EFFECT OF ADDITION OF PLASTIC FIBRES ON STRENGTH CHARACTERISTICS OF A SUBGRADE SOIL

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IN

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DECLARATION

I hereby declare that this work which is being presented in the thesis entitled "**Effect Of Addition of Plastic Fibres on Strength Characteristics of a Subgrade Soil**" in partial fulfilment of the requirement for the award of degree of **Master of Engineering** in the field of **Civil Engineering** with specialization in **Infrastructure Engineering** submitted at **Thapar Institute of Engineering & Technology (Patiala)** is an authentic record of my own work carried out during the period from 14.8.2018 to 15.7.2019 under the guidance of Sh. Rajesh Pathak and Dr. Tanuj Chopra.

The matter embodied in this thesis has not submitted by me for the award of any other degree or diploma.

Date: 15/07/2019

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This is to certify that the above declaration made by the student concerned is correct according to the best of our knowledge and belief.

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An efficacious project can on no occasion be prepared by the single effort or the person to whom project is assigned, but it also demands the help and guardianship of some conversant person who helps in the undersigned actively or passively in the completion.

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LIST OF ABBREVATIONS

CBR	-	California Bearing Ratio
LWD	-	Light Weight Deflectometer
FWD	-	Falling Weight Deflectometer
IRC	-	Indian Road Congress
HPDE	-	High-Density Polyethylene
MDD	-	Maximum Dry Density
OMC	-	Optimum Moisture Content
FA	-	Fly Ash
UCS	-	Unconfined Compressive Strength
RHA	-	Rice Husk Ash
LL	-	Liquid Limit
PL	-	Plastic Limit
PI	-	Plasticity Index
PA	-	Pond Ash
UTS	-	Ultimate Tensile Strength
SG	-	Specific Gravity
LFS	-	Ladle Furnace Slag
MSA	-	Million Standard Axles
GSB	-	Granular Subbase
WMM	-	Water Mix Macadam
DBM	-	Dense Bituminous Macadam
BC	-	Bituminous Concrete

ABSTRACT

In today's time, plastic materials (which otherwise pose great threat to environment), can be alternatively and smartly utilized in civil engineering as a soil stabilizing material (apart from the more traditional cement and lime) to achieve economy and reduce waste impact on environment.

In present study,effect of addition of plastic Fibres (shredded wrappers) on the strength characteristics of flexible pavements have been studied. Available literature has been reviewed, and then experiments were performed to compute the liquid limit, plastic limit and plasticity index of soil to categorize type of soil. OMC and MDD were computed at various plastic contents (by % of dry weight of soil). The CBR test has been performed at different percentage plastic contents. The maximum value of CBR was obtained as 4.01% at 1.5% plastic content.

The design of pavement section was carried out done for different traffic volumes to find the most efficient and economical traffic condition for which this method could be most advantageous. Thickness of pavement for each layer (as per CBR corresponding to 0% and 1.5% plastic content) was determined using IRC-37:2018 design plates. The theoretical values of vertical compressive and horizontal tensile strains at critical locations has been determined. The theoretical value of modulus of elasticity (with 0 % and 1.5 % optimum plastic addition) ware calculated using IRC 37:2018. Trial sections filled with virgin soil and reinforced soil at various percentages of waste plastic content were compacted manually to 250 mm thickness and the subgrade modulus were calculated experimentally by using a Light Weight Deflectometer. The theoretical and experimental modulus values were compared, and the most optimized pavement thickness has been designed with IIT PAVE.

CHAPTER -1

INTRODUCTION

In the past decade, plastic waste management has developed into a serious issue all across the world. With the ever rise in population there has been a growing demand of commodities manufactured using various types of plastics. Many plastics are non-biodegradable. There have been reported cases in India of animals unknowingly consuming them and dying as polythene bags cause blockage in their food pipes. In rural areas, waste plastics are still burnt today that releases harmful smoky gases that in turn cause hazardous environmental effects like smog, cancer etc. Soil stabilizers such as geosynthetics, fly ash, cement kiln dust, jute, blast furnace slag, high density polythene, Copper slag, GGSB etc. can be used to engineer the soil properties. From a geotechnical point of view, it was realized that waste plastic could prove beneficial if it was kept away from direct environmental contact. Especially in civil engineering, such types of plastics can be utilized as engineering materials instead of the more conventional ones. Plastics alone do not possess good engineering properties, therefore even partial replacement of standard construction materials with waste plastic will not only have really beneficial and positive impact on the environment, but also will go way forward in reducing construction costs by significant margins. This addition of waste plastic to enhance the engineering soil properties comes under a broader category, called soil stabilization. It could be defined as any process which helps improving the engineering properties of the soil, such as its shear strength, bearing capacity etc. Its various types are:

1. Soil-Lime stabilization
2. Soil-Cement stabilization
3. Soil-Bitumen stabilization
4. Mechanical soil stabilization

Since plastic as a waste is available in abundance, hence it is economical to use plastic as a soil stabilizer. Also being non-biodegradable in nature it has serious impact on environment. Therefore, it can work as an ideal admixture for the subgrade.

1.1 DEFINITION

The random mixed fibre with the soil mass is known as the fibre reinforces soil. Mixing of fibres into soil essentially makes it a composite material comprising of soil as a base and plastic fibres as admixtures in this case. Hence, replacing the soil mass with a material of high or more tensile strength will fundamentally increase the mechanical behaviour of the soil because of the increased interfacial contact area between soil and fibres.

1.2 THESIS OUTLINE

Acknowledging the above parameters, the thesis was entitled "**Effect of Addition of Plastic Fibres on strength Characteristics of a Subgrade Soil**", which deals with measuring the impact of plastic addition on fine grained soils (to be utilised as subgrade material for flexible pavement). The plastic used is a thin film (plastic wrapper), which are easily available in abundance. Impact of plastic addition is measured using the following standardized tests:

1. California Bearing Ratio Test
2. Standard Proctor Test.
3. Light Weight Deflectometer

Further based on CBR value thickness of pavement has been determined using IRC 37:2018. Thereafter, stain analysis was done using IITPAVE to determine the optimum thickness of flexible pavement. A trial section in the field, was constructed with base virgin soil by manual compacting to 250 mm thickness and the subgrade modulus was calculated experimentally by using a Light Weight Deflectometer which was then compared to theoretical value of subgrade modulus using IRC37:2018.

The thesis comprises of six chapters:

- ❖ **First** chapter gives the general introduction to the study, defines the problems and presents its way to rectify them.
- ❖ **Second** chapter studies the past studies done in this field by doing a through literature review.
- ❖ **Third** chapter describes experimental programme followed throughout the study in detail.
- ❖ **Fourth** chapter deals with the results and findings from the experimental programme.
- ❖ **Fifth** chapter is the design and analysis of flexible pavement dealing with the applications of the study.
- ❖ **Sixth** chapter is the concluding chapter.

CHAPTER -2

LITERATURE REVIEW

The background study of thesis was done thoroughly by studying the following literature review:

***Khaled Sobhan et al*. (2003)** experimented with the use of recycled aggregate and waste HDPE strips for the pavement foundations using fatigue behaviour analysis. The main objective being the evaluation of a material that containing 90% recycled materials for foundation layer below the flexible or rigid pavement. Following materials were used – around 90 % of recycled aggregate and cement and fly ash in very low quantity of about 4% each, and about 2 % of 50 mm waste HDPE strips. Different trial specimens were casted by varying the proportion of different materials. Experiments that were performed are - UCS, split tension, and static flexural tests. S–N curve is used to express the connection among stress ratio & number of cycles of failure. They reported fatigue and damage behaviour of an alternate pavement foundation material which incorporates recycled aggregate, fly ash, and waste HDPE strips.

***S. Kolias et al.* (2005)** studied usefulness of high calcium fly ash and cement in the stabilisation of fine-grained clayey soil (CL, CH). While varying the percentages of fly ash and cement, various strength tests were carried out in uniaxial compression. Three type of clayey soils were used for the analysis. Cylindrical specimens were used for indirect tensile (splitting) and unconfines compressive strength tests.

Compaction for different percentages of FA shows that with increase in FA content from 5 to 20 percent OMC is increased while the MDD decreases. The results show that there is a advantage of stabilising clayey soil with calcium FA but it is subjected to type of soil and stabilising agent.

For practical examination of results two equivalent pavements were designed having same subgrade strain and same horizontal strain at bottom of bituminous layer as shown in Figure 2.1.

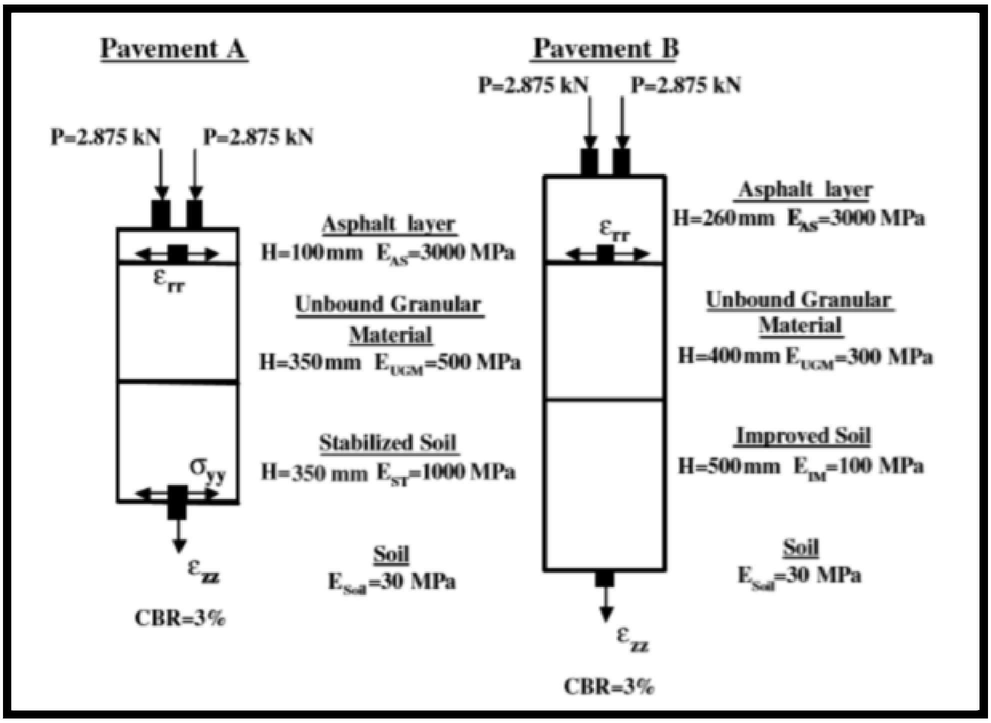

Figure 2. 1 Equivalent Pavements

Hence, there is considerable decrease in the thickness of asphalt layer in Pavement A as compared to Pavement B demonstrating the advantageous effect of addition of stabilised layer on top of poor subgrade.

***Li Chena et al*. (2007)** recommended to use sewage sludge ash mixed in cement at varying ratios for enhancing strength characteristics of subgrade soil as a soil stabilizer. Samples were prepared by changing the amount of sludge ash with soil. Li Chena carried out Standard proctor test, CBR, UCS, and triaxial compression tests. From the tests conducted an increase of 3 to 6 times was found in UCS value of sample. In addition to that swelling behaviour was also reduced by 5 to 50% for those samples. Also, a major increase was observed in the CBR values that rose up to 30 times.

***Musa Alhassan et al*. (2008)** found that use of soil additives like cement and lime makes the construction of road financially high. Also hazardous to environment as mass use of Portland cement produces large amount of CO2. So, he devised the use of rice husk ash (RHA) as an alternative. Soil samples were taken from Maikunkele area in Northern Nigeria from a depth of 2.0 m. Various laboratory tests were conducted on the natural soil including particle size distribution, LL and PL, standard proctor test, CBR, UCS etc. Improvement of the soil with ash showed a decline in MDD while increasing the OMC with increased ash content. In addition to that, it was concluded that CBR increases from 8.5% to 18.5% at 6% of rice husk ash content percentage.

***Chauhan et al. (*2008)** carried out the performance assessment of silty sand subgrade reinforced with fibre (synthetic & coir fibres) and fly ash. From strength viewpoint permanent strain, resilient modulus and resilient strain behaviour of subgrade soil was computed by performing repeated and static triaxial tests of reinforced and unreinforced soil samples.

30 % of fly ash was found to be optimum having a decreased MDD and increased OMC with its increased percentage. Also, 0.75% and 1% of coir and polypropylene fibre respectively by weight were found to be optimum. The subgrade soil stress–strain behaviour under static load condition improved noticeably by 63.88% (coir fibre) & 37.50% (synthetic fibre) respectively when their optimum quantity was randomly distributed into the mix. This paper establishes that fibre reinforcement augments resilient response of soils, but its sheer volume of augmentation be subject to its nature. Coir fibre helped in stalling the collapse of subgrade in pavement as resilient strain was observed to be less in coir fibre reinforced soil as compared to synthetic fibre. Same with the resilient modulus showing enhancements of 45.50% in case of coir fibre reinforcement and 40% enhancement in case of synthetic one.

***Choudhary et al.* (2010)** experimented with HDPE to be used as reinforcement in soil by improving its properties. HDPE strips were obtained from plastic waste, then mixed thoroughly with soil along with varying percentages of HDPE proportions. Lengths of strips were also varied. Large quantity of CBR tests were performed on reinforced soil ultimately concluding the beneficial effect of using HDPE strips as a soil reinforcement agent.

