to soil alone.

2.3 GAPS AND FINDINGS

Following observations have been pulled out from the broad overview of the literature presented in this chapter:

i) Extensive research work is reported on use of oriented and randomly oriented fibre reinforcements using laboratory testing, while this brought out the positive improvement of geotechnical behaviour of soils. Yet little work reports on the usage of waste fiber PP materials.

ii) The majority of works carried out in the area of sub-base or base improvements of the diverse types of pavements using coir geotextiles to control erosion and watershed management. Just a few works have been reported involving the utilisation of PP for the the advance of engineering properties of land. Consequently, a scope of systematic research study in this field is lacking.

2.4 SUMMARY

The review of literature indicate that PP is a versatile material with attractive properties and advantages, as a result of this PP is now being used widely all over the world to stabilise the soil.

Chapter 3

MATERIALS AND CHARACTERISTICS

3.1 MATERIALS

3.1.1 POLYPROPYLENE

PP (PP) also known as polypropene, is a thermoplastic polymer used in a wide variety of applications including packing, it is widely use in ready mix concreate and it is easily available in india and other country. According to global market report production of PP since 2013, is 55 million tonnes. In synthetic fiber PP is the world second widest product after polythene. Chemically PP is denoted by C3H6.

3.1.2 BENEFITS OF POLYPROPYLENE

1. PP (pp) is a lightweight fiber; it has density of 0.91 gm/cm³.

2. PP average diameter approx is 0.034 mm.

3. Its average length is 12 mm.

4. It does not absorb water. It presents that it has good resistance towards water absorb.

5. PP has excellent chemical resistance. PP fibers are very resistant to most acids and alkalis.

6. The thermal conductivity of this fiber is lower than that of other fibers.

3.1.3 DRAWBACKS OF POLYPROPYLENE

1. It has low melting temperature.

2. It has high creeping rate.

3.1.4 PROPERTIES OF POLYPROPYLENE

PROPERTY	POLYPROPYLENE
Fiber Type	Single Fiber
Relative Density	0.91
Thermal Conductivity	6.0 (with air as 1.0)
Average Length And Diameter	15 mm And 0.3 mm Respectively
Tensile Strength (gf/den)	3.5-5.5
Elongation (%)	40-100
Abration Resistance	Good
Moisture Absorption (%)	0-0.05
Softening Point (°C)	140
Melting Point (°C)	165
Resistance to Mildew, Moth, Chemical	Excellent

Table 1 (Properties of PP)

Chapter 4

METHODOLOGY AND RESULT

4.1 TESTS ON REINFORCED AND UNREINFORCED SOILS AS PER INDIAN STANDARD

4.1.1 GRAIN SIZE ANALYSIS

In accordance with IS: 2720-PART-4-1985

APPARATUS :

1. Balance.

2. Sieves.

3. Sieve shaker.

PREPARATION OF SOIL SAMPLE :

After receiving the soil sample it is dried in air or in oven (maintained at a temperature of 600C). If clods are there in soil sample then it is broken with the help of wooden mallet.

PROCEDURE :

1. The sample is dried to constant mass in the oven at a temperature of 1100±50C and all the sieves which are to be used in the analysis are cleaned.

2. The oven dry sample is weighed and sieved successively on the appropriate sieves starting with largest. Each sieve is shaken for a period of not less than 2 minutes

3. On completion of sieving the material retained on each sieve is weighed.

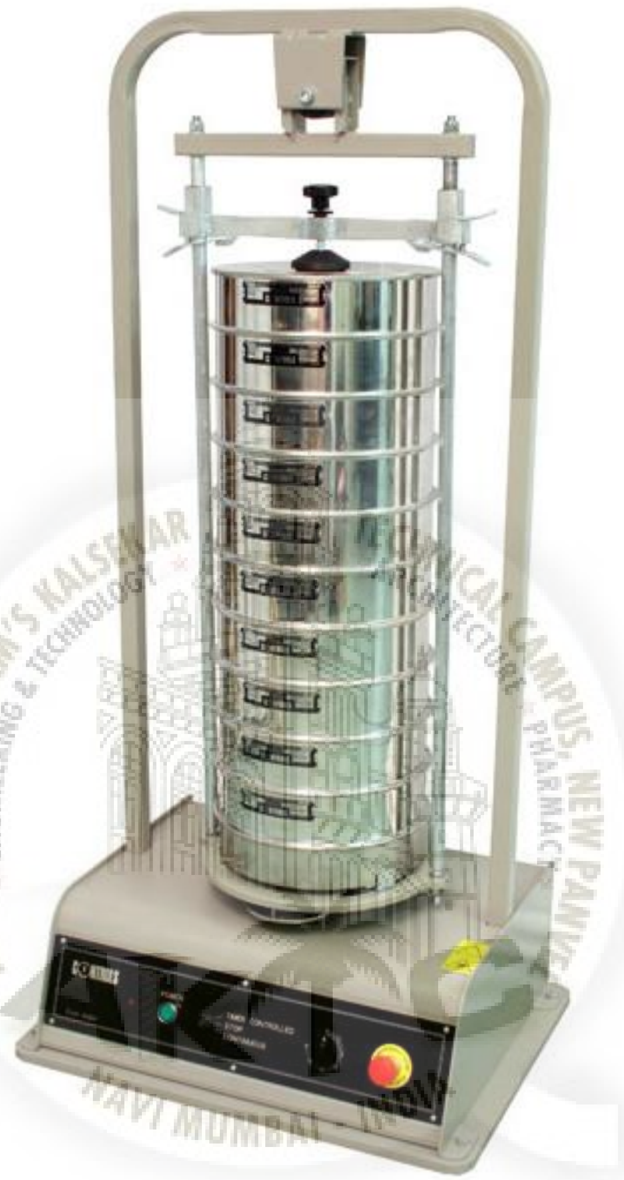


Figure 2 (Sieves on Mechanical Shaker)

CALCULATION :

The percent retained (%), Cumulative retained (%) & percent finer (%) is calculated.

Percent retained on each sieve = Weight of retained sample in each sieve / Total weight of sample

The cumulative percent retained is calculated by adding percent retained on each sieve as a cumulative procedure. The percent finer is calculated by subtracting the cumulative percent retained from 100 percent.

RESULT :

PARTICLE SIZE DISTRIBUTION	
1. Gravel (%)	3
2. Sand (%)	7
3. Silt (%)	51
4. Clay (%)	39

Table 2 (Particle Size Distribution)

4.1.2 ATTERBERG'S LIMITS

Performing test to find atterberg's limits as per Indian Standard (IS: 2720-PART-5-1985).

4.1.2.1 LIQUID LIMIT

The liquid limit is determined in the laboratory with the help of the standard liquid limit apparatus designed by Casagrande.

The apparatus consists of a hard rubber base of B.S. hardness 21-25, over which a brass cup drops through the desired height. The brass cup can be raised and lowered to fall on the rubber base with the help of a cam operated by a handle. The height of fall of the cup can be adjusted with the help of adjusting screws. Before starting the test, the height of fall of the cup is adjusted to 1 cm.

Two types of grooving tools are used;

(i) the Casagrande (BS) tool, and

(ii) the ASTM tool.

The IS: 9259-1979 designates these tools as grooving tool. The Casagrande tool cuts a groove of size 2 mm wide at the bottom, 11.0 mm wide at the top, and 8 mm high. While the ASTM tool cuts a groove 2 mm wide at the bottom, 13.6 mm at the top, and 10 mm deep. The ASTM tool is used only for more sandy soils where the Casagrande tool tends to tear the sides of the groove.

APPARATUS :

1. Casagrande apparatus.

2. Sieve No. 40 (ASTM).

3. Spatula.

4. Containers.

5. Tray.

6. Electric Oven.

7. Balance.

Figure 3 (Casagrande Apparatus)

PROCEDURE :

1. About 120 g of the specimen passing through 425 micron sieve is mixed thoroughly with distilled water in the evaporation dish or on a marble plate to form a uniform paste.

2. A portion of the paste is placed in the cup over the spot where the cup rests on the base, squeezed down and spread into position and the groove is cut in the soil pat.

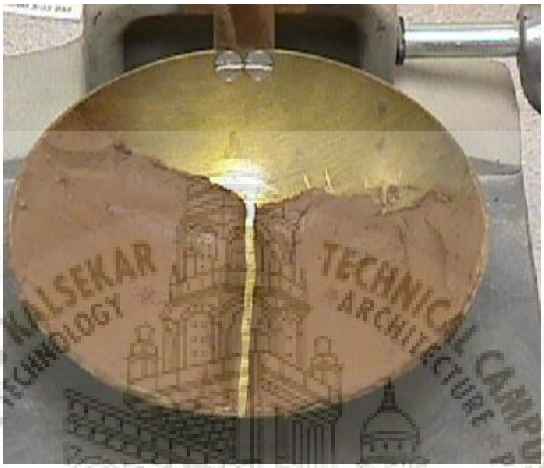


Figure 4 (Casagrande Apparatus)

3. The handle is rotated at a rate about 2 revolutions per second, and the number of blows is counted until the two parts of the soil sample come into contact at the bottom of the groove along a distance of 10 mm. Some soils tend to slide on the surface of the cup instead of the flowing. If this occurs, the result should be discarded, and the test repeated until flowing does not occur.

4. After recording the number of blows, approximately 10 gram of soil from near the closed groove is taken for water content determination. Since it is difficult to adjust the water content precisely equal to the liquid limit when the groove should close in 25 blows, the liquid limit is determined by plotting a graph between the number of blows as abscissa on a logarithmic scale and the corresponding water content as ordinate.

For plotting the flow curve, at least four to five sets of reading in the range of 10 to 50 blows should be taken. The water content corresponding to 25 blows is taken as the liquid limit.