***Kolay et al.* (2011)** studied the use and disposal of class F pond ash (PA) from coal fired power plant on tropical peat soil. Kolay’s paper was intended to show its beneficial effect on peat soil, collected from Sarawak, Malaysia. As PA content increases, MDD increases, whereas OMC decreases. Also, UCS value of the peat soils increases with the increase of PA content. This study depicts PA has a potential in utilisation as a material admixture for tropical peat soil.

***Dr. Amin Chegenizadeh et al*. (2012)** conducted study on sand reinforced with paper reinforcement. The objective was to increase the modulus of elasticity of sand. Material use was Australian sand which is commonly use in industrial projects and research projects, and paper that has been used as reinforcement in this investigation. First, paper soil was well mixed and then placed for 24 hrs. Mould and hammer were used to compact the specimen. Different paper reinforcement content and different paper reinforcement length was mixed with soil for the study.

Conclusion of this research could be briefed as, by increasing paper reinforcement percentage there was a rise in elastic modulus. While performing this experiment, it was observed that ductility behaviour of reinforced sand increases due to paper reinforcement inclusion. Also, inclusion of Short and randomly paper reinforcement exhibited more dependable solution for the enhancing the strength of mix.

***Hejazi et al*. (2012)** did a comprehensive review of the type of soil reinforcements that are being used to improve the soil characteristics by using both types of natural and synthetic fibres through referencing already published data and following results were summarised:

Table 2. 1 Past Investigations Performed on Synthetic-Fibres for Reinforcing Soil

Fibre type	D (µm)	SG(g/c m^2)	E(G Pa)	UTS(MPa)	Length (mm)	Optimized fiber percentage	Soil types used	Conclusions
Polypropylene fibers	23–150	0.92	3-3.5	120-450	6, 12, 18 ,24, 35 and 50	0–3 %	-Sand -Silty sand -Clayey soil -Black cotton	It enhances soil strength and ductility, while reducing swelling and shrinkage potential and overcome chemical and biological degradation, improves resistance to freeze–thawing.
Polyester fibers	30-40	1.35	10-30	400-600	3, 6, 12, 20 and 64	0-1%	-Fine sand -Clay	Fibres enhances ultimate strength of soil, folding of fibers increases UCS slightly, UCS will improve with fiber length and fiber content increases.
Polyethylene Fibres	400-800	0.92	0.14-1	100-620	12, 25 and 50	0-4%	-Clay -Sand	Fibres rises fracture energy, toughness, CBR and secant modulus of soil.
Glass Fibres	3-19	2.49-2.60	53-95	1500-5000	25	0-1%	-Silty sand -Sand	Fibre enhances cohesive nature of soil. UCS enhances upto 1.5 times by adding 1% glass fiber in cemented sand with respect to virgin sand. Fibre in silty sand efficiently improves peak strength.
Polyvinyl alcohol fibers	1000-4000	2.05	-	-	12	1%	-Cemented river sand	2 times surge in UCS and axial strain in comparison with non fiber reinforced specimen. Increased ductility.

Note.** D: Diameter, UTS: ultimate tensile strength, SG: specific gravity

Table 2. 2 Past Investigations Performed on Natural-Fibres for Reinforcing Soil

Fibre type				Length (mm)	Optimized fiber percentage	Soil types used	Conclusions
Coir fibres				Randomly distributed:10–500 mm and 50 mm	1% by weight with 20 aspect ratios	-Black cotton	It decreases MDD of soil while OMC increases.
D (μm)	SG(g/cm^2)	E(GPa)	UTS(MPa)			-Laterite soil	Up to 1% of coir content increases compressive and tensile strength of composite soil
10–20	1.15–1.33	4–5	250			-Clay	Fibre, soil & cement block has low thermal conductivity.
Sisal fibers				10, 15, 20 and 25; 20 mm: optimized	0.75%	-Clay	Imparts substantial ductility and to some extent increases compressive strength
D (μm)	SG(g/cm^2)	E(GPa)	UTS(MPa)			-Silty sand	The shear strength of the composite soil increases in a non-linear manner with increased length of fiber up to 20 mm and 0.75% fiber percentage.
25-400	1.2-1.45	26-32	560				
Palm Fibres				15, 20, 30, 40 and 45; 30 mm: optimized	0.5%	-Silty sand	It increases the UCS, CBR and shear strength parameters of the soft soil. Palm fibers percentage of 3% improve the compressive strength of compound bricks.
D (μm)	SG(g/cm^2)	E(GPa)	UTS(MPa)				
25-60	1.3-1.46	0.55	21-60				
Jute Fibres				5, 10, 15 and 20; 10 mm: optimized	0.8%	-Clay	Fibre reduced the MDD while increasing the OMC. CBR value is increases up to 2.5 times compared to the virgin soil.
D (μm)	SG(g/cm^2)	E(GPa)	UTS(MPa)				
10-50	1.44-1.46	22	453-550				
Barley-straw-fibres				Randomly distributed: 10–500mm	1%	-Clayey silty soil	Fibre decreases shrinkage, reduces the curing time and enhances compressive strength if an optimal reinforcement ratio is used. Flexural and shear strengths increase, and more ductile failure is obtained.
D (μm)	SG(g/cm^2)	E(GPa)	UTS(MPa)			-Clayey sandy soil	
1000-4000	2.05	-	-			--Silty sand	

Note.** D: Diameter, SG: specific gravity, UTS: ultimate tensile strength

***Juan M. Manso et al*, (2013)** investigated on the use of ladle furnace slag in soil stabilization. Clayey soils have often been stabilized by addition of materials like cement, lime etc. So as to gain desirable properties for clay to be used in civil engineering projects. By-products of various industries can also be used for this objective. The properties of Ladle Furnace Slag (LFS) and the properties of different clayey soils with the addition of this slag to improve its properties has been studied. The behavior of the different soil and slag mixes were almost like that of the mixture of soil and lime. The results of the tests performed for the improvements of soil with respect to the various soil properties, like the plasticity index, expansiveness, bearing capacity and durability have been studied.

***Mercy Joseph Poweth et al*, (2013)** gave the sustainable method of disposing quarry, dust, tyre waste and wastes-plastic to be used as an admixture in sub grade. Experimental programme included CBR and Standard Proctor Test for finding the optimum percentages of material used in soil. Out of all the admixtures quarry dust has a potential beneficial result to show hence is recommended to be mixed with the soil suitable for sub grade. Also, he concluded that using tyres alone are not suitable for subgrade and plastic mixed soil with quarry dust just preserves the CBR value whereas tyre mixed soil with quarry dust yields lesser CBR values.

***Akshat Malhotra et al*, (2014)** carried out UCS tests in successions to study the effect of HDPE plastic waste on expansive soils. For different proportion by weights of dry soil, HDPE plastic (40 micron) waste were added. There was an increment in UCS of black cotton soil on addition of plastic waste. It was reported that 4.5 % plastic waste gives the maximum value for UCS as 287.32kN/m which is exponentially greater than the base soil UCS. The increase in the UCS value was three times the virgin soil (71.35kN/m) value.

***Dr. A.I. Dhatrak et al*, (2015)** studied the effect of plastic waste when mixed with soil. It was observed that inclusion of plastic bottles chips is effective in constructing improved strength subgrade of flexible pavement. In his paper author made use of various experiments predominantly CBR on soil hand blended with various proportions of plastic content. Final outcome being that usage of plastic waste strips will enhance the soil compressive strength parameter and is recommended to be used as subgrade.

***Jasmin Varghese Kalliyath et al, (*2016)** studied the potential use of plastic cover wastes for soil stabilization which leads to this study having usage in three major fields that are utilization of natural resource, waste management & economy. The plastic covers were chosen as they are degradable and inert, effectively remaining in soil for many years to come. The shredded fibres were used in the percentages of 0.25%, 0.5%, 1% and 1.5% as a replacement to soil by weight to study their effect on soil behaviour. The percentage of 0.5% plastic fibres in expansive clayey soil gives maximum UCS and MDD. 0.5% plastic content in recommended as optimum content to enhance the engineering properties of silty clay soil.

***Arpitha G C et al*, (2017)** used of plastic present in the form shopping bags, plastic bottle etc, as a reinforcing material to conduct the CBR when mixed with soil for improving the engineering characteristics and stabilizing the subgrade soil. From this study, it was concluded that plastic derived from bottle strips can be an effective alternative for soil admixture to increase the CBR of a soil by substantial amount. In the study the maximum CBR value was achieved for 2 % of plastic bottle strip content and it decreases with the further addition of plastic bottle strips. 0.75 % was the optimum quantity of the strip content added to soil for its effective utilization. Further, from the results obtained after testing with 2 % plastic bag strips of the total weight of the soil is the optimum percentage of strips to be added to the soil for reinforcement but decreases when further amount of plastic bags strips are added.

Sanjeev Singh et al, (2017) studied scrap rubber tyres effect on fine grained soil for altering engineering properties of soil by conducting unconfined compressive strength tests (UCS) by replacing 5, 10, 15 and 20 % of rubber tire scraps of different sizes by weight with soil. Two types of scrap tyres were used i.e.

1. R- 425 µ- Passing 600 µ sieve and retained on 425 µ sieve
2. R- 150 µ- Passing 425 µ sieve and retained on 150 µ sieve

An increase was detected in the UCS with increase in percentage of tyre scrap indicating soil strength improvement. Maximum value of UCS was observed to be 1.75 kg/cm2 for the R- 425 µ type replacement.

Dr. Babitharani.H **et al, (2017)** discusses the effect of addition of polypropylene fibres (used in a variety of applications to include packaging for consumer products) in different proportions i.e. 0%, 0.05%, 0.15% & 0.25% by weight. The results are reported on the basis of various tests conducted during the study namely water content, Specific gravity of the soil, Determination of soil index properties (Atterberg Limits), Liquid limit by Casagrande's apparatus, Plastic limit, Particle size distribution by sieve analysis, Preparation of reinforced soil samples, Determination of shear strength by Direct shear stress & Unconfined compression test.

Direct shear test on soil sample depicts the increase in cohesion to be 50%, 34.6%, and 22.4% respectively with a rise in the internal angle of friction (φ) of 10%, 3.9% and 6.1% respectively. The value of c surged 100% net and a 20% increase was observed in φ, therefore for such soil, the use of randomly dispersed polypropylene fibre reinforcement is suggested. UCS value surged a net 50%, Thus making its use for soil effective.

From the above literature reviewed, it was concluded that much research on shredded plastic as a subgrade soil stabilizer had not been done and hence it was adopted for the project.

CHAPTER -3

EXPERIMENTAL PROGRAMME

3.1 MATERIALS

A concise description of the procedures and materials used in the investigation are given as following:

3.1.1 Soil

The soil chosen for studying the effect of plastic on the strength characteristics of soil used for pavement subgrade falls in the category of fines grained soil having a 70% passing percentage from a 75-micron sieve. Soil has been procured from Noorkhrian village located in the outskirts of the Patiala city, Punjab. The soil investigation is done by Indian Standard Code. Index properties (Liquid limit (LL), Plastic limit (PL), Plasticity index (PI)) were determined in accord with the IS standards. The various engineering properties are shown in the Table 3.1.

Table 3. 1 Engineering Properties of Soil

S.No.	Property	Result	IS code
1	% finer than 75 microns	73.22	IS: 2720 (Part 4)- 1985
2	LL (%)	34.00	IS: 2720 (Part 5)- 1985
3	PL (%)	16.67	IS: 2720 (Part 5)- 1985
4	PI (%)	17.33	IS: 2720 (Part 5)- 1985
5	Classification	CL	IS: 1498 - 2007
6	Unconfined compressive Strength, q_u (kN/m^2)	83.26	IS: 2720 (Part 10)- 1991

3.1.2 Waste Plastic

Plastic selected for the study was collected as form of waste shredded wrappers of fast food eatables such as chocolates, potato chips, candies etc. as shown in Fig.3.1. These plastics are made from aluminium laminated with polypropylene or low-density polyethylene film which forms an aluminium and hot plastic mess forming a multi layered type of plastic which in turn very difficult to recycle.

Figure 3. 1 Shredded Plastic Wrappers

Therefore, keeping the unrecyclable nature of the plastic in mind it was selected for the study to simultaneously reduce the waste plastic heap as well as making its sustainable use. The general specifications are provided in Table 3.2.

Table 3. 2 Plastic Properties

Type of plastic	Shredded plastic wrappers (lays, chocolate etc.)
Length	5-10 mm
Thickness	Up to 60 μ

3.2 COMPACTION TEST

The reduction of air voids existing in soil mass by means of applying dynamic forces (by using weights) is known as compaction test. In present study compaction test is done to compute the OMC and MDD in conformity with the codal provisions of IS :2720 (Part 7) - 1980. The degree of compaction is measured in terms of its maximum dry density and its moisture content, energy of compaction and type of soil. Soil attains MDD at a definite water content for a given energy of compaction which is stated as OMC.

3.2.1 Applications

By performing the proctor test soil achieves its MDD at a specific moisture content known as OMC and after OMC is achieved further rise in moisture content will lead to reduction in dry density.

This maximum dry density is a useful parameter in the construction of any infrastructure requiring the compaction of soil which is required for achieving stability of field difficulties like embankments, roads, earthen dams etc. Compaction results in the increase in density of soil, shear strength, bearing capacity and decreases porosity, permeability, void ratio and settlements.

Figure 3. 2 Automatic Compactor

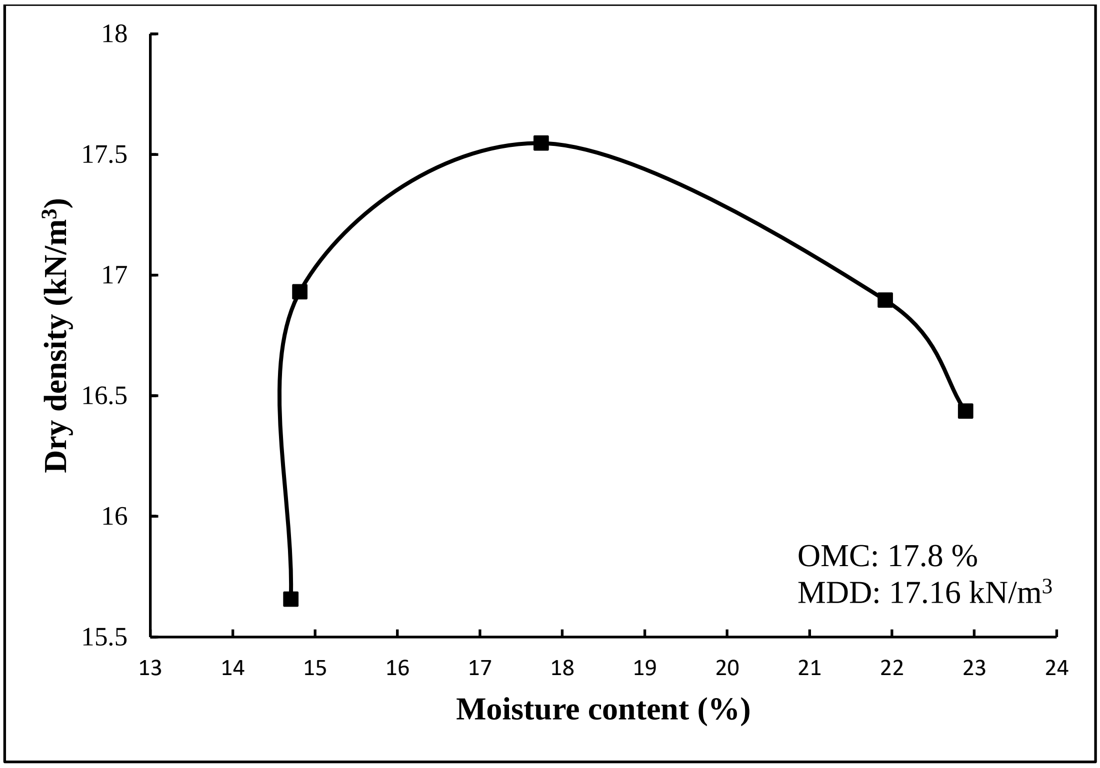

Figure 3. 3 Compaction Curve for Unreinforced Soil

The compaction test has been performed for plastic content of 0.25%, 0.5%, 1% and 1.5% as shown in Figures 3.4 to 3.7.

Figure 3.4 depicts effect of 0.25% plastic content at OMC. The slope of curve is less steep as compared to 0 % as shown in Figure 3.3. Result of 0.5% plastic content on OMC is presented in Figure 3.5 The curve slope gradually increases at first and after that a steep rise was found in its value until it reaches MDD then it follows the same trend as that of 0 % and 0.25 % as presented in Figure 3.3 and Figure.3.4 respectively. The effect of 1.0 % plastic content on OMC is as shown in Figure 3.6. The slope of curve gradually increases at first and then there is a steep rise in its value until it reaches MDD and after that it follows the same trend as that of 0 %, 0.25 % and 0.5 % respectively as shown in Figures 3.3, 3.4 and 3.5. Also, similar was the variation of compaction curve for 1.5 % plastic content as shown in Figure 3.7.

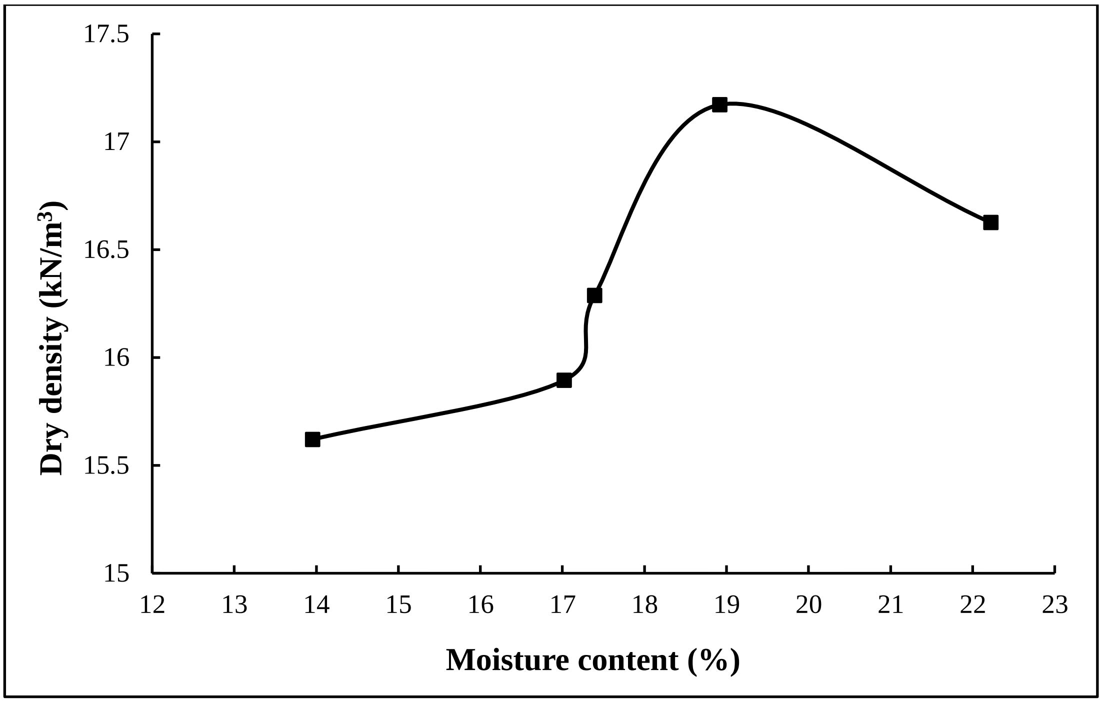

Figure 3. 4 Compaction Curve at 0.25 % Plastic Content

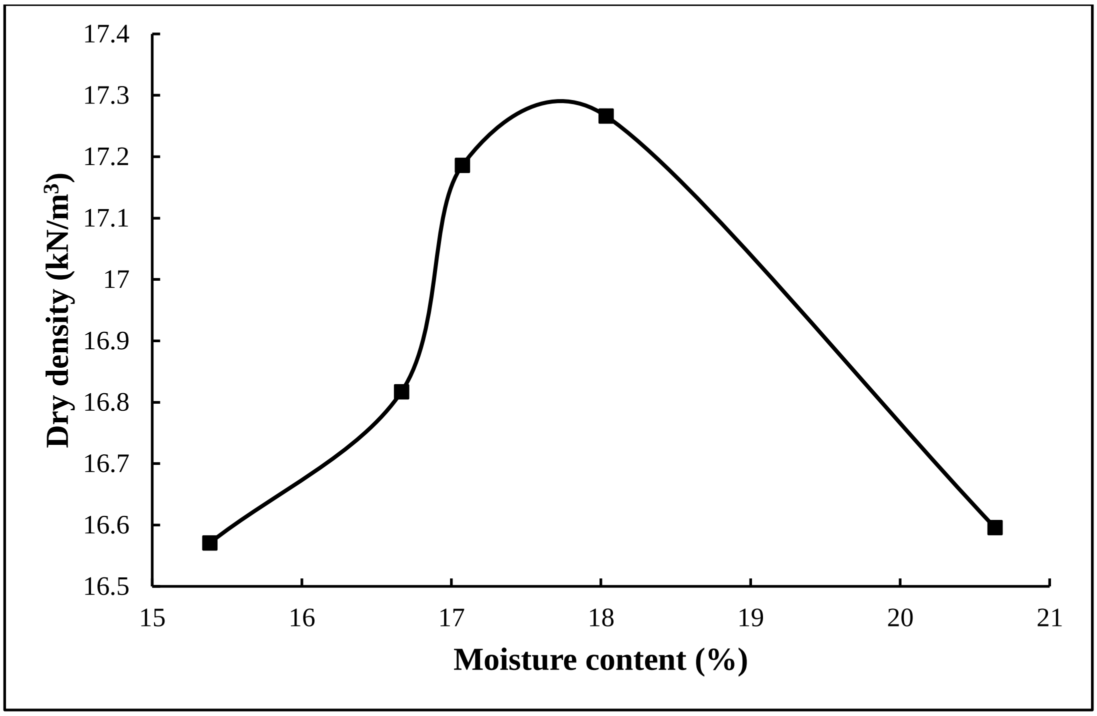

Figure 3.5 Compaction Curve at 0.5% Plastic Content

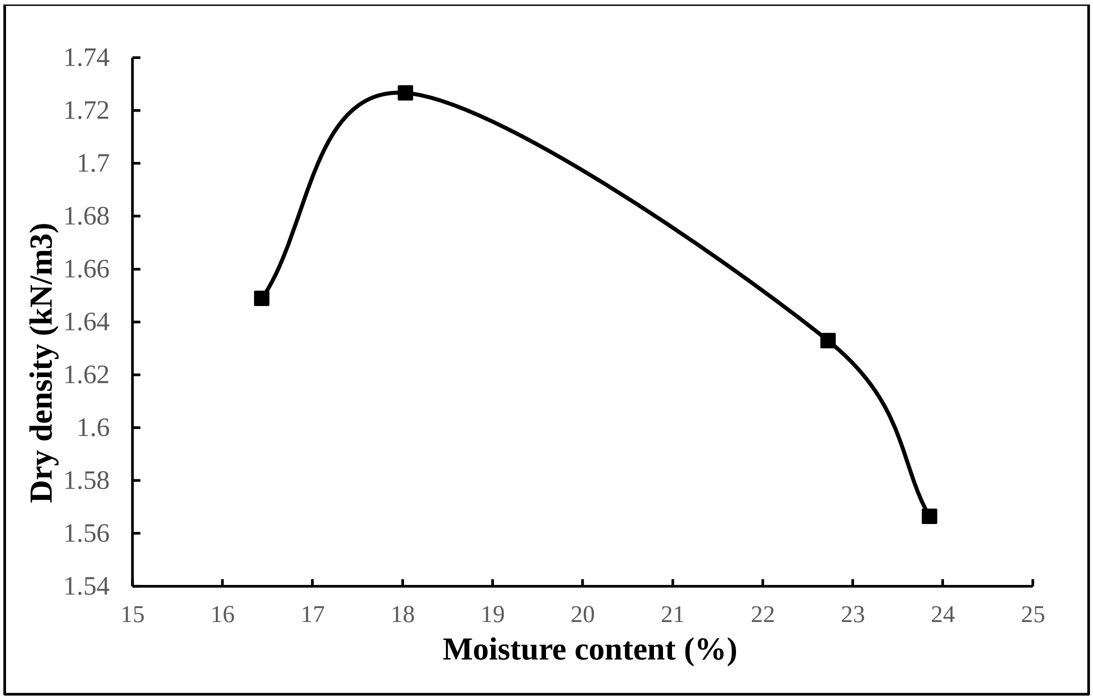

Figure 3.6 Compaction Curve at 1 % Plastic Content

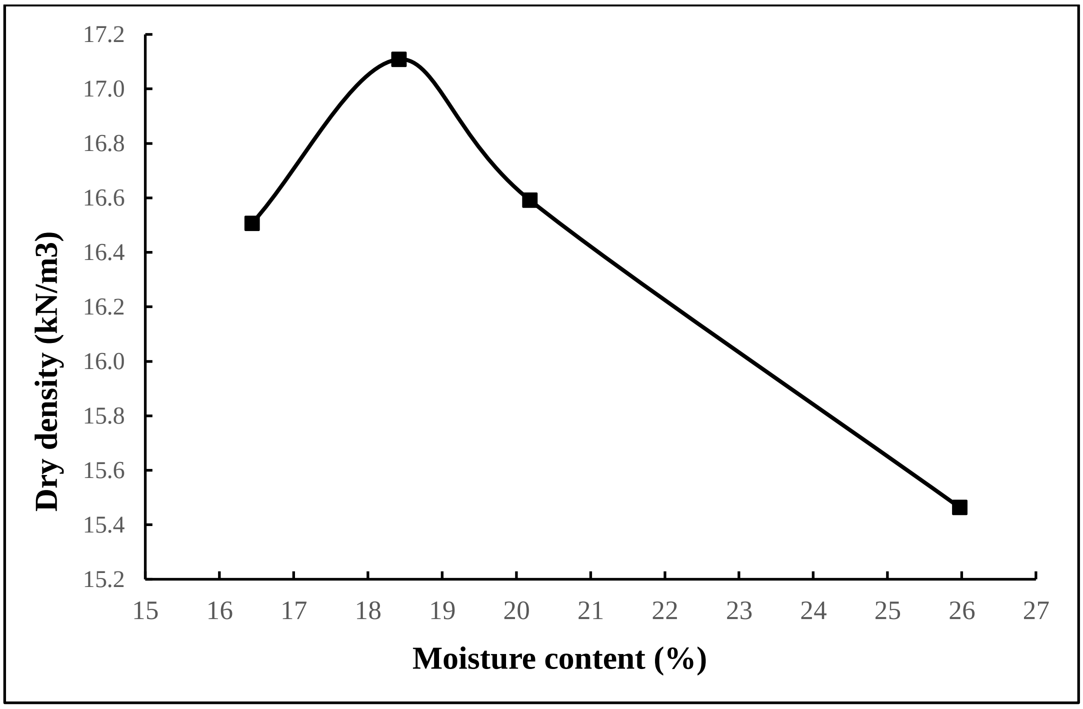

Figure 3.7 Compaction Curve at 1.5% Plastic Content

It is observed that there was a very slight change in the OMC while increasing the plastic content percentage. As moisture is added to soil mass, its particles are greased by water adsorbed on their surface and it promotes easy movements between the soil particles as friction gets reduced due to presence of more water. As further water is added to the soil, water particles starts taking place of soil particles which ultimately leads in the decrement of density. Due to larger size of plastic its addition in soil does not cause any reduction in voids present in between soil particles. Hence, not affecting interactions between water and soil. Therefore, there is no significant change in OMC.