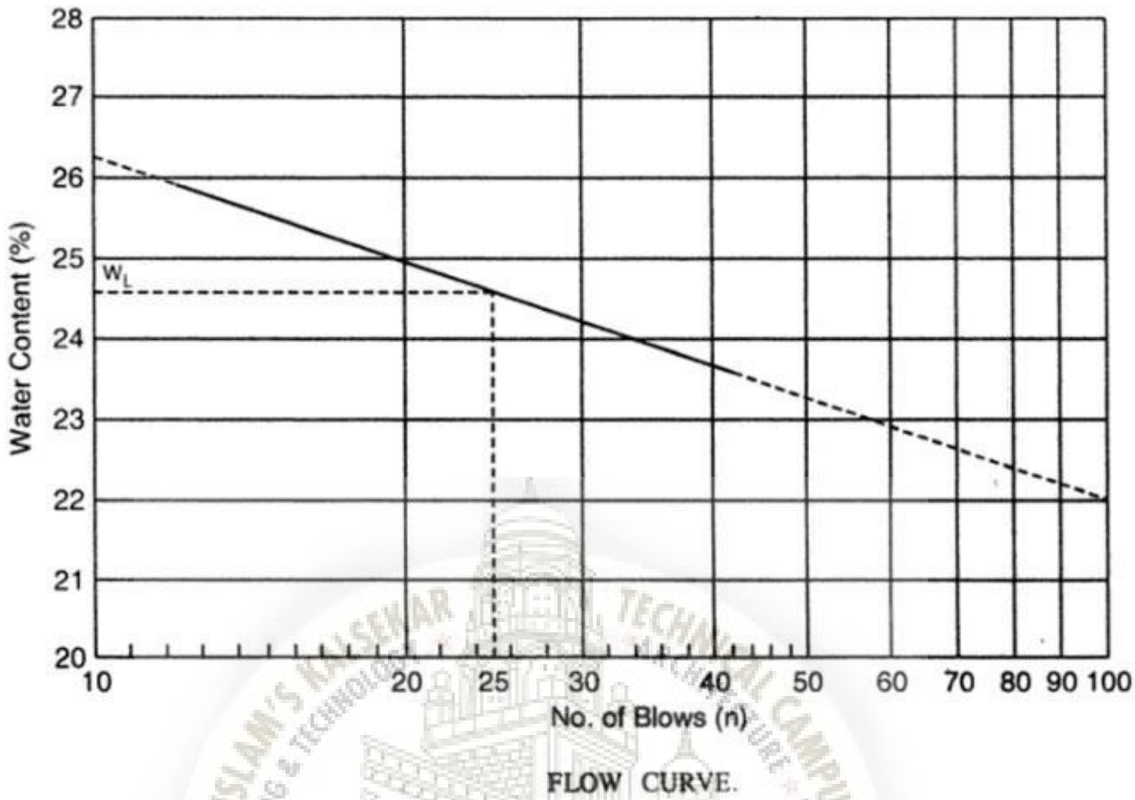


Figure 5 (Semi-log Graph Used For Computation Of Liquid Limit)

4.1.2.2 PLASTIC LIMIT

APPARATUS :

1. Glass plat (2 x 2 feet).

2. Spatula.

3. Sieve No. 40 (ASTM).

4. Electric oven.

5. Balance.

Figure 6 (Plastic Limit tests Apparatus)

PROCEDURE :

1. To determine the plastic limit, the soil specimen, passing 425 micron sieve, is mixed thoroughly with distilled water until the soil mass becomes plastic enough to be easily moulded with fingers.

2. The plastic soil mass should be left for enough time to allow water to permeate through the soil mass.

3. A ball is formed with about 8 g of this plastic soil mass and rolled between the fingers and a glass plate (or marble plate) with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length.

4. When a diameter of 3 mm is reached, the soil is re-moulded again into a ball.

5. This process of rolling and re-moulding is repeated until the thread starts just crumbling at a diameter of 3 mm.

6. The crumbled threads are kept for water content determination.

7. The test is repeated twice more with fresh samples.

8. The plastic limit (PL) is then taken as the average of three water contents.

The plasticity index is calculated from the relation: PI = LL – PL.

4.1.2.3 SHRINKAGE LIMIT

APPARATUS :

The equipment for the determination consists of

(i) a porcelain evaporating dish, about 12 cm in diameter with a flat bottom,

(ii) a stainless steel shrinkage dish, 45 mm in diameter and 15 mm in height, with a flat bottom.

(iii) two glass plates, each 75 x 75 mm, one of plain glass and the other having three metal prongs, and

(iv) a glass cup 50 mm in diameter and 25 mm in height, with its top rim, ground smooth and level.

Figure 7 (Shrinkage Limit test Apparatus)

PROCEDURE :

1. The volume V1 of the shrinkage dish is first determined by filling it to overflow with mercury, removing the excess by pressing a flat glass plate over its top and then taking the mass of the dish filled with mercury.

2. The mass of the mercury contained in the dish, divided by its density (13.6 g/cm3) gives the volume of the dish.

3. About 50 g of soil passing 425 microns IS sieve is mixed with distilled water sufficient to fill the voids completely and to make the soil pasty enough to be readily worked into the shrinkage dish without the inclusion of air-bubbles.

4. The inside of the shrinkage dish is coated with a thin layer of Vaseline.

5. A volume of wet soil of about one-third the volume of the dish is put in its center, and the soil is caused to flow to the edges by tapping it gently on a hard surface.

6. The dish is gradually filled by adding more soil in installments followed by gently tapping to exclude the inclusion of air.

7. The excess soil is struck off with a straight edge, and all soil adhering to the outside of the dish is wiped off.

8. The dish filled with soil is then immediately weighed.

9. The mass M1, of the wet soil pat, of volume V1, is thus known by subtracting the mass of the empty dish from the mass of the wet soil plus the dish taken above.

10. The dish is then placed in the oven. The soil pat will have volumetric shrinkage on drying, as shown in the Figure (b). The mass Md of the dry soil pat is found.

11. To find the volume Vd of the dry soil pat, the glass cup is first filled with mercury, and the excess mercury is removed by pressing the glass plate with three prongs firmly over the top of the cup. The cup is wiped off any mercury which may be adhering to its outside surface and is placed in the evaporating dish. The dry soil pat is placed on the surface of the mercury of the cup and is carefully forced down by means of glass with prongs. The mass of the mercury so displaced divided by its density gives the volume Vd of the dry soil pat.

The shrinkage limit is then calculated from the below Equation.

$$w_S = \left[w_1 - \frac{(V_1 - V_d)\,\rho_w}{M_d} \right] \times 100$$

4.1.3 STANDARD PROCTOR TEST

Performing test to find OMC and MDD by using standard proctor test as per Indian Standard (IS: 2720-PART-7-1980).

APPARATUS :

1. Cylindrical mould& accessories [volume = 1000cm3].

2. Rammer [2.6 kg].

3. Balance [1gaccuracy].

4. Sieves [19mm].

5. Mixing tray.

6. Trowel.

7. Graduated cylinder [500 ml capacity].

8. Metal container.

Figure 8 (Mould and Hammer of SPT)

PROCEDURE :

1. Collect the soil sample weighing 3kg. The sample must be 3kg after air drying it. Usually, this soil will be pulverized soil that passes through 4.75mm sieve. If the soil is coarse grained type, the water is added such that its water content comes to 4%. If the soil is fine grained, water is added to make its water content to 8%. The water content of the sample after addition must be less than the optimum water content. The soil after addition of water is mixed thoroughly

and covered with a wet cloth. This sample is kept aside for 15 to 30 minutes for undergoing maturing process.

2. Next, the apparatus is prepared by cleaning the mould thoroughly. The mould have to be dried and greased lightly. The mass of the mould with base plate and without collar is weighed. Let it me (Wm).

3. The mould placed over solid base plate is then filled with prepared matured soil to one third of the height. This layer will take 25 blows with the rammer. The rammer has a free fall height of 310 mm.

Note: If a bigger mould is used, the no: of blows for each layer will be 56 no's. Here the capacity of the mould will be 2250 ml. The compaction must be done in such a way that the blows are evenly distributed over the surface of each layer.

4. Next the second layer is added. Before adding the second layer the top of the first layer have to be scratched. Now the soil is filled to two thirds of the height of the mould. This too is compacted with 25 blows.

5. Later the third layer is added. It is compacted similarly. The final layer must project outside the mould and into the collar. This amount must not be greater than 6mm.

6. The bond between the soil in the mould and the collar is broken by rotating the collar. Next the collar is removed and the top layer of soil is trimmed and leveled to the top layer of mould.

7. Next, the mass of the mould with compacted soil and base plate is determined (Wms). Hence the mass of the compacted soil (Ws) is determined as:

Ws = Wm -Wms

8. The mass of compacted soil and the volume of the mould gives bulk density of the soil. From the bulk density the dry density can be determined for the water content used (w).

9. The same procedure from (1-8) is repeated by increasing the water content in the soil by 2 to 3%. Each test will provide different set of values of water content and dry density of soil. From the values obtained compaction curve is graphed between the dry density and water content.

CALCULATION OF COMPACTION CURVE :

1. Weight of Compacted Soil (Ws) in grams.

Ws = Wm -Wms

2. Bulk Density Bulk Density of Soil in gm/ml

$$\rho = \frac{Ws}{V}$$

3. Dry Density Dry Density of Soil, w = water content

$$\rho_d = \frac{\rho}{1+w}$$

COMPACTION CURVE OF SOIL (MDD & OMC) :

The compaction curve is the curve drawn between the water content (X-axis) and the respective dry density (Y-axis). The observation will be initially an increase of dry density with the increase in the water content. Once it reaches a particular point a decrease of dry density is observed. The maximum peak point of the soil compaction curve obtained is called as the Maximum dry density value. The water content correspond to this point is called as the Optimum water content (O.W.C) or optimum moisture content (O.M.C).