Table 3. 3 Standard Proctor Test results

Plastic content (%)	OMC (%)	MDD (kN/m3)
0	17.8	17.16
0.25	19	16.87
0.50	17.8	16.97
1.00	17.9	16.97
1.50	17.8	16.8

3.3 CALIFORNIA BEARING RATIO TEST

California Bearing Ratio (CBR) is an empirical test method. CBR is known to be a measure of resistance offered to soil mass by the penetrating load, in this test a force per unit area is applied to the soil sample under controlled test conditions. CBR is calculated as the ratio of force per unit area as described in Table 3.4 applied by means of a cylindrical piston so as to penetrate the soil mass at a constant rate of 1.25 mm/min. Hence it is the ratio of load at corresponding penetration to the standard material as shown in the equation given below.

$$\text{CBR} = \frac{\text{Test load (kg)}}{\text{standard load (kg)}} \text{ X } 100$$

Table 3. 4 Standard load Values for Specified Penetration

Penetration, (mm)	Standard load, (kg)	Unit standard load, (kg/cm^2)
2.5	1370	70
5.0	2055	105

CBR test may be performed on either undisturbed or remoulded specimens by either dynamic compaction (done using rammers as per IS heavy or light compaction method at appropriate OMC) or static compaction (knowing the OMC and MDD of soil the volume of soil required to completely fill the mould is computed and is compressed into the mould using a compression assembly).

Figure 3. 8 CBR Penetration Assembly

3.4 LIGHT WEIGHT DEFLECTOMETER

Light Weight Deflectometer (LWD) is a handheld miniature version of Falling Weight Deflectometer (FWD) which is also known as the light FWD which was developed in Germany for the measurement dynamic modulus of in situ soil. The code which has been followed is ASTM E2583- 07 (2015).

LWD itself is a small portable version of the Falling Weight Deflectometer (FWD). It's working is similar to that of FWD in which it uses a load and geophones of similar accuracy as that of Falling Weight Deflectometer. The LWD can also be used on thin bituminous pavement surfaces. It can also be used directly over the unbound subbase and subgrade. The results that are obtained from the LWD are used to compute the present and remaining strength of different layers of pavements.

LWD being a non-destructive and dynamic test is highly suitable for quality control of soil-surfaced roads, thin bituminous overlays, embankments etc. Applications of LWD are best utilized for particular soil types like coarse and mixed grained soils having 60 mm as maximum grain size.

3.4.1 Description of Light Weight Deflectometer

1. In LWD there is a mechanism for holding weights at a constant height. Weight can be released using a lock-unlock system. When unlocked, weights are dropped freely, and this falling load generates load pulse through a circular plate that is fixed at the bottom of the guide rod. This plate rests on the material to be tested.
2. Height of falling weight is at 720 mm which is adjustable as per requirement and the total weight of guide rod and that of falling weight is about 15 kg.
3. There is a mechanism of a grip used to raise the weight to the top and fix it.
4. Lock pins or magnets are used to release and hold the falling weights.
5. Rubber material is used as a damping system that provides an even transmission of the pulse due to impact falling load. Typical range of this pulse is 15 to 30 m/s.
6. A cup which has sensor in the middle of the plate is installed which connects to an electronic device. Basically, the function of this cup is to record the movements of the plate.

7. A loading plate is installed in the device for the uniform distribution of the impulse load on the testing surface. Diameter varies between 100 to 300 mm and the loading plate weight around 5 kg.
8. A cable is provided in the LWD device which connects loading plate sensor to data processing and storage systems. Every measurement can be immediately seen in GPS with help of geophones. All data can be seen on handheld electronic equipment easily.

Figure 3.9 Light Weight Deflectometer

3.4.2 Procedure

1. First, the surface over which the load is to be dropped is levelled and LWD is placed over the material.
2. Then the falling weight and buffer pads required are decided by the user which is then placed on the top of loading plate. Weights can generate a force of 10, 15 and 20 kN.
3. Lock mechanism is used to clutch the falling weight at the top, at a certain height of 720 mm.
4. The geophone is then connected with the LWD for the measurement of deflections.
5. Before the placement of LWD over the soil to be tested, sensor is placed at the bottom of loading plate.
6. After all the settings are completed, the weight is allowed to fall freely by releasing the lock pin mechanism or magnetic lock mechanism.
7. Further then measurements are taken through the geophone, that measures the deflection values.
8. The data is transferred to the PC and LWDMODE application is used for further analysis of the raw data.

CHAPTER-4

RESULT AND DISCUSSION

4.1 CALIFORNIA BEARING RATIO

During CBR test various curves showing variation of load with penetration of plunger attained for unreinforced and reinforced soil with variable percentages of waste plastic contents are as follows:

4.1.1 Load Penetration Curves for Unreinforced Samples

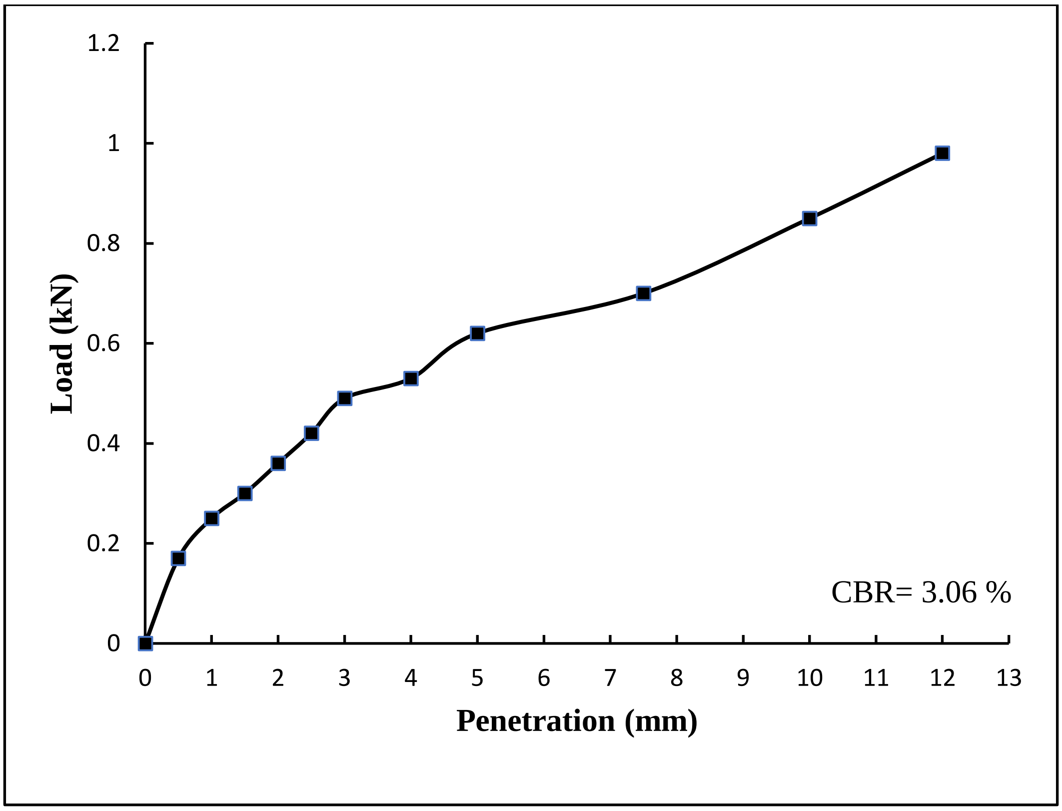

Figure 4.1. Load Versus Penetration Curve for Unreinforced Soil

Figure 4.1 depicts variation of load (kN) with penetration of plunger into the soil mass (mm). The maximum penetration for which the load reading is recorded is 12 mm. The CBR value comes out to be 3.06 % computed using equation provided in section 3.3.