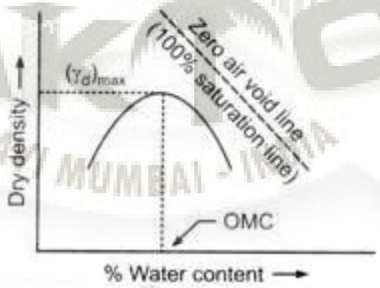


Figure 9 (Compaction Curve for the computation of OMC and MDD)

The graph shown in figure-9 is the compaction curve. Initially for a water content lesser than O.M.C the soil is rather stiffer in nature that will have lots of void spaces and porosity. This is the reason for lower dry density attainment. When the soil particles are lubricated with the increase in the water content, the soil particles will be densely packed resulting in increased density. Now beyond a limit (OMC) the addition of water will not bring a change in dry density or will decrease the dry density. The graph represents a zero-air void or 100 % saturation line. This is based on the theoretical maximum dry density where it occurs when there is 100 % saturation. As the condition of zero voids in soil is not real and a hypothetical assumption, the soil can never become 100% saturated.

The theoretical maximum dry density can be determined by the equation

$$(\rho_d)_{\text{the max}} = \frac{G\,(\rho w)}{1+wG}$$

G=specific gravity of solids; mass density of water = mass density of water; w= water content; The theoretical zero void line can be drawn by plotting the theoretical maximum dry density in the compaction curve if the value of 'w' and G is known.

4.1.4 BEARING RATIO VALUE BY CBR TEST

To perform the CBR test of unreinforced and reinforced plastic strip of soil specimen as per Indian Standard (IS:2720-PART-16-1987).

INTRODUCTION:

The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions. The test procedure should be strictly adhered if high degree of reproducibility is desired. The CBR test may be conducted in re-moulded or undisturbed specimens in the laboratory. The test has been extensively investigated for field correlation of flexible pavement thickness requirement. Briefly, the test consists of causing a cylindrical plunger of 50mm diameter to penetrate a pavement component material at 1.25mm/minute. The loads, for 2.5mm and 5mm are recorded. This load is expressed as a percentage of standard load value at a respective deformation level to obtain CBR value. The standard load values were obtained from the average of a large number of tests on different crushed stones and are given.

Laboratory CBR test:

APPARATUS :

a) Loading Machine: Any compression machine, which can operate at a constant rate of 1.25mm/minute, can be used. A metal penetration piston or plunger of diameter 50mm is attached to the loading machine.

b) Cylindrical moulds: Moulds of 150mm diameter and 175mm height provided with a collar of about 50mm length and detachable perforated base are used for this purpose. A spacer disc of 148mm diameter and 47.7mm thickness is used to obtain a specimen of exactly 127.3mm height.

c) Compaction Rammer: The material is usually compacted as specified for the work, either by dynamic compaction or by static compaction. The details for dynamic compaction suggested by the ISI are given.

d) Adjustable stem, perforated plate, tripod and dial gauge: The standard procedure requires that the soil sample before testing should be soaked in water to measure swelling. For this purpose the above listed accessories are required.

e) Annular weight: In order to simulate the effect of the overlaying pavement weight, annular weights each of 2.5 kg weight and 147mm diameter are placed on the top of the specimen, both at the time of soaking and testing the samples, as surcharge.

Figure 10 (Loading Machine for CBR test)

PROCEDURE :

The CBR test may be performed either on undisturbed soil specimens obtained by fitting a cutting edge to the mould or on remoulded specimens. Remoulded soil specimens may be compacted either by static compaction or by dynamic compaction. When static compaction is adopted, the batch of soil is mixed with water to give the required moisture content; the correct weight of moist soil to obtain the desired density is placed in the mould and compaction is attained by pressing in the spacer disc using a compaction machine or jack. The preparation of soil specimens by dynamic compaction or ramming is more commonly adopted and is explained below.

About 45 kg of material is dried and sieved through 19mm sieve. If there is note worthy proportion of materials retained on 19mm sieve, allowance for larger size materials is made by replacing it by an equal weight of material passing 19mm sieve and retained on 4.75mm sieve. The optimum moisture content and maximum dry density of the soil are determined by adopting either light compaction or heavy compaction as per the requirement. Each batch of soil (of at least 5.5 kg weight for granular soil and 4.5 to 5.0 kg weight for fine grained soils) is mixed with water up to the optimum moisture content or the field moisture content if specified so. The spacer disc is placed at the bottom of the mould over the base plate and a coarse filter paper is placed over the spacer disc. The moist soil sample is to be compacted over this in the mould by adopting either the light compaction or heavy compaction. For IS heavy compaction or the modified Proctor compaction, the soil is divided into five equal parts; the soil is compacted in five equal layers, each of compacted thickness about 26.5mm by applying 56 evenly distributed blows of the 4.89 kg rammer. After compacting the last layer, the collar is removed and the excess soil above the top of the mould is evenly trimmed off by means of the straight edge. It is important to see if the excess soil to be trimmed off while preparing each specimen is of thickness about 5.0mm; if not the weight of soil taken for compacting each specimen is suitably adjusted for the repeat tests so that the thickness of the excess layer to be trimmed off is about 5.0mm. Any hole that develops on the surface due to the removal of coarse particles during trimming may be patched with smaller size material. Three such compacted specimens are prepared for the CBR test. About 100g of soil samples are collected from the each mould for moisture content determination, from the trimmed off portion.

The clamps are removed and the mould with the compacted soil is lifted leaving below the perforated base plate and the spacer disc, which is removed. The mould with the compacted soil is weighed. A filter paper is placed on the perforated base plate, the mould with compacted soil is inverted and placed in position over the base plate (such that the top of the soil sample is now placed over the base plate) and the clamps of the base plate are tightened. Another filter paper is placed on the top surface of the sample and the perforated plate with adjustable stem is placed over it. Surcharge weights of 2.5 or 5.0 kg weight are placed over the perforated plate and the whole mould with the weights is placed in a water tank for soaking such that water can enter the specimen both from the top and bottom. The swell measuring device consisting of the tripod and the dial gauge are placed on the top edge of the mould and the spindle of the dial gauge is placed touching the top of the adjustable stem of the perforated plate. The initial dial gauge reading is recorded and the test set up is kept undisturbed in the water tank to allow soaking of the soil specimen for four full days or 96 hours. The final dial gauge reading is noted to measure the expansion or swelling of the soil specimen due to soaking.

The swell measuring assembly is removed, the mould is taken out of the water tank and the sample is allowed to drain in a vertical position for 15 minutes. The surcharge weights, the perforated plate with stem and the filter paper are removed. The mould with the soil sample is removed from the base plate and is weighed again to determine the weight of water absorption.

The mould with the specimen is clamped over the base plate and the same surcharge weights are placed on the specimen centrally such that the penetration test could be conducted. The mould with base plate is placed under the penetration plunger of the loading machine. The penetration plunger is seated at the center of the specimen and is brought in contact with the top surface of the soil sample by applying a seating load of 4.0 kg. The dial gauge for measuring the penetration values of the plunger is fitted in position. The dial gauge of the proving ring (for load readings) and the penetration dial gauge are set to zero. The load is applied through the penetration plunger at a uniform rate of 1.25 mm/min. The load readings are recorded at penetration readings of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10.0 and 12.5 mm. In case the load readings start decreasing before 12.5mm penetration, the maximum load value and the corresponding penetration value are recorded. After the final reading, the load is released and the mould is removed from the loading machine. The proving ring calibration factor is noted so that the load dial values can be converted into load in kg. About 50g of soil is collected from the top three cm depth of the soil sample for the determination of moisture content.

CALCULATION :

The swelling or expansion ratio is calculated from the observations during the swelling test using the formula:

Expansion ratio or swelling = 100 (df – di)/h

Where, df = final dial gauge reading after soaking, mm

di = initial dial gauge reading before soaking, mm

h = initial height of the specimen (127.3 mm), mm

The load values noted for each penetration level are divided by the area of the loading plunger (19.635cm2) to obtain the pressure or unit load values on the loading plunger. The load-penetration curve is then plotted in natural scale for each specimen. If the curve is uniformly convex upwards, no correction is needed. In case there is a reverse curve or the initial portion of the curve is concave upwards, necessity of a correction is indicated. A tangent is drawn from the steepest point on the curve to intersect the base at point, which is the corrected origin corresponding to zero penetration. The unit load values corresponding to 2.5 and 5.0 mm penetration values are found from the graph. The CBR value is calculated from the formula:

CBR = (Unit load carried by soil sample at defined penetration level / Unit load carried by standard crushed stones at above penetration level) X 100.

Standard Load And Unit Standard Load Corresponding to Penetration Value As Per IS :

PENETRATION (mm)	STANDARD LOAD (kg)	UNIT STANDARD LOAD (kg/cm²)
2.5	1030	70
5	2055	105
7.5	2630	134
10	3180	162
12.5	3600	183

Table 3 (Standard Load and Unit Standard Load Corresponding to Penetration)

4.1.5 UNCONFINED COMPRESSION TEST

To perform the UCC test as per Indian Standards (IS: 2720-PART-10-1991).

APPARATUS :

1. Compression device.

2. Load and deformation dial gauges.

3. Sample trimming equipment.

4. Balance.

5. Moisture can.

Figure 11 (Compression Machine for UC test)

PROCEDURES :

1.Extrude the soil sample from Shelby tube sampler. Cut a soil specimen so that the ratio (L/d) is approximately between 2 and 2.5. Where L and d are the length and diameter of soil specimen, respectively.

2.Measure the exact diameter of the top of the specimen at three locations 120° apart, and then make the same measurements on the bottom of the specimen. Average the measurements and record the average as the diameter on the data sheet.

3.Measure the exact length of the specimen at three locations 120° apart, and then average the measurements and record the average as the length on the data sheet.

4.Weigh the sample and record the mass on the data sheet.

5.Carefully place the specimen in the compression device and center it on the bottom plate. Adjust the device so that the upper plate just makes contact with the specimen and set the load and deformation dials to zero.

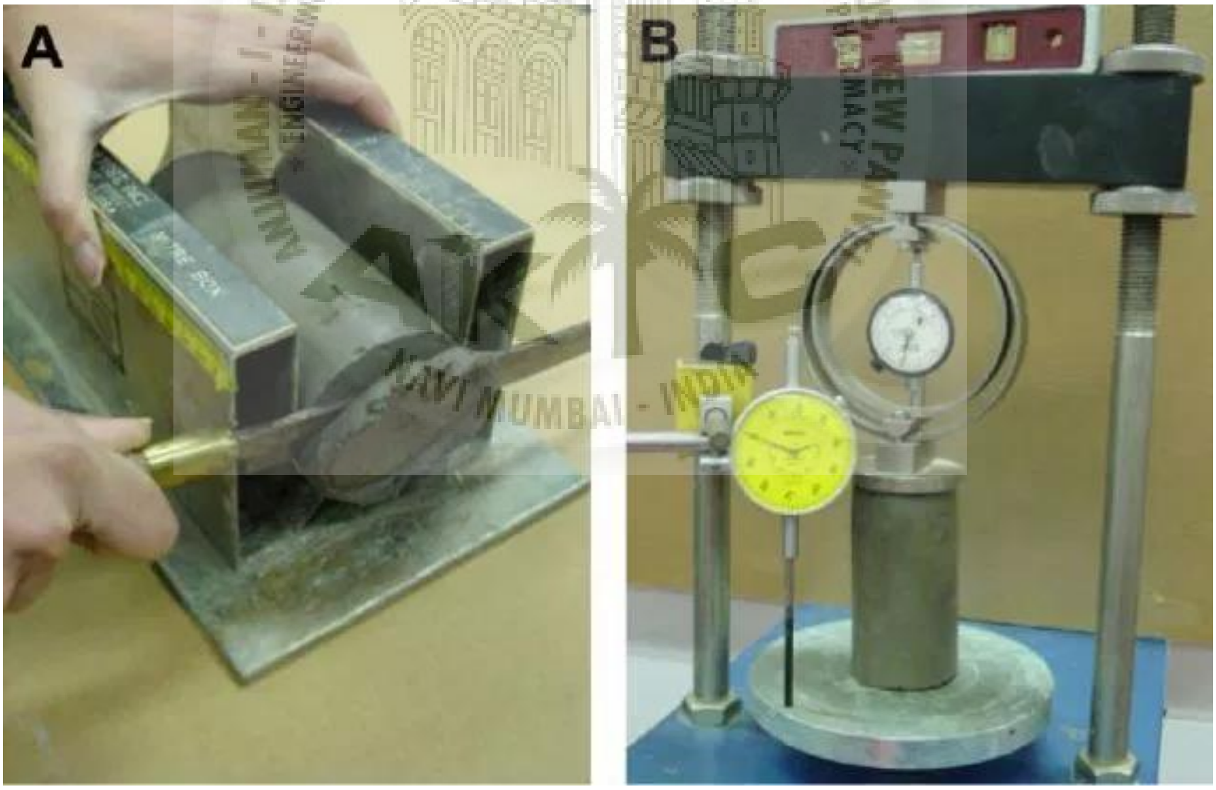


Figure 12 (UC test)

6.Apply the load so that the device produces an axial strain at a rate of 0.5% to 2.0% per minute, and then record the load and deformation dial readings on the data sheet at every 20 to 50 divisions on deformation the dial.

7. Keep applying the load until (1) the load (load dial) decreases on the specimen significantly, (2) the load holds constant for at least four deformation dial readings, or (3) the deformation is significantly past the 15% strain that was determined in step 5.

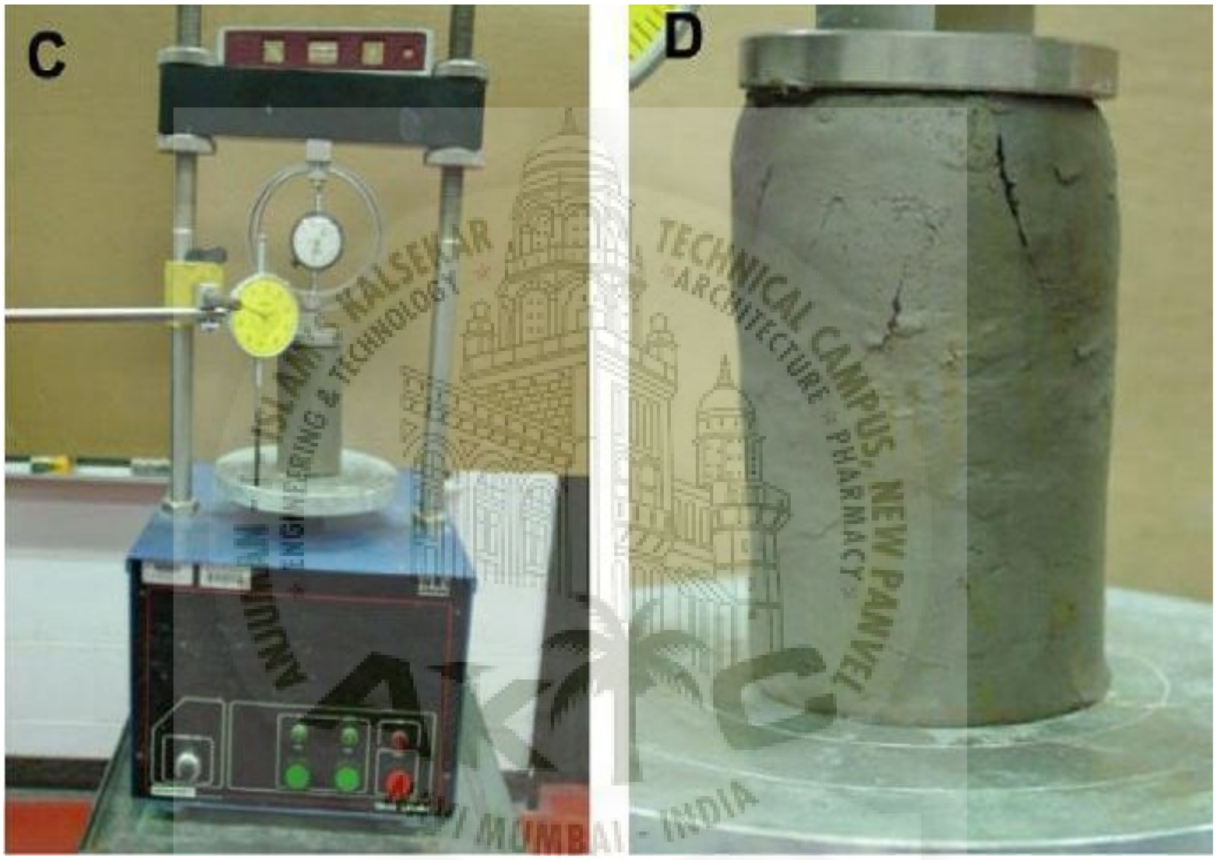


Figure 13 (UC test)

8.Draw a sketch to depict the sample failure.

9. Remove the sample from the compression device and obtain a sample for water content determination. Determine the water content as in Experiment.

ANALYSIS :

1. Convert the dial readings to the appropriate load and length units, and enter these values on the data sheet in the deformation and total load columns. (Confirm that the conversion is done correctly, particularly proving dial gage readings conversion into load)

2. Compute the sample cross-sectional area $A0 = \pi*(d2)/4$

3. Calculate the deformation (ΔL) corresponding to 15% strain (e).

Strain (e) = ΔL / L0

Where L0 = Original specimen length (as measured in step 3).

4. Computed the corrected area, A' = A0 / (1-e)

5. Using A', compute the specimen stress, sc = P/A' (Be careful with unit conversions and use constant units).

6. Compute the water content, w%.

7. Plot the stress versus strain. Show qu as the peak stress (or at 15% strain) of the test. Be sure that the strain is plotted on the abscissa. (See fig-14)

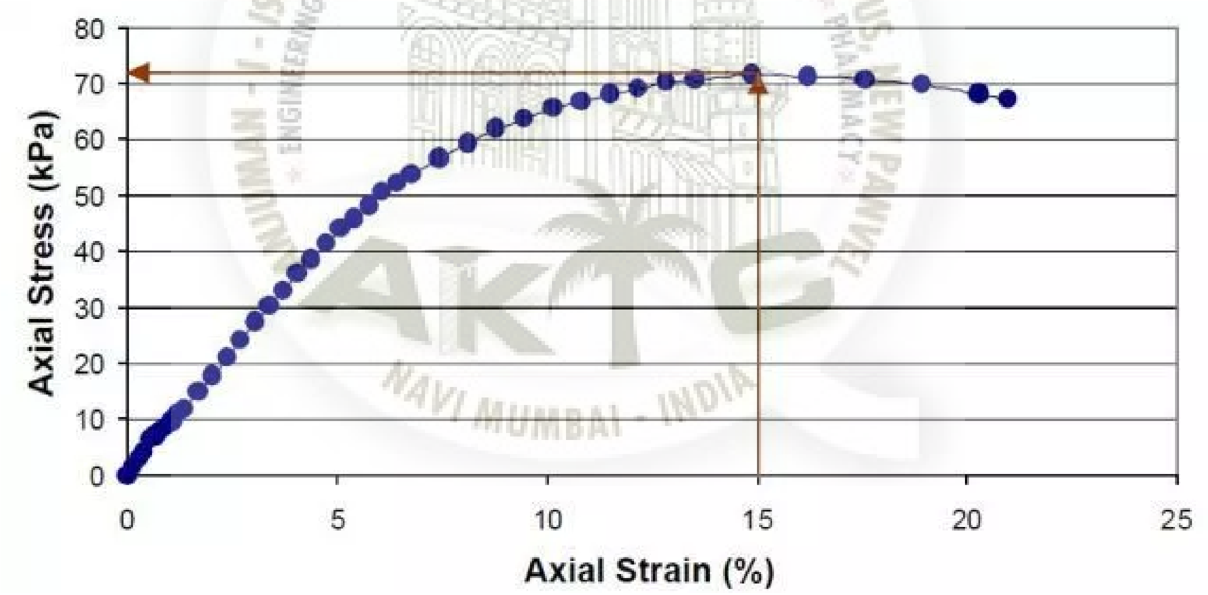


Figure 14 (Stress v/s Strain Curve)

(8) Calculate shear strength s_u as follows,

s_u = c (or cohesion) = q_u/2.