4.1.2 Load Penetration Curves for Plastic Reinforced Soil

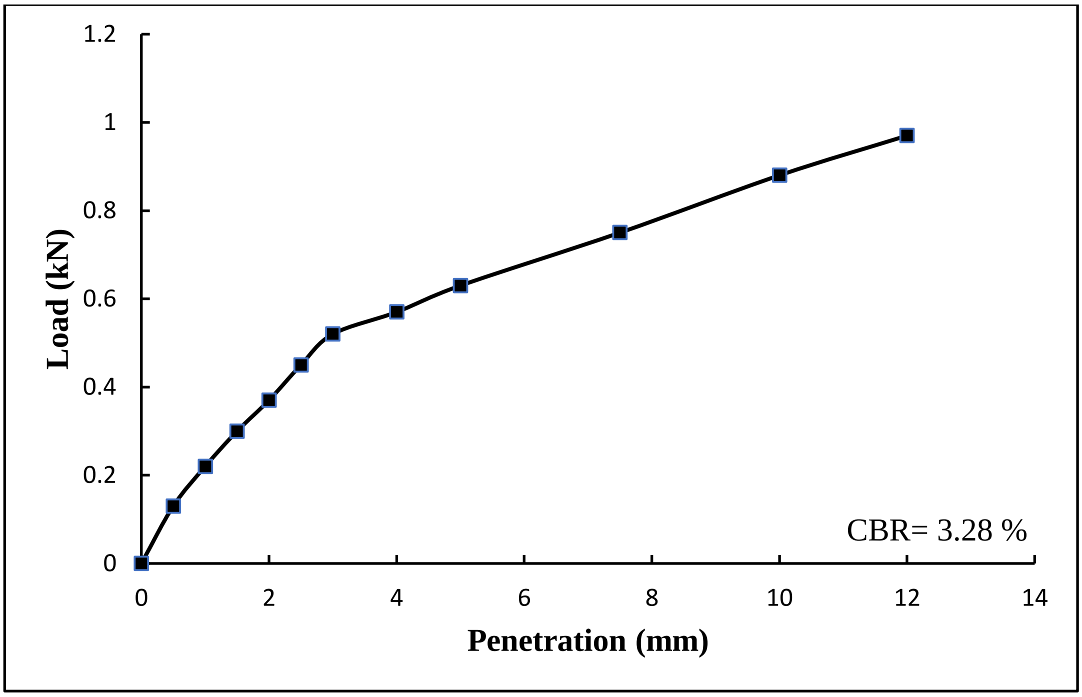

Figure 4.2. Load Versus Penetration Curve with 0.25 % Plastic Content

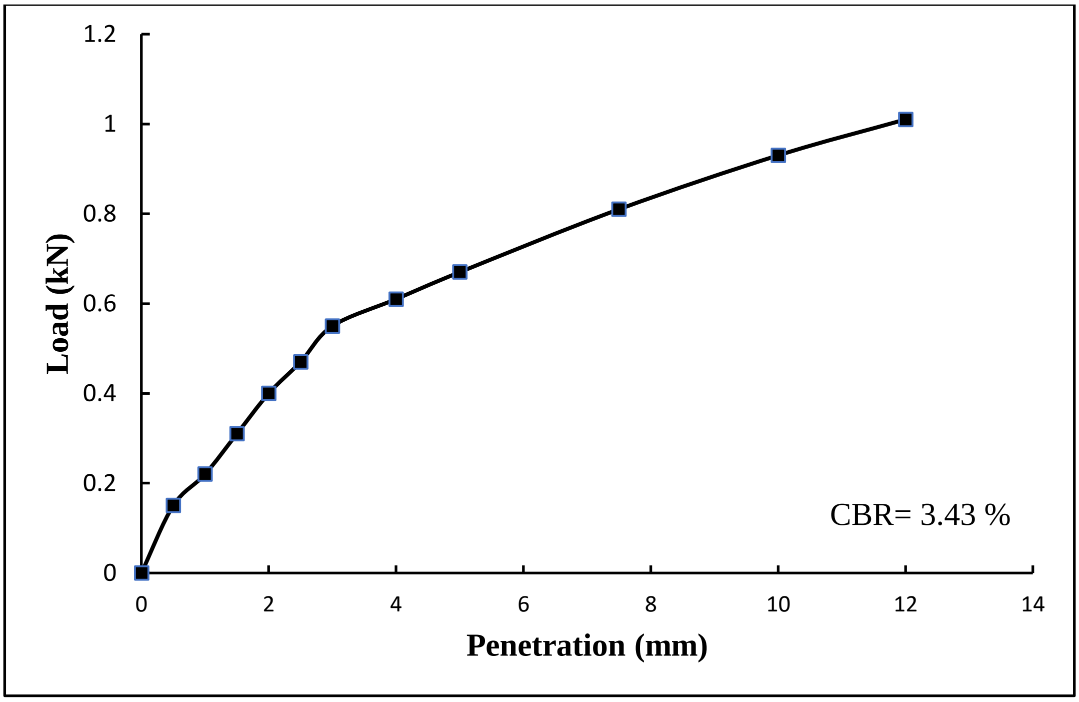

Figure 4.3. Load Versus Penetration Curve with 0.50 % Plastic Content

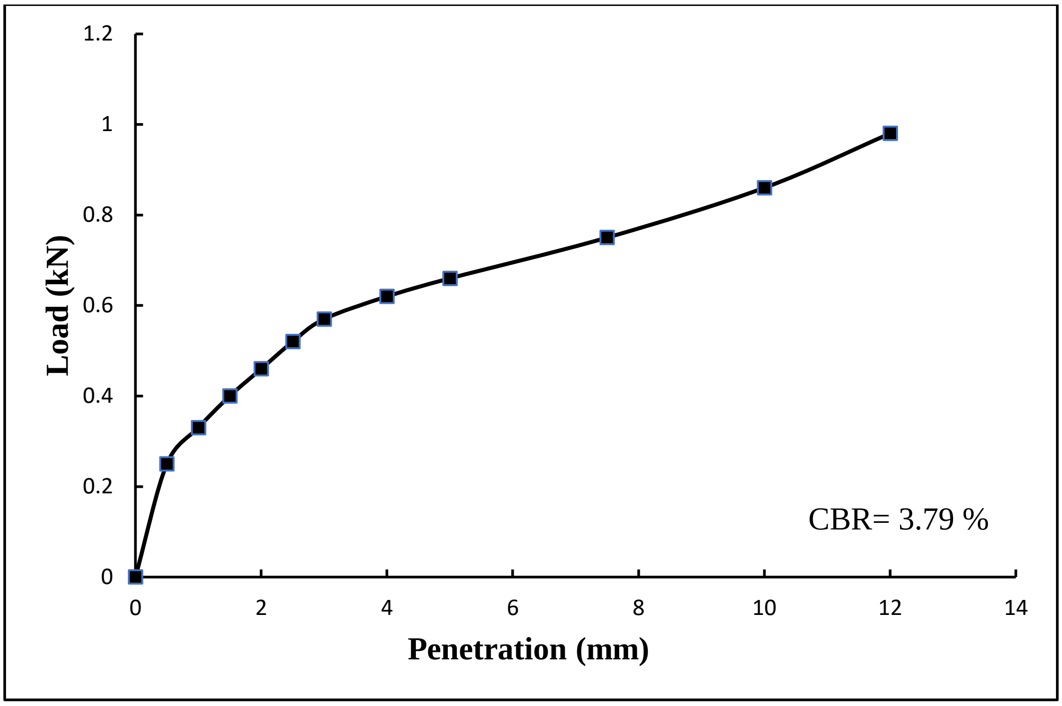

Figure 4.4. Load Versus Penetration Curve with 1 % Plastic Content

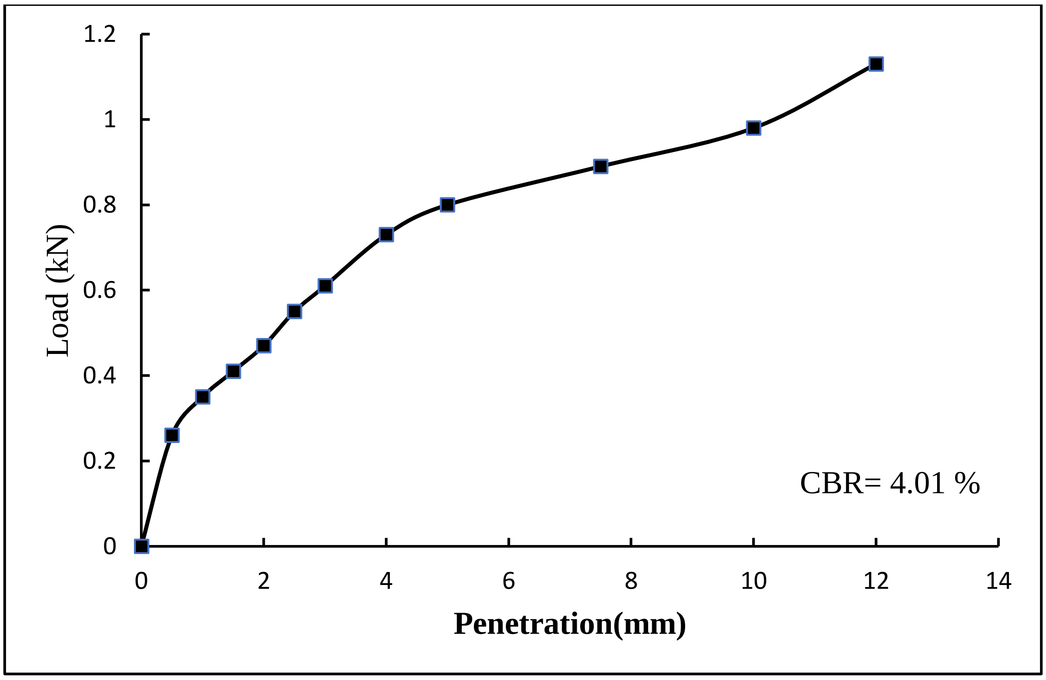

Figure 4.5. Load Versus Penetration Curve with 1.5 % Plastic Content

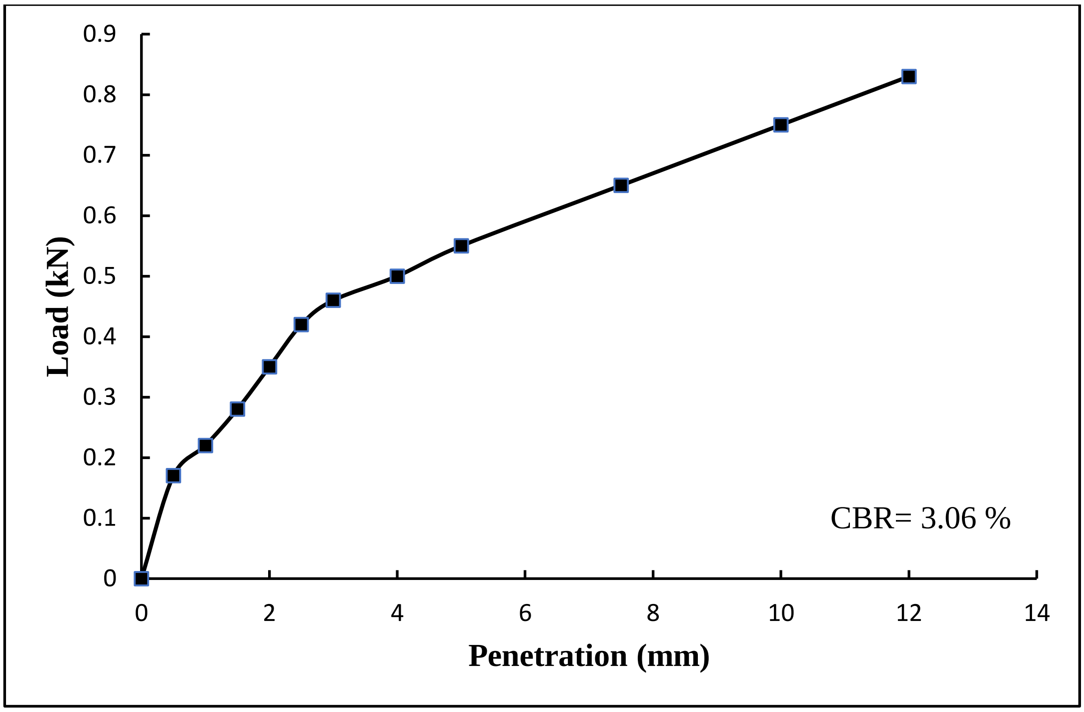

Figure 4.6. Load Versus Penetration Curve with 2 % Plastic Content

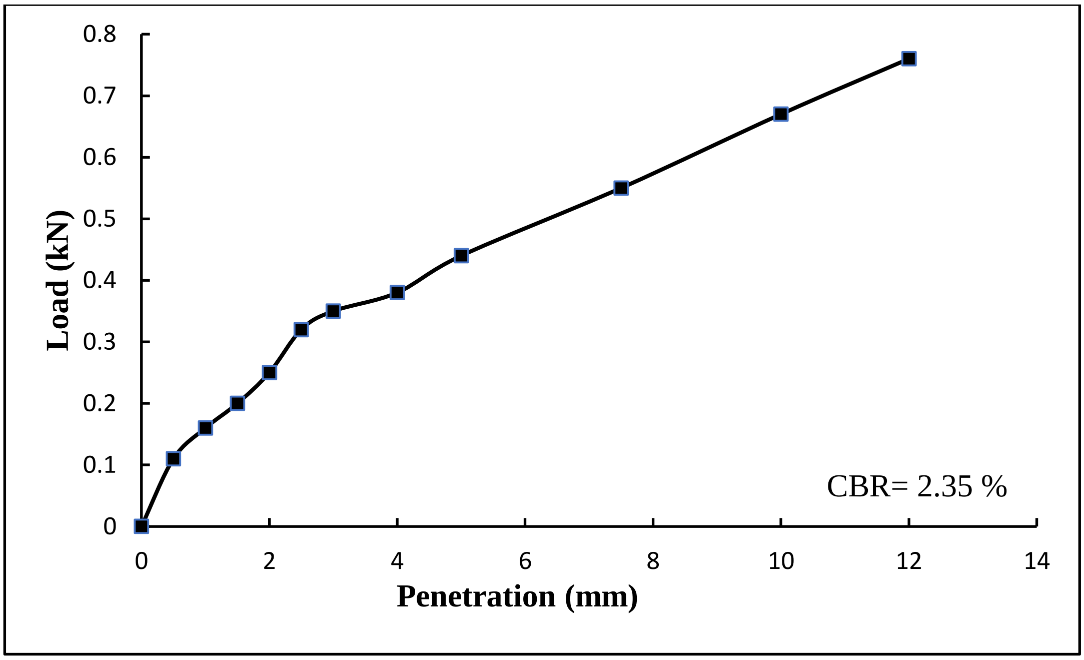

Figure 4.7. Load Versus Penetration Curve with 3 % Plastic Content

Fig. 4.2-4.7 shows variation of load (kN) along penetration of plunger into the soil mass (mm) for soil reinforced with waste plastic.

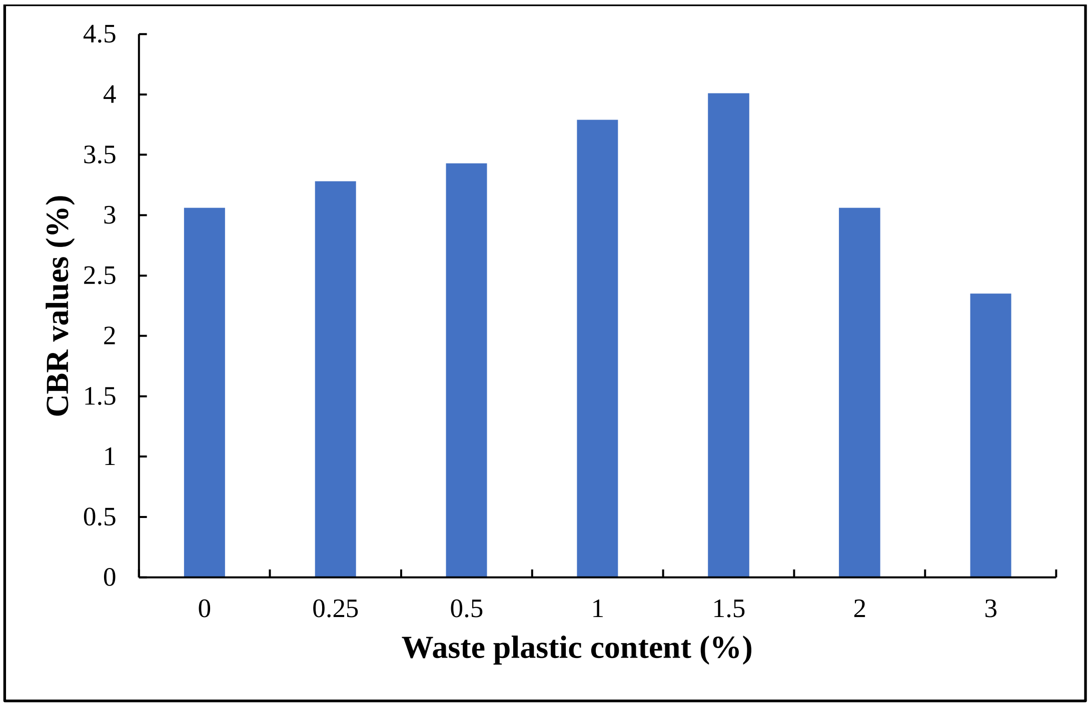

Figure 4.8. CBR Values with Different Waste Plastic Content

Fig 4.8 and Table 4.1 shows results of CBR test. From histogram it is evident that with increased waste plastic content there is an increase in the CBR of soil. It reaches its maximum value at waste plastic content of 1.5 % and after that decreases with further increase in plastic content. The maximum CBR obtained was 4.01 %.

Table 4. 1 CBR Values with Different Waste Plastic Content

Waste plastic content (%)	0	0.25	0.5	1	1.5	2	3
CBR value (%)	3.06	3.28	3.43	3.79	4.01	3.06	2.35

4.2 LIGHT WEIGHT DEFLECTOMETER

LWD test was performed on trial sections to determine the practical field values of the subgrade modulus of soil. It has been done to simulate actual field conditions by constructing a smaller prototype model of subgrade and see the actual difference in between CBR modulus and modulus determined from the LWD test.

4.2.1 Trial Section for Unreinforced Soil

For the calculation of modulus of subgrade using Light weight deflectometer, two trail section of size 60cm * 45cm * 25cm were prepared. The section was prepared in two layers i.e. 150 mm and 100 mm. For achieving 150 mm thickness firstly the mould was filled up to 250 mm and the compacted to reach the thickness of 150mm similar was the case for achieving 100 mm thickness.