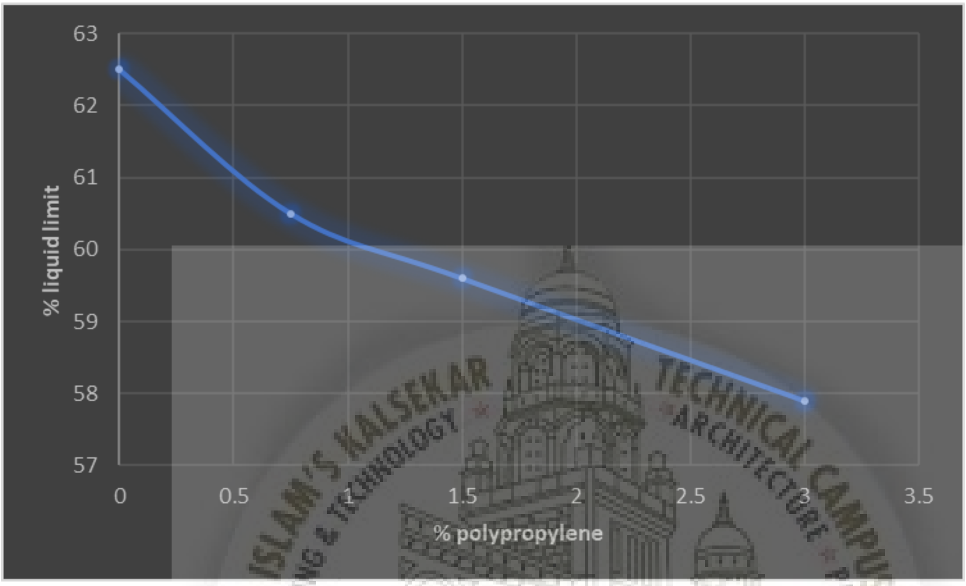
4.1.6 COMPARISION OF REINFORCED AND UNREINFORCED SOIL

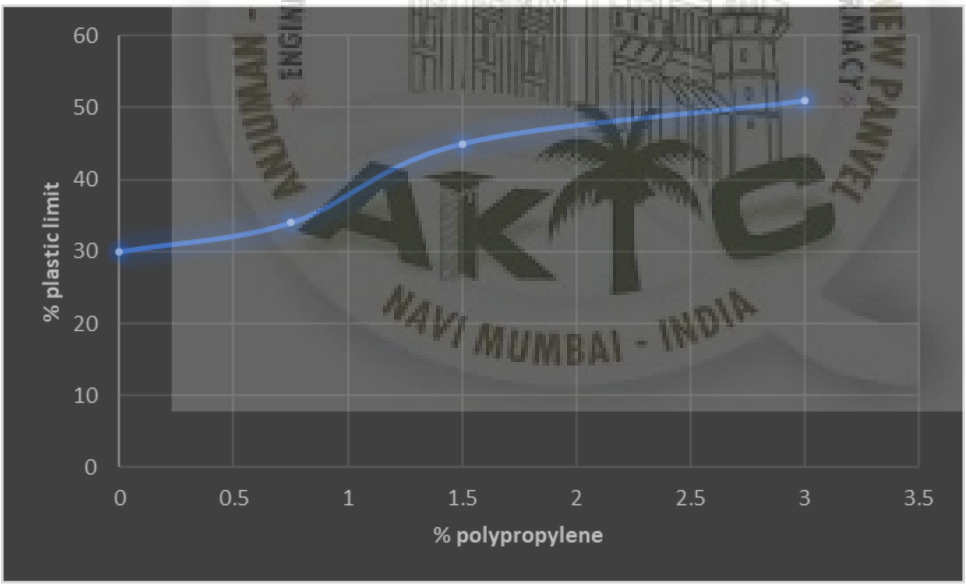
PARAMETERS	UR-SOIL	R-SOIL(0.75%)	R-SOIL(1.5%)	R-SOIL(3%)
L.L (%)	62.5	60.5	59.6	57.9
P.L (%)	30	34	45	51
S.L (%)	25.6	29.5	33.6	38.8
Ip	32.5	26.2	14.6	6.9
OMC (%)	26.03	27.7	26.8	28.87
MDD (g/cc)	1.485	1.67	1.705	1.788
CBR (%)	1.92~2	2.57~3	2.93~3	3.84~4
UCC (g/cc)	1.51	0.23	0.15	0.11

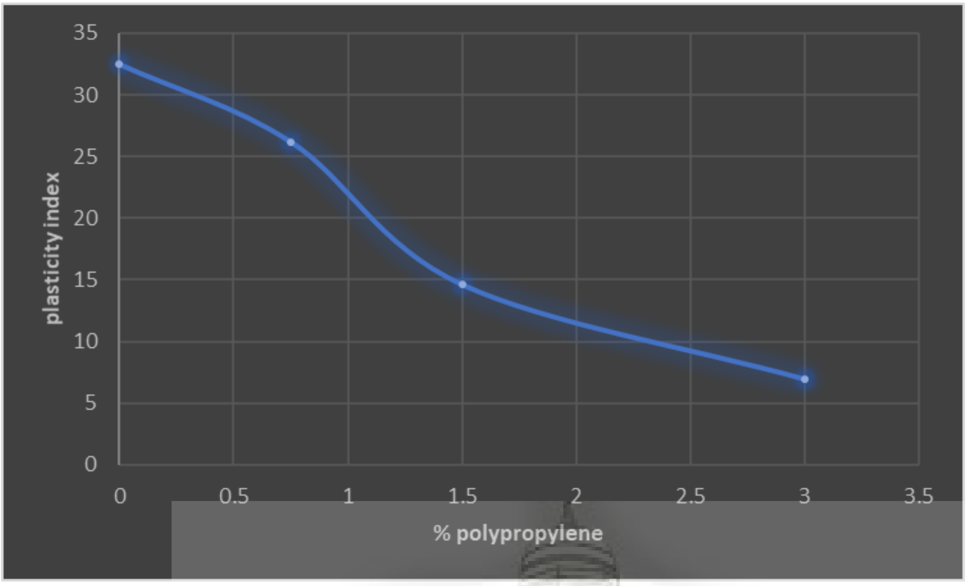
Table 4 (Comparision of UR-soil and R-soil)

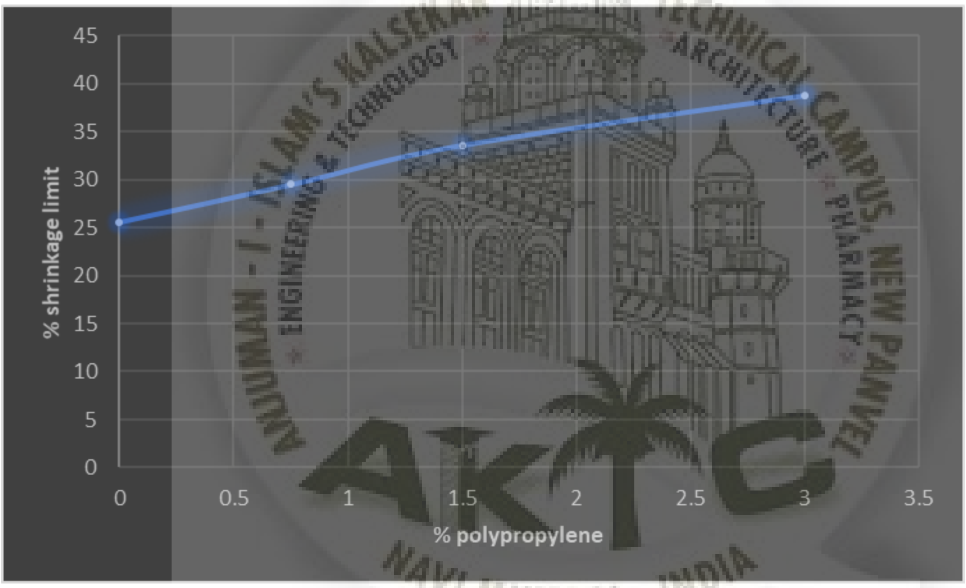
4.2 GRAPHS SHOWING VARIATION

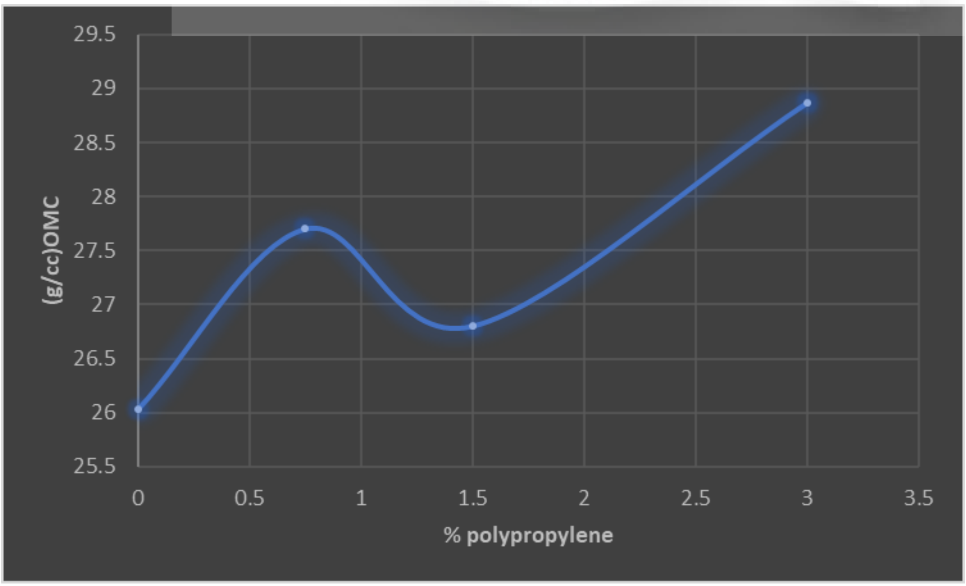
On y-axis percentage of polypropylene reinforced is shown, while on x-axis results for various tests performed are shown.

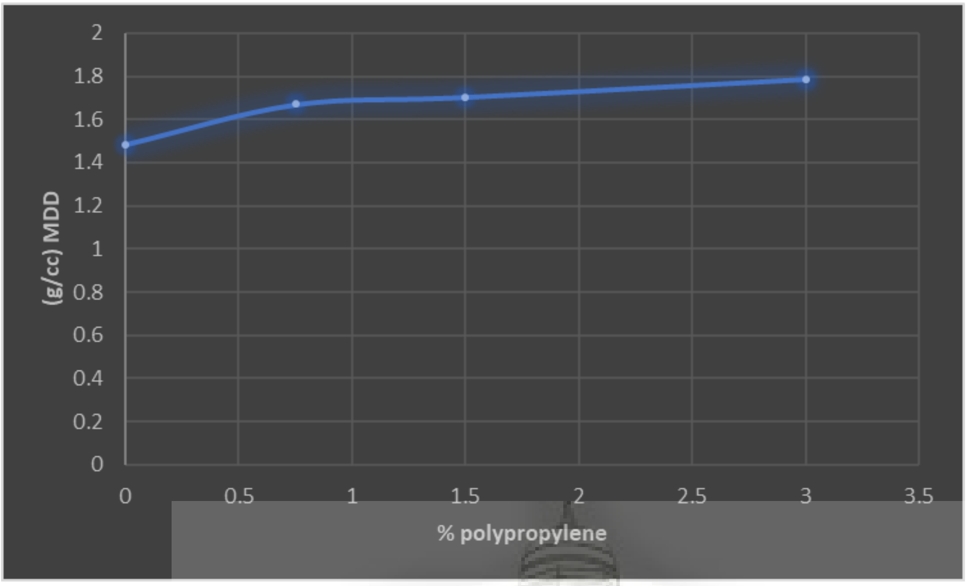


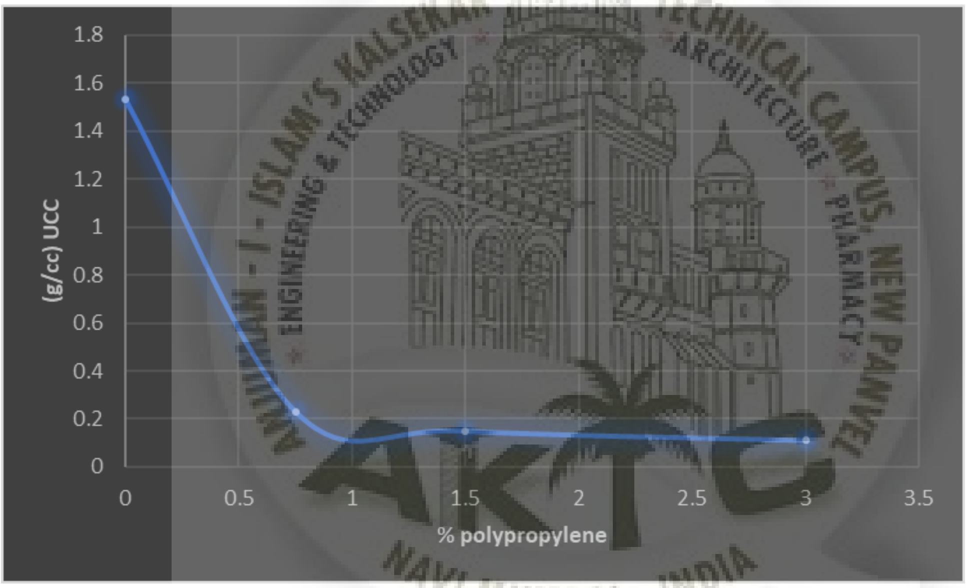


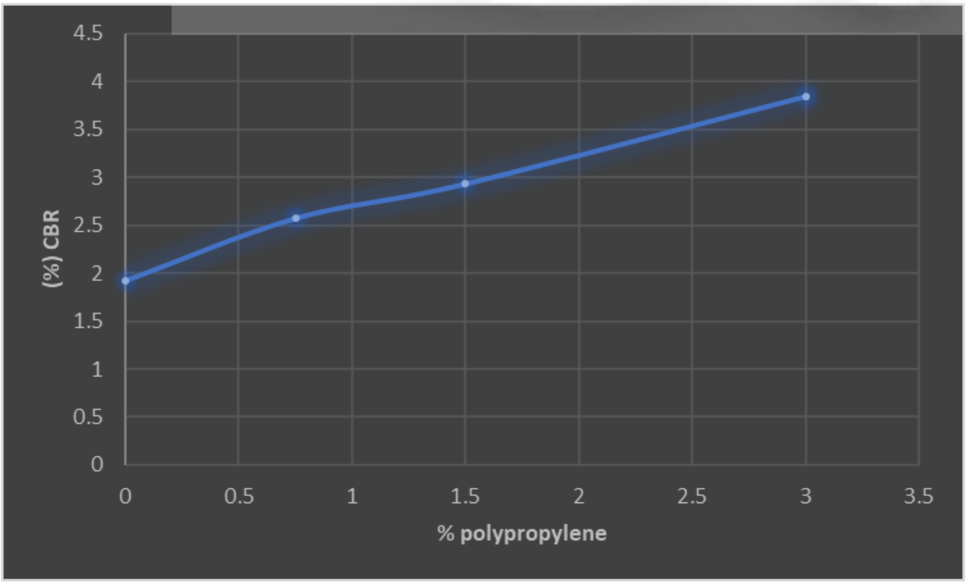

plasticity index
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
% polypropylene


% shrinkage limit
45
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
% polypropylene


(g/cc)OMC
29.5
29
28.5
28
27.5
27
26.5
26
25.5
0
0.5
1
1.5
2
2.5
3
3.5
% polypropylene


(g/cc) MDD
% polypropylene
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3
3.5


(g/cc) UCC
% polypropylene
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3
3.5


(%) CBR
% polypropylene
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5

4.3 MECHANISTIC APPROACH

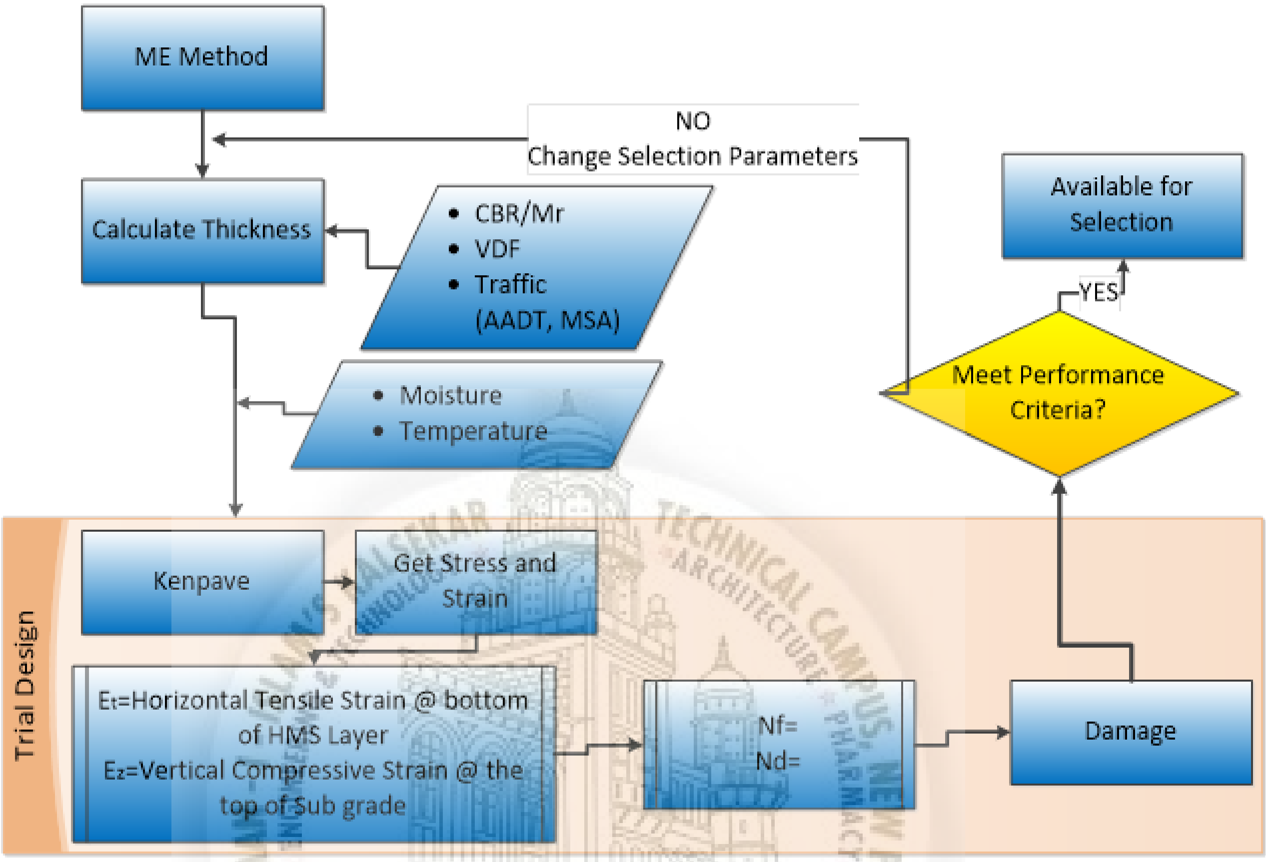


Figure 15 (Mechanism of Mechanistic Approach)