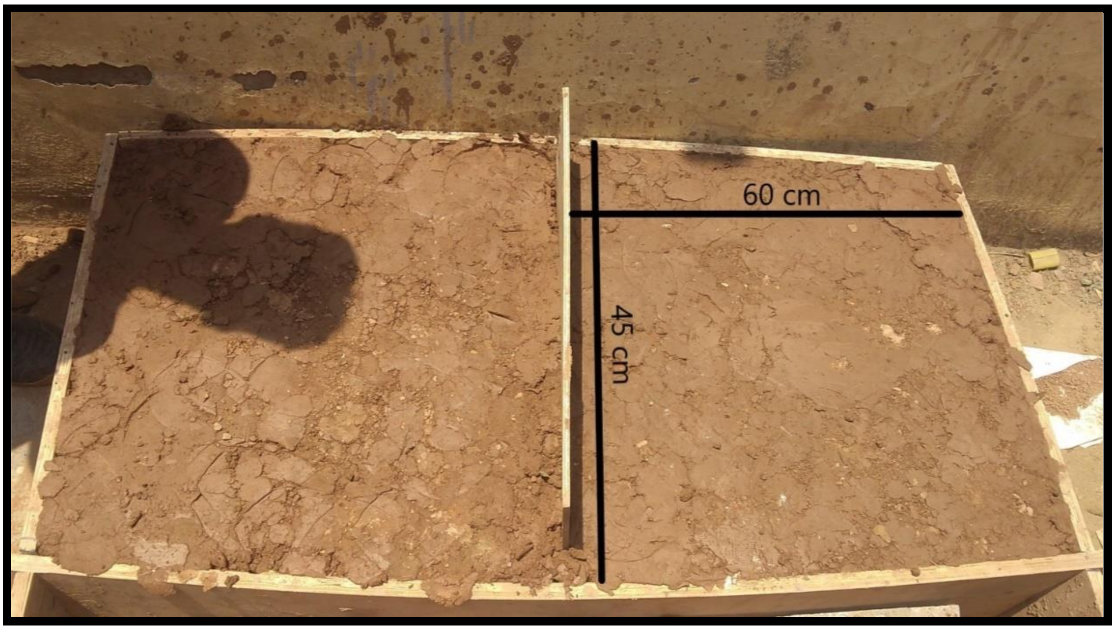

Figure 4.9. Trial Section for Unreinforced Soil

Various methods of compaction were tried. Roller of 100 kg and vibrator had been used. Roller was too heavy for the soil and completely slipped over the soil. The vibrator too was not capable of compacting the soil. Hence rammer has been used for compaction. The weight of rammer was 11.95 kg.

Figure 4.10 Compaction Rammer **Figure 4.11 Setting up of LWD**

The trial sections were required to be of the same MDD as was determined in laboratory i.e. 17.16 kN/m^3. Therefore, for achieving this MDD repeated core cutter tests were performed and for the first depth of 150 mm the MDD of 16.82 kN/m^3 and for next 100 mm depth the MDD achieved was 16.18 kN/m^3.

Therefore, average MDD achieved is 16.5 kN/m^3 which is 96 percentiles of the maximum dry density.

For 20 kN, E_o (subgrade modulus) comes out to be 28.2 MPa.

4.2.2 Trial Section for Reinforced Soil

Two trial sections were made to study impact of reinforcing soil mass with waste plastic content. Their respective dimensions being 62cm * 70cm * 25cm for 1 % plastic content and 62cm * 45cm * 25cm for 1.5 % plastic content. Same rammer as earlier is used for compaction weighing 11.95 kg. and, same procedure for constructing the trial section was followed i.e. layered construction.

Therefore, the MDD achieved for 1 % and 1.5 % plastic content is 97 percentiles of the maximum dry density.

For 20 KN, E_o (subgrade modulus) for 1% plastic content comes out to be 33.3 MPa.

For 20 KN, E_o (subgrade modulus) for 1.5% plastic content comes out to be 38.5 MPa.

Table 4. 2 Comparative subgrade modulus

Plastic content (%)	Subgrade modulus as per IRC:37-2018	Subgrade modulus from LWD test
0	30	28.2
1	37.9	33.3
1.5	40.1	38.5

The variation of subgrade modulus obtained from LWD and from IRC:37-2018 are as shown in Table 4.2 and Figure 4.12. it can be interpreted from the given data that there was a difference of 6 % in the subgrade modulus obtained from both the methods for 0 % plastic content addition and 4 % in case of 1.5 % plastic content addition. The subgrade modulus obtained from empirical relations provided in IRC:37-2018 overstates the modulus when compared to the modulus attained by LWD method though the difference being very small.

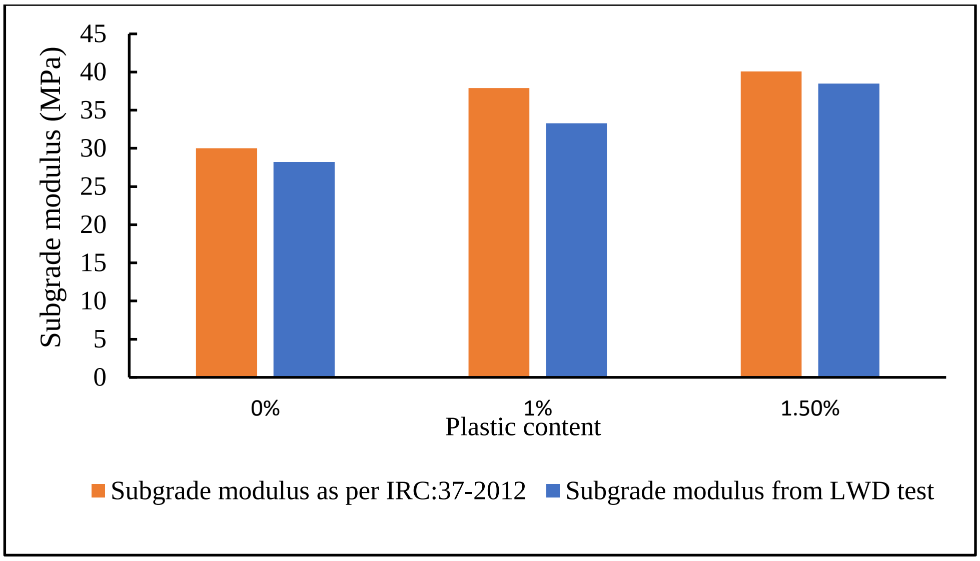

Figure 4.12 Comparative Subgrade Modulus

Figure 4.13 Performing LWD on Reinforced Trial Section

CHAPTER-5

ANALYSIS & DESIGN OF FLEXIBLE PAVEMENT

5.1 DESIGN CONSIDERATIONS

For the analysis and application point of view of the study following assumptions are made for design of flexible pavement:

1. The pavement is designed and compared for three cases with the traffic of 30, 75 and 125 msa.
2. The maximum permissible strains are calculated for 90% reliability equations from IRC:37-2018 and actual strains are calculated from IITPAVE.
3. Subgrade resilient modulus was calculated using equation from the IRC:37-2018 and verified by performing LWD test on a constructed trial section in the field.

5.2 CRUST THICKNESS AS PER IRC:37-2018 FOR 3 % CBR

The calculation of crust thickness for three cases of traffic 30, 75 and 125 msa respectively were in accordance with IRC:37-2018. Pavement optimization is done by narrowing the gap between maximum permissible strains and actual strains calculated from IITPAVE. The CBR used is 3% when no addition of waste plastic fibres.

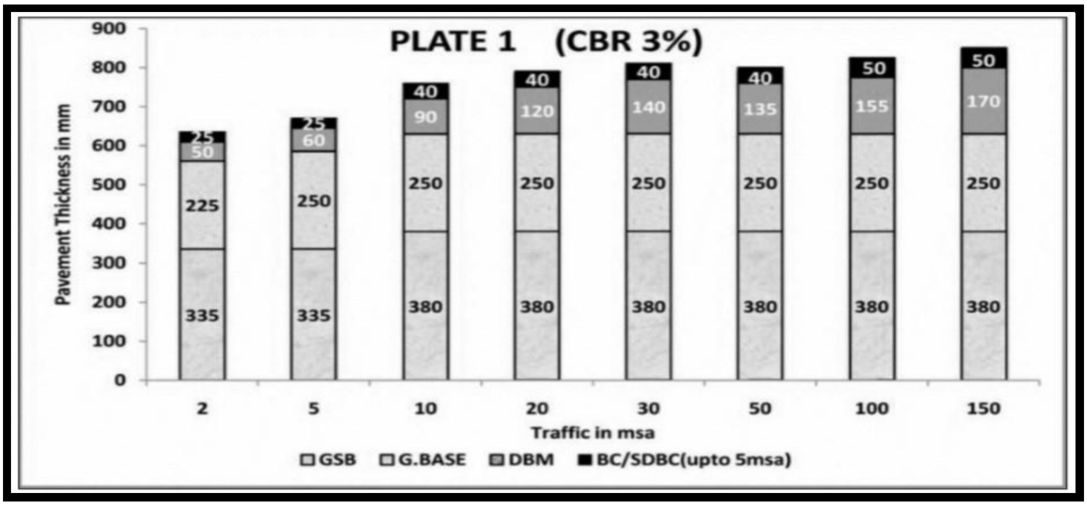

Figure 5.1 IRC 37:2012 Design Plate 1

Table 5. 1 Pavement Thicknesses for Different Traffic Volumes from Plate 1

Layers	Thickness (mm) (IRC:37-2012)		
	30 msa	75 msa	125 msa
Bituminous Concrete	40	45	50
Dense Bituminous Macadam	140	145	165
Granular Base	250	250	250
Granular Subbase	380	380	380
Subgrade	500	500	500
TOTAL THICKNESS (excluding subgrade)	**810**	**820**	**845**

5.2.1 Theoretical Calculation of Strains at Critical Location

Two types of pavement distress resulting from repeated application of vehicular loads were considered as follows:

1. Vertical compressive strain at top of sub-grade. (**Rutting**)
2. Horizontal tensile strain at bottom of bituminous layer. (**Fatigue Cracking**)

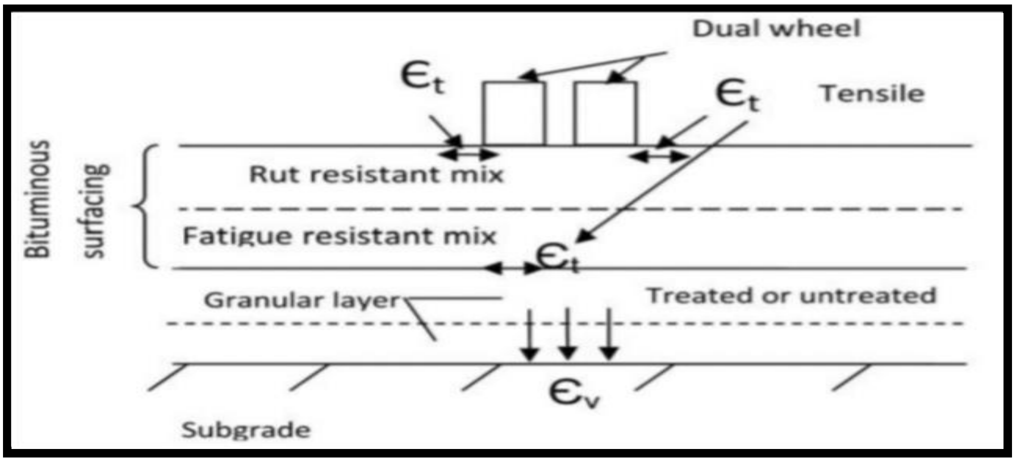

Figure 5.2 Strains at Critical Locations

Computation of Resilient Modulus (M_{RS}):

1. Subgrade Resilient Modulus (IRC 37: 2018, equation 6.1)

Elastic moduli of subgrade = $\mathbf{10 * CBR}$ for ($\boldsymbol{CBR} < \mathbf{5}$%)

Using IITPAVE software, maximum surface deflection (δ) was determined where elastic moduli of subgrade and embankment has been estimated from equations 6.1 of IRC 37: 2018, by means of their respective laboratory CBR values. Using this maximum surface deflection (δ), the resilient modulus, M_{RS} of the subgrade layer was estimated using equation 6.3 of IRC:37-2018 as shown below:

$$M_{RS} = \frac{2(1-\mu^2)pa}{\delta}$$

Where,

p = contact pressure = 0.56 MPa

a = radius of circular contact area, which can be calculated using the load applied (40,000 N) and the contact pressure 'p' (0.56 MPa) = 150.8 mm

μ = Poisson's ratio

M_{RS} = 31.899 MPa

2. Resilient Modulus of GSB layer (IRC 37: 2018, equation 7.1)

$$M_{RGRAN} = 0.2 * h^{0.45} * M_{RSUPPORT}$$

M_{RGRAN} = 116.014 MPa

Where,

h = thickness of granular layer in mm

M_{RGRAN} = resilient modulus of the granular layer (MPa)

$M_{RSUPPORT}$ = (effective) resilient modulus of the supporting layer (MPa)

3. Resilient modulus of bitumen mixes as per IRC:37-2018, Table 9.2 for a temperature of 35^{0}C and VG40 grade of bitumen is 3000 MPa.

Calculation of Strains:

1. Allowable Horizontal tensile strain (IRC 37: 2018, equation 3.4)

$$N_f = 0.5161\ X\ C \times 10^{-4} \times \left[\frac{1}{\varepsilon_t}\right]^{3.89} \times \left[\frac{1}{M_R}\right]^{0.854}$$

Where,

C = 10^M, and $M = 4.84\ X\ (\frac{Vbe}{Va+Vbe} - 0.69)$

V_a = per cent volume of air void in the mix used in the bottom bituminous layer

V_{be} = per cent volume of effective bitumen in the mix used in the bottom bituminous layer

N_f = fatigue life (standard axles).

M_R = resilient modulus of the bituminous layer.

ε_t = Maximum Tensile strain at the bottom of the bituminous layer.

2. Allowable Vertical compressive strain (IRC 37: 2012, equation 3.2)

$$N_t = 1.41 \times 10^{-8} \times \left[\frac{1}{\varepsilon_v}\right]^{4.53379}$$

Where,

N_t = Number of cumulative standard axles.

ε_v = Vertical strain in the subgrade.

Table 5. 2 Pavement Limiting and Actual Strains

Traffic (msa)	30	75	125
ε_t X (10^{-4}) limiting	1.835	1.443	1.262
ε_v X (10^{-4}) limiting	4.160	3.399	3.037
ε_t X (10^{-4}) actual	1.825	1.706	1.455
ε_v X (10^{-4}) actual	3.021	2.884	2.577

5.2.2 Pavement Thickness Optimization

From Table 5.2 designed pavement is safe for the traffic of 30 msa in both criteria whereas for heavy traffic volumes of 75 and 125 msa pavement strains are safe in rutting criteria but in case of fatigue criteria it fails to deliver the required allowable strains. Therefore, to get the strains under the maximum allowable limit's pavement thickness have been adjusted accordingly using IITPAVE software as shown in Table 5.3.

Table 5. 3 Corrected Thickness for Different Traffic Volumes

Layers	Thickness (mm)		
	30 msa	75 msa	125 msa
Bituminous Concrete	40	55	55
Dense Bituminous Macadam	140	165	185
Granular Base	250	250	250
Granular Subbase	380	380	380
Subgrade	500	500	500
TOTAL THICKNESS (excluding subgrade)	**810**	**850**	**870**

Table 5. 4 Corrected Pavement Strains

Traffic (msa)	30	75	125
ε_t X (10^{-4}) limiting	1.835	1.443	1.262
ε_v X (10^{-4}) limiting	4.160	3.399	3.037
ε_t X (10^{-4}) actual	1.825	1.411	1.254
ε_v X (10^{-4}) actual	3.091	2.521	2.312

Table 5.4 shows that the actual strains in both the criteria falls within the allowable limits hence the design thickness will be as shown is Table 5.3.

5.3 CRUST THICKNESS AS PER IRC:37-2018 FOR 4 % CBR

Required traffic in msa for the calculation of crust thickness is assumed as 30, 75 and 125 and thickness calculated is in accordance of IRC:37-2018. The CBR used is 4% with addition of optimum content of waste plastic fibres.

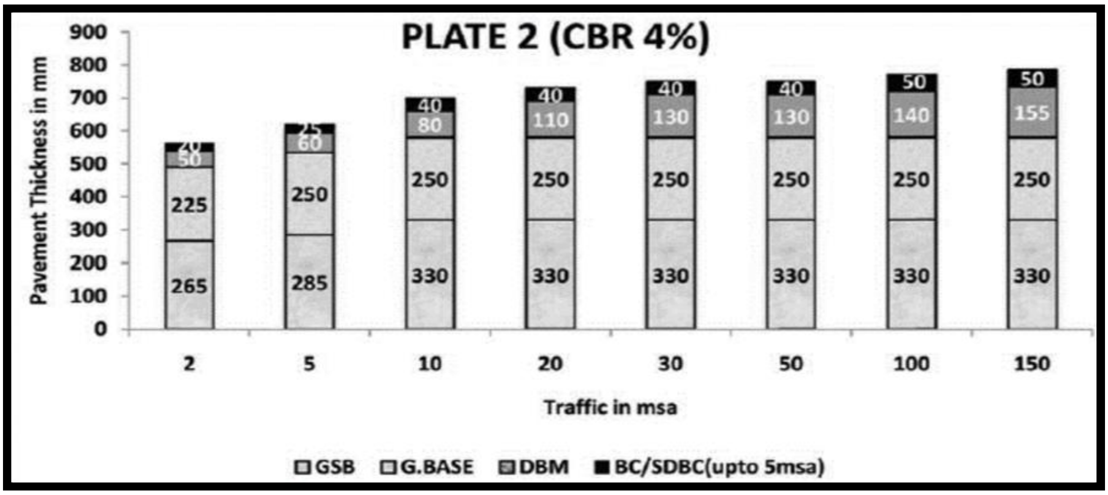

Figure 5.3 IRC:37-2012 Design plate 2

Table 5. 5 Pavement Thicknesses for Different Traffic (msa) From Plate 2

Layers	Thickness (mm) (IRC:37-2012)		
	30 msa	75 msa	125 msa
Bituminous Concrete	40	45	50
Dense Bituminous Macadam	130	135	150
Granular Base	250	250	250
Granular Subbase	330	330	330
Subgrade	500	500	500
TOTAL THICKNESS (excluding subgrade)	**750**	**760**	**780**

5.3.1 Theoretical Calculation of Strains at Critical Location

Calculation of Resilient Modulus (M_{RS}):

Similar to section 5.2.1 the resilient moduli are calculated as follows:

1. Subgrade resilient modulus (M_{RS}) = 40.57 MPa
2. Granular Base course (M_{RGRAN}) = 142.16 MPa
3. Resilient modulus of bitumen mixes as per IRC:37-2012, CL 7.4.2, Table7.1 for a temperature of 35^0 C and VG40 grade of bitumen is 3000 MPa.

Calculation of Strain:

From IRC:37-2018, maximum allowable horizontal tensile strains and maximum allowable vertical compressive strains have been calculated in a similar manner as was done in section 5.2.1 and compared with actual strains calculated using IITPAVE software as shown in Table 5.6.

Table 5. 6 Pavement Allowable and Calculated Strains

Traffic (msa)	30	75	125
$\varepsilon_t \times (10^{-4})$ limiting	1.835	1.443	1.262
$\varepsilon_v \times (10^{-4})$ limiting	4.160	3.399	3.037
$\varepsilon_t \times (10^{-4})$ actual	1.821	1.701	1.495
$\varepsilon_v \times (10^{-4})$ actual	2.883	2.751	2.511

5.3.2 Pavement Thickness Optimization

From Table 5.6 the designed pavement is safe for the traffic of 30 msa in both criteria whereas for heavy traffic volumes of 75 and 125 msa the pavement strains are safe in rutting criteria but in case of fatigue criteria it fails to deliver the required limiting strains. Therefore, to get the strains under the maximum allowable limits the pavement thickness is to be adjusted accordingly using IITPAVE software as shown in Table 5.7.

Table 5. 7 Corrected Thickness for Different Traffic Volumes

Layers	Thickness (mm)		
	30 msa	75 msa	125 msa
Bituminous Concrete	40	50	60
Dense Bituminous Macadam	130	160	175
Granular Base	250	250	250
Granular Subbase	330	300	300
Subgrade	500	500	500
TOTAL THICKNESS (excluding subgrade)	**750**	**760**	**785**

Table 5. 8 Corrected Pavement Strains

Traffic (msa)	30	75	125
ε_t X (10^{-4}) limiting	1.835	1.443	1.262
ε_v X (10^{-4}) limiting	4.160	3.399	3.037
ε_t X (10^{-4}) actual	1.821	1.422	1.225
ε_v X (10^{-4}) actual	2.883	2.527	2.260

Note** By reducing the thickness of GSB from 330 to 300 mm M_{RGRAN} was reduced from 142.160 MPa to 138.802 MPa.

Table 5.8 shows that the calculated strains in both the criteria falls within the allowable limits hence the design thickness have been shown is Table 5.7.

5.4 ANALYSIS OF PAVEMENT DESIGN RESULTS

Table 5.9 – 5.11 shows the crust thickness for different traffic volumes of 30 msa, 75 msa and 125 msa for reinforced and unreinforced soil.

Table 5. 9 Crust Thickness For 30 msa Traffic with Different Percentages of Plastic

Plastic content	0 %	1.5 %
BC	40	40
DBM	140	130
WMM	250	250
GSB	380	330
Total thickness (mm)	**810**	**750**

Table 5. 10 Crust Thickness For 75 msa Traffic with Different Percentages of Plastic

Plastic content	0 %	1.5 %
BC	55	50
DBM	165	160
WMM	250	250
GSB	380	300
Total thickness (mm)	**850**	**760**

Table 5. 11 Crust Thickness For 125 msa Traffic with Different Percentages of Plastic

Plastic content	0 %	1.5 %
BC	55	60
DBM	185	175
WMM	250	250
GSB	380	300
Total thickness (mm)	**870**	**785**

From Table 5.9-5.11 it is evident that for every assumed traffic volume type (30, 75 and 125 msa) the pavement thickness was reduced to a considerable extent when subgrade is reinforced with waste plastic fibres. For 1.5 % waste plastic in case of 30 msa traffic the total thickness is reduced from 810 mm to 750 mm with a reduction of 60 mm. For 1.5 % waste plastic in case of 75 msa traffic the total thickness is reduced from 850 mm to 760 mm with a reduction of 90 mm. For 1.5 % waste plastic in case of 125 msa traffic the total thickness is reduced from 880 mm to 800 mm with a reduction of 85 mm. Also pavement thickness were also designed from the experimentally determined subgrade modulus from LWD as shown in Figure 5.5.

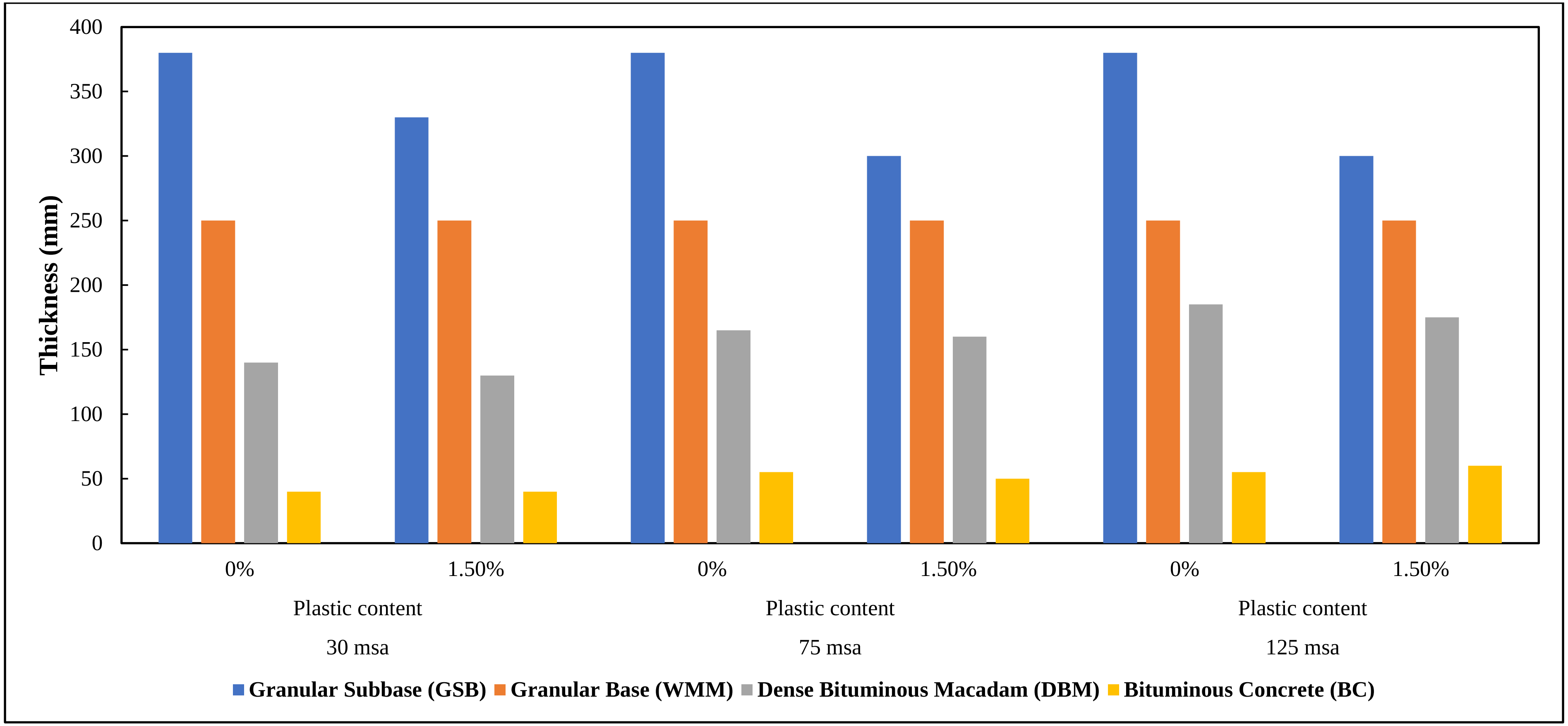

Figure 5.4 Comparative Thickness of Pavement for Reinforced and Unreinforced Section for Different Traffic (msa)