This methodology uses stresses, strains and deformations in the pavement caused by traffic and/or the environment that have been calculated from real-world pavement response models to predict its performance. These performance measures can be used to evaluate not only the need for an overlay but remaining pavement life as well. The mechanistic-empirical approach is a hybrid approach. Empirical models are used to fill in the gaps that exist between the theory of mechanics and the performance of pavement structures. Simple mechanistic responses are easy to compute with assumptions and simplifications (i.e., homogeneous material, small strain analysis, static loading as typically assumed in linear elastic theory), but they by themselves cannot be used to predict performance directly; some type of empirical model is required to make the appropriate correlation. Mechanistic-empirical methods are considered an intermediate step between empirical and fully mechanistic methods.

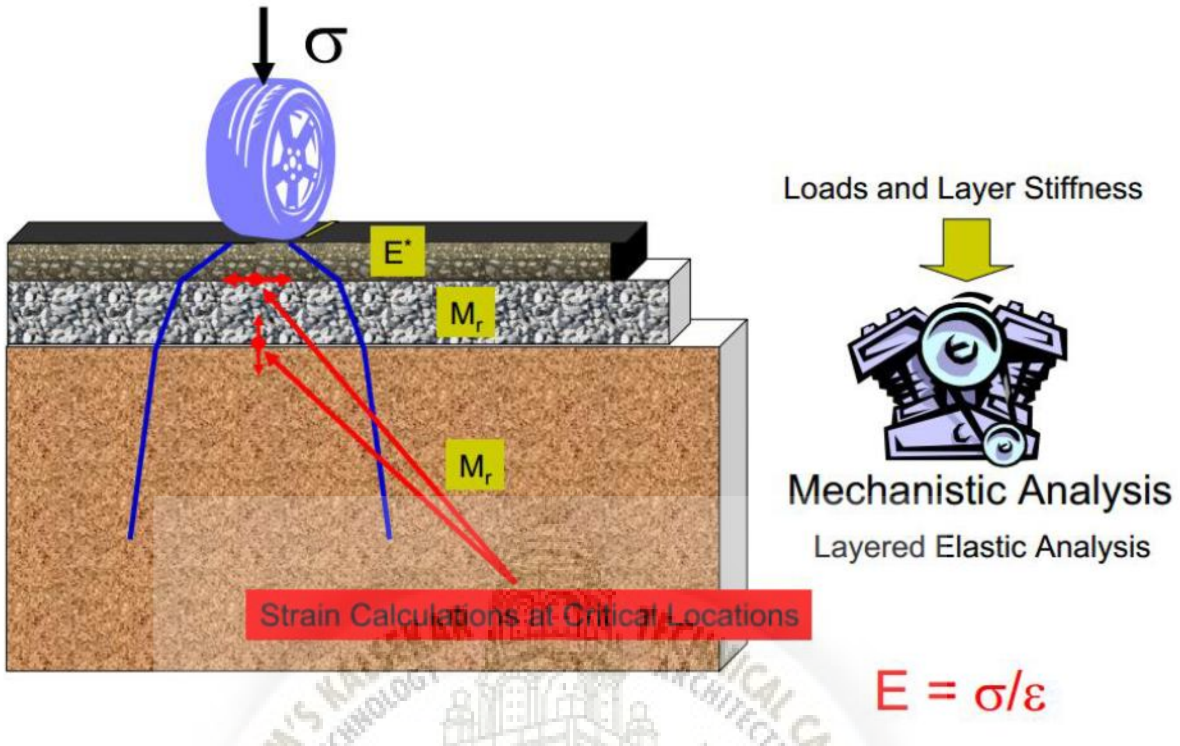


Figure 16 (Mechanistic Analysis)

Mechanistic-Empirical Design Approach

This methodology uses computations of pavement responses such as stresses, strains, and deformations and then adjusts accordingly based on performance models from empirical approach

PAVEMENT RESPONSE UNDER AXLE LOAD :

When axle load is applied, pavement shows certain deflection. This deflection is due to the strains induced in the pavement. To resist this strain, stresses are generated in the pavement. These stresses further can even lead to reason for pavement failure. Strain distribution is well explained in the fig.17.

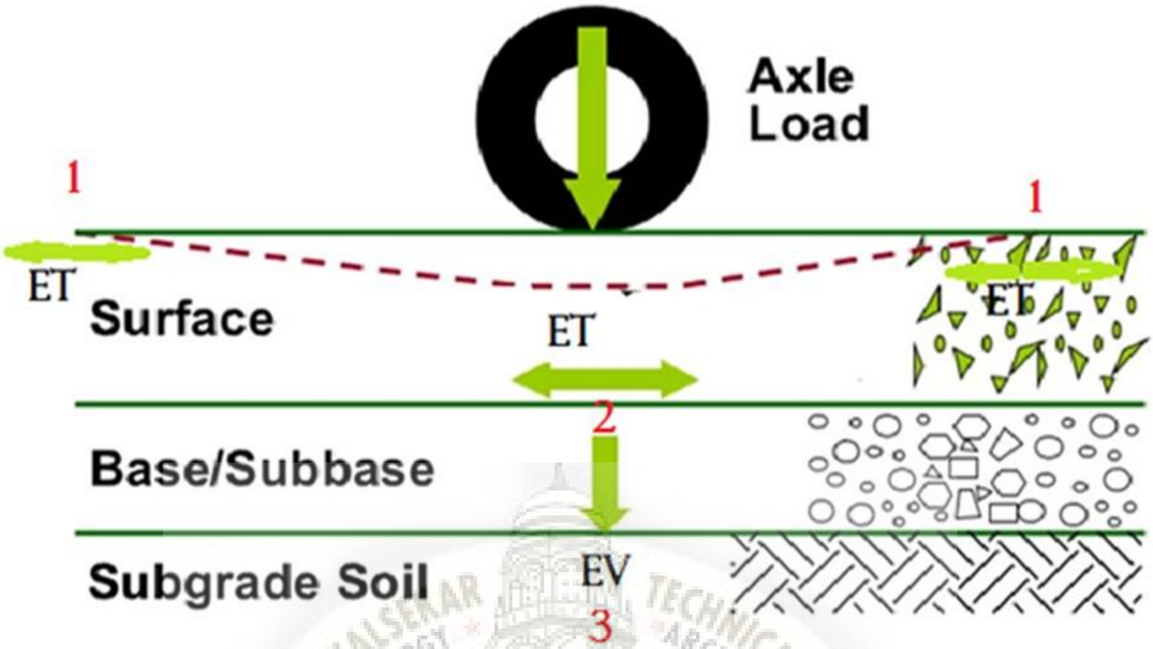


Figure 17 (Pavement Response Under Axle Load)

ASSUMPTION :

The layered elastic approach works with relatively simple mathematical models and thus, requires some basic assumptions. These assumptions are:

- Pavement layers extend infinitely in the horizontal direction.
- The bottom layer (usually the subgrade) extends infinitely downward.
- Materials are not stressed beyond their elastic ranges.

ADVANTAGES :

The basic advantages of a mechanistic-empirical pavement design method over a purely empirical one are:

- It can be used for both existing pavement rehabilitation and new pavement construction
- It accommodates changing load types
- It can better characterize materials allowing for:

- Better utilization of available materials
- Accommodation of new materials
- An improved definition of existing layer properties
- It uses material properties that relate better to actual pavement performance
- It provides more reliable performance predictions
- It better defines the role of construction
- It accommodates environmental and aging effects on materials

Chapter 5

ANALYSIS AND DESIGN

5.1 INPUT PARAMETERS FOR IIT PAVE

1. Two lane single carriageway road.
2. Initial traffic in the year of completion of construction = 3000 CV/day.
3. Traffic growth rate per annum = 5 %.
4. Design life = 15 year.
5. Vehicle damage factor = 4.5(for plain terrain).
6. Lane distribution factor = 75%.

5.2 DESIGN CALCULATION

1. FOR 10 YEAR DESIGN LIFE

N = (365 ×[(1+r)n-1]×A×D×F)/r

(365×[(1+0.05)10 -1]×3000×4.5×0.75)/0.05

N = 46.48 MSA.

2. FOR 15 YEAR DESIGN LIFE

$N = (365 \times [(1+r)n-1] \times A \times D \times F)/r$

$= (365 \times [(1+0.05)15 - 1] \times 3000 \times 4.5 \times 0.75)/0.05$

$N = 79.75$ MSA.

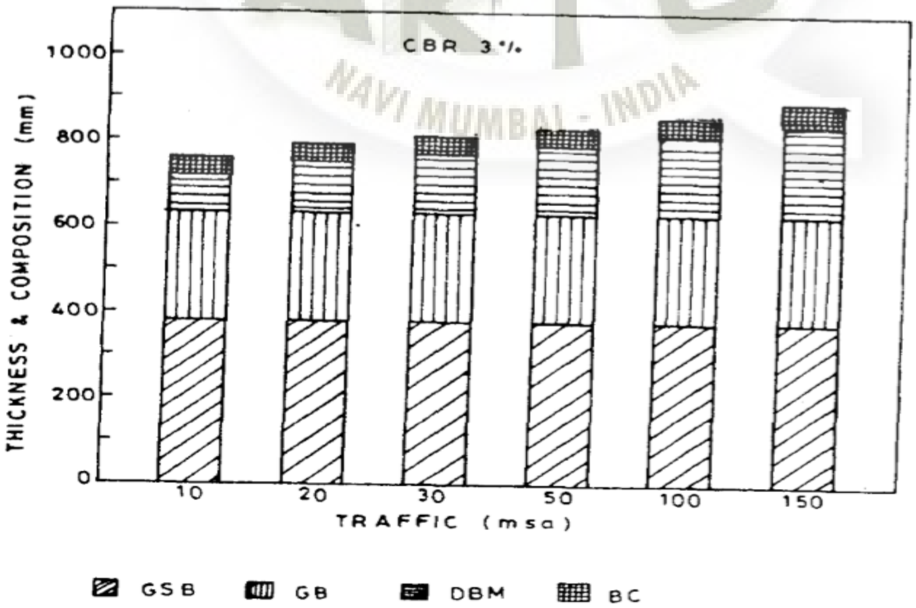
Now, refering IRC 37: 2001 pavement thickness is read from the chart , for CBR

For Traffic 46.48 Msa and 79.75 Msa.

PAVEMENT DESIGN CATALOGUE

PLATE 2 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 10-150 msa

Cumulative Traffic (msa)	Total Pavement Thickness (mm)	CBR 3% PAVEMENT COMPOSITION: Bituminous Surfacing BC (mm)	DBM (mm)	Granular Base & Sub-base (mm)
10	760	40	90	Base = 250 Sub-base = 380
20	790	40	120	
30	810	40	140	
50	830	40	160	
100	860	50	180	
150	890	50	210	



Below table shows the total thickness and thickness of each layers of unreinforced soils and reinforced soil with optimum PP fiber :

SOIL	REINFORCED SOIL	UNREINFORCED SOIL
CBR (%)	1.92	2.93
TOTAL THICKNESS (mm)	955	860
GRANULAR SUBBASE (mm)	460	380
GRANULAR BASE (mm)	250	250
DBM (mm)	195	180
BC (mm)	50	50

Table 5 (Thickness of UR-soil And Optimum R-Soil)

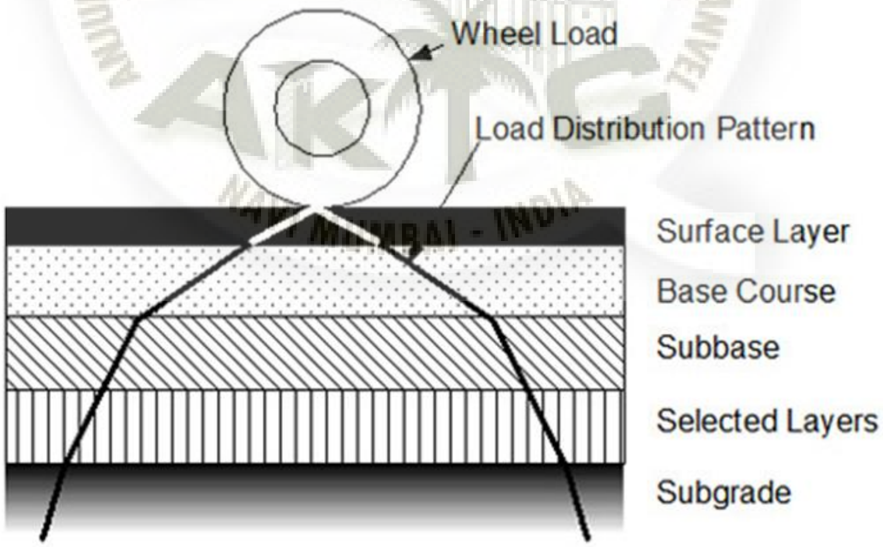


Figure 18 (Flexible Pavement Layer)

5.3 ANALYSIS AND DESIGN OF FLEXIBLE PAVEMENT BY IIT PAVE

RESILENT MODULUS OF DIFFERENT LAYER AT OPTIMUM FIBER’S CBR 3% :

5.3.1 RESILENT MODULUS OF SUBGRADE

M.R = 10 x CBR

= 10 x 3

= 30 MSA.

5.3.2 RESILENT MODULUS OF GRANULAR BASE AND SUBBASE LAYER

Mr = 0.2 x (M.R) x h^0.45

= 0.2 x 30 x (380+250)^(0.45)

= 109.107 MPA.

5.3.3 RESILENT MODULUS OF BITUMINOUS LAYER

= 1700 MPa VG30 at 35ºC.

IIT PAVE OUTPUT AT CBR 3% RESULT :

```
No. of layers              3
E values (MPa)       1700.00  109.11   30.00
Mu values               0.350.400.40
thicknesses (mm)      230.00  630.00
single wheel load (N) 20000.00
tyre pressure (MPa)      0.56
Dual  Wheel
```

Z	R	SigmaZ	SigmaT	SigmaR	TaoRZ	DispZ	epZ	epT	epR
230.00	155.00	-0.5364E-01	0.4472E+00	0.3200E+00	-0.1980E-01	0.5925E+00	-0.1895E-03	0.2082E-03	0.1072E-03
230.00L	155.00	-0.5364E-01	-0.3141E-02	-0.1101E-01	-0.1980E-01	0.5925E+00	-0.4397E-03	0.2082E-03	0.1072E-03
230.00	0.00	-0.5320E-01	0.4442E+00	0.3615E+00	-0.8260E-02	0.5786E+00	-0.1972E-03	0.1978E-03	0.1322E-03
230.00L	0.00	-0.5320E-01	-0.2911E-02	-0.8024E-02	-0.8260E-02	0.5786E+00	-0.4475E-03	0.1978E-03	0.1322E-03
860.00	0.00	-0.8485E-02	0.1493E-01	0.1589E-01	-0.9348E-03	0.4258E+00	-0.1908E-03	0.1097E-03	0.1220E-03
860.00L	0.00	-0.8490E-02	0.2594E-03	0.9309E-05	-0.9340E-03	0.4257E+00	-0.2866E-03	0.1217E-03	0.1101E-03

1. DETERMINATION OF ACTUAL STRAIN FROM IIT PAVE SOFTWARE FOR 3% CBR :

- HORIZONTAL TENSILE STRAIN (εt) = 208.2 Micro Strain.

- VERTICAL COMPRESSIVE STRAIN (εz) = 286.6 Micro Strain.

2. DETERMINATION OF PERMISSIBLE STRAIN :

TENSILE LAYER AT BOTTOM OF BITUMINOUS LAYER :

$$Nf = 2.21\times10^{-4}\times(1/\varepsilon t)^{3.89}\times(1/MR)^{0.854}$$

Where,

Nf = fatigue life in number of standard axels,46.48 msa

εt =Maximum Tensile strain in the bottom of bituminous layer,

MR = resilient modulus of the bituminous layer,1700Mpa

therefore, εt = 239.9-Micro Strain.

- VERTICAL SUBGRADE STRAIN ON THE TOP OF SUBGRADE :

$$Nr = 1.41\times10^{-8}\times[1/\varepsilon v]^{4.5337}$$

Where,

N = number of cumulative standard axles, 79.75msa

εv = vertical strain in the subgrade (in micro strain)

therefore, εv = 335.32 Micro strain.

The adequacy of design is checked by the program by comparing this strain with the allowable strain as predicted by the fatigue and rutting models, in built in the program,

1. Horizontal tensile strain in bituminous layer is **239.9 Micro Strain > 208.2 Micro Strain.**

2. Vertical compressive strain on subgrade is **355.32 Micro Strain > 286.6 Micro Strain.**

HENCE THE PAVEMENT COMPOSITION IS SAFE.

BASED ON RESULT FROM MANUAL CALCULATION AND IIT PAVE FOLLOWING CONCLUSIONS ARE MADE :

SOIL	UNREINFORCED SOIL	REINFORCED SOIL
CBR (%)	1.92 ~ 2	2.93~3
TOTAL THICKNESS (mm)	955	860
GRANULAR SUBBASE (mm)	450	380
GRANULAR BASE (mm)	260	250
DBM (mm)	195	180
BC (mm)	50	50
Et (Actual)	216.2	208.2
Ez (Actual)	321.4	286.6
Et (Permissible)	239.9	
Ez (Permissible)	335.32	

Table 6 (Comparison of Strains)

Chapter 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

This chapter provided a basic overview about the process and test methodology adopted. It also includes tests to be performed on PP. This chapter also describes the procedure to be adopted for testing of reinforced and unreinforced soil. It also describes the mechanistic method for designing and analysing the flexible pavement.

6.2 CONCLUSION

The following are main conclusion of this study on different parameters of the soil by adding polypropylene fiber :

- The OMC does not show a significant change by addition of PPF, whereas MDD reduces as fiber content increases in compaction tests.
- The fiber reinforced soils exhibits more ductile behavior than unreinforced soil.
- The strength is increased in low percentage of PPF addition, it ensures more economical in construction.
- Finally it was concluded that PP can potentially stabilise the clayey soil.

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