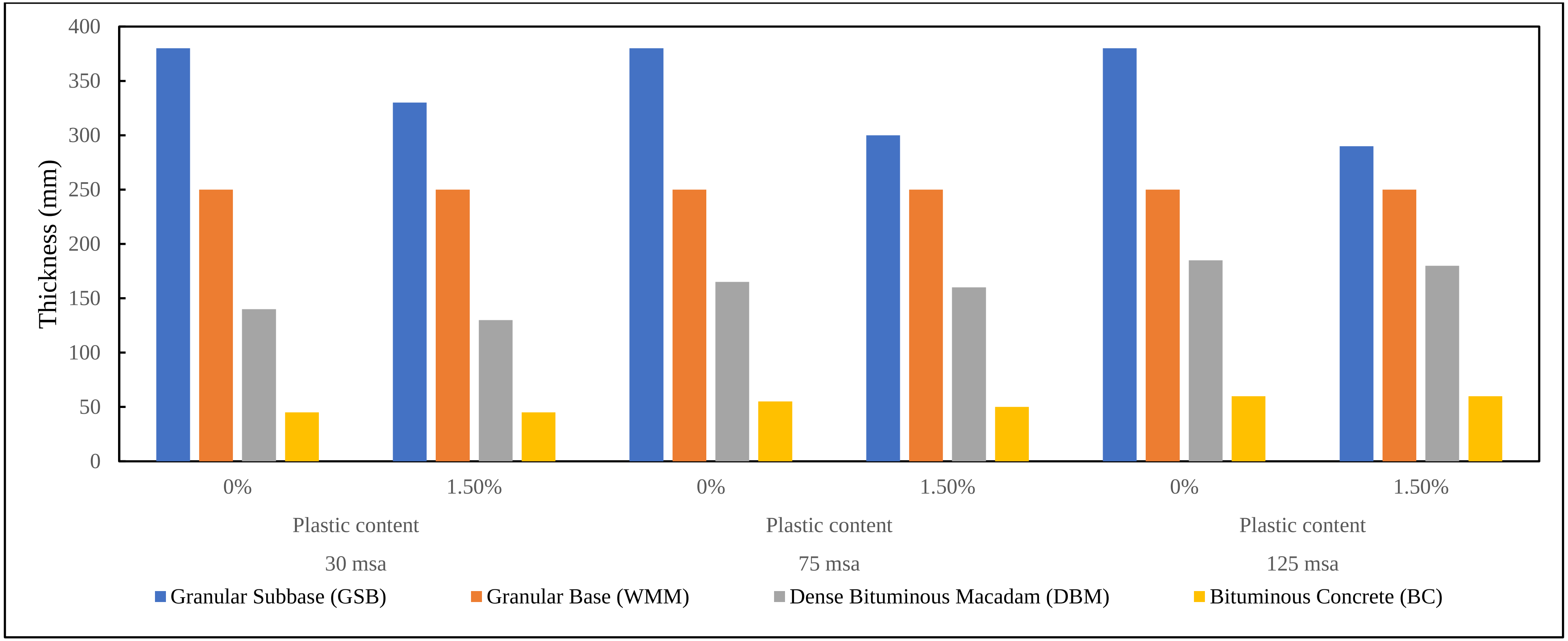

Figure 5.5 Comparative Thickness of Pavement for Reinforced and Unreinforced Section for Different Traffic (msa) Using Subgrade Modulus Determined from LWD

Figure 5.4 shows the Comparative thickness of pavement for reinforced (1.5 %) and unreinforced (0 %) section for different msa. There is a reduction of total pavement thickness of 7.4 % for 30 msa traffic, reduction of 10.58 % for 75 msa traffic and 9.77 % for 125 msa traffic. The maximum reduction was observed with the 75 msa traffic as shown in figure 5.5.

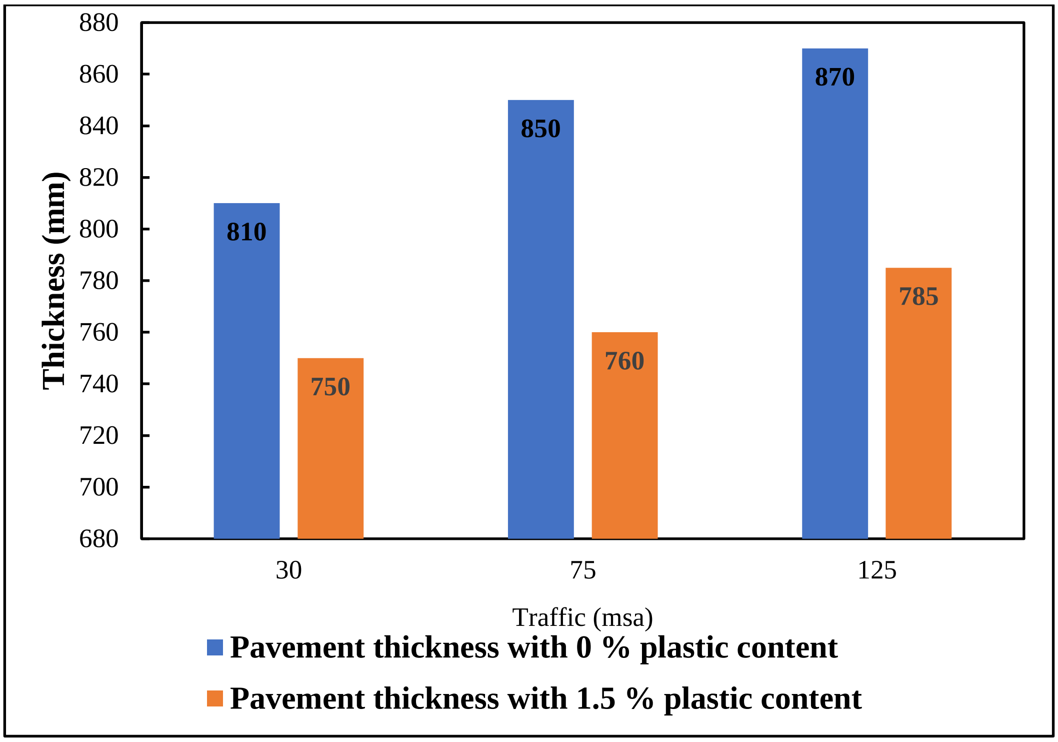

Figure 5.6 Pavement Thickness Comparison

Figure 5.5 shows the comparative thickness of pavement for reinforced (1.5 %) and unreinforced (0 %) section for different traffic volumes using the modulus determined from the LWD conducted on the trial section in the field. The thickness designed were similar to the designed thickness from the modulus derived from the codal provisions of the IRC:37-2018.

Similar was the case with allowable strains and calculated strains i.e. the horizontal tensile strain and vertical compressive strain obtained by software were less than the allowable stains as shown in the figure 5.6.

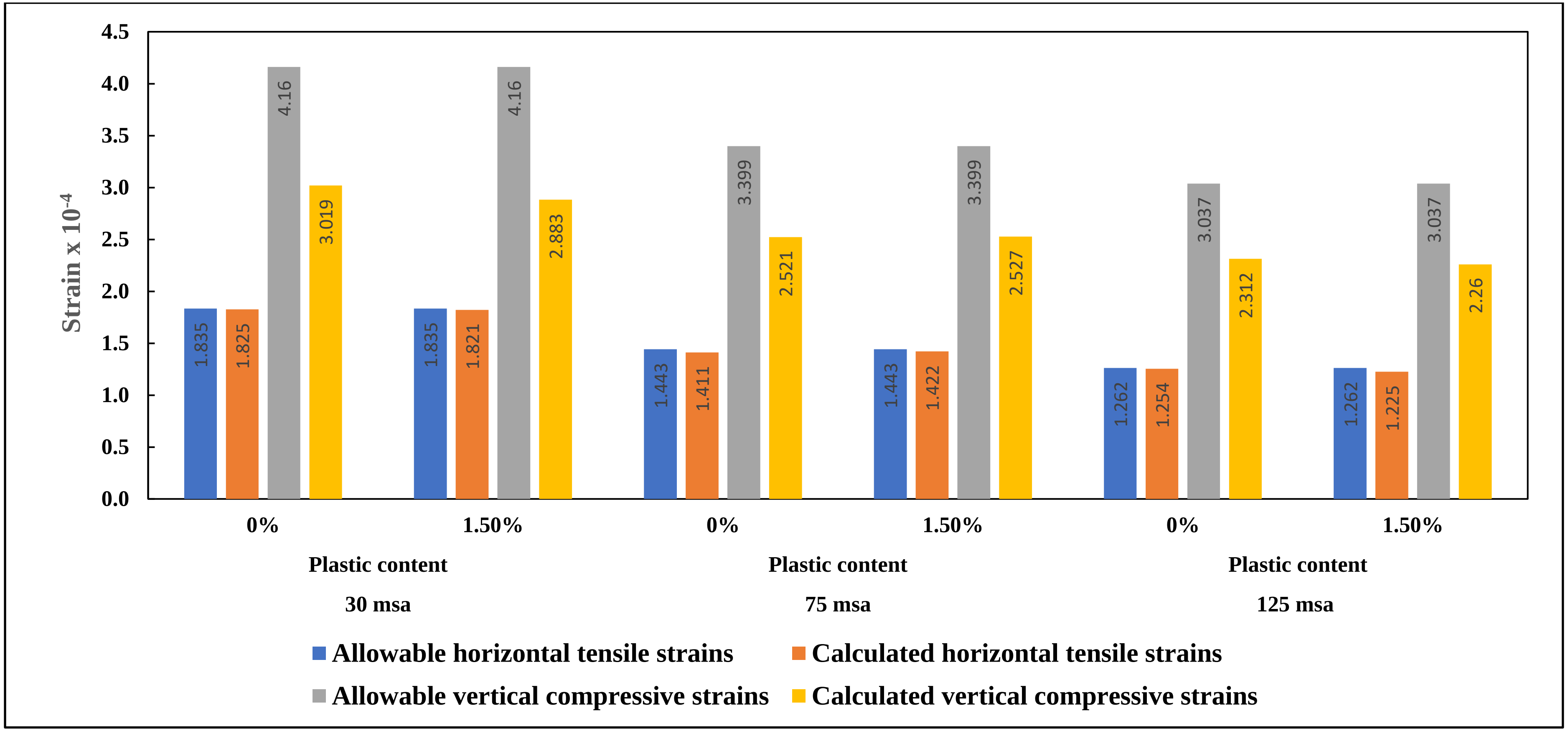

Figure 5.7 Comparison of Allowable Strains with Calculated Strains for Different Traffic

5.4 COST ANALYSIS

Cost analysis has been done for road section of 1 km length, 8.5 m width as shown in Table 5.12. Cost of different layers has been taken from present schedule of rates.

Table 5. 12 Cost Analysis

S. No	Description	Layers (30 msa)	Layer Thickness (mm)	Rate of layer (per cum)	Quantity (cum)	Total cost of layer/km (Rs)
1	Soil sample with 0 % plastic content	BC	40	10944.65	340	3721181
		DBM	140	10064.25	1190	11976457
		G.Base	250	2641.4	2125	5612975
		GSB	380	2517.7	3230	8132171
		Total cost of road per km (Rs)				**2,94,42,785**
2	Soil sample with 1.5 % plastic content	BC	40	10944.65	340	3721181
		DBM	130	10064.25	1105	11120996
		G.Base	250	2641.4	2125	5612975
		GSB	330	2517.7	2805	7062148
		Total cost of road per km (Rs)				**2,75,17,301**
S. No	Description	Layers (75 msa)	Layer Thickness (mm)	Rate of layer (per cum)	Quantity (cum)	Total cost of layer/km (Rs)
1	Soil sample with 0 % plastic content	BC	55	10944.65	467.5	5116623
		DBM	165	10064.25	1402.5	14115110
		G.Base	250	2641.4	2125	5612975
		GSB	380	2517.7	3230	8132171
		Total cost of road per km (Rs)				**3,29,76,881**
2	Soil sample with 1.5 %	BC	50	10944.65	425	4651476
		DBM	160	10064.25	1360	13687380

	plastic	G.Base	250	2641.4	2125	5612975
	content	GSB	300	2517.7	2550	6420135
		Total cost of road per km (Rs)				**3,03,71,966**

S. No	Description	Layers (125 msa)	Layer Thickness (mm)	Rate of layer (per cum)	Quantity (cum)	Total cost of layer/km (Rs)
1	Soil sample with 0 % plastic content	BC	55	10944.65	467.5	5116623
		DBM	185	10064.25	1572.5	15826033
		G.Base	250	2641.4	2125	5612975
		GSB	380	2517.7	3230	8132171
		Total cost of road per km (Rs)				**3,46,87,803**
2	Soil sample with 1.5 % plastic content	BC	60	10944.65	510	5581771
		DBM	175	10064.25	1487.5	14970571
		G.Base	250	2641.4	2125	5612975
		GSB	300	2517.7	2550	6420135
		Total cost of road per km (Rs)				**3,25,85,453**

From Table 5.12 it was observed that the pavement construction cost is reduced by 6.54 % for 30 msa traffic ,7.89 % for 75 msa traffic & 6.06 % for 125 msa traffic for four lane divided carriageway when the subgrade is reinforced with waste plastic Fibres.

CHAPTER-6

CONCLUSION

The objective of this project entitled" Effect of addition of Plastic Fibres on subgrade strength characteristics for a Flexible Pavement" was to determine the influence of plastic addition on strength characteristics of fine-grained subgrade soil. From the conducted experiments following conclusions can be made:

- With the increase in plastic content (up to 1.5%) there is no significant change observed in either the OMC or the MDD.
- The maximum improvement in CBR is obtained while using 1.5% plastics content i.e. 4.01 %.
- The CBR value at 2% and 3% plastic content were found to be even less than the CBR of base soil.
- The maximum CBR value of modified soil is approximately 1.3 times that of base soil
- The difference between theoretical value of subgrade resilient modulus and LWD modulus derived from the trial sections in the field is 4% for base virgin soil and 6% for reinforced soil.
- The pavement thickness is optimized by maximum of 10.58 % for traffic of 75 msa, 9.77 % for traffic of 125 msa and least for the traffic of 30 msa by 7.4 %.
- Total cost of 7.89 % was reduced for the traffic of 75 msa which was observed to be more when compared to 30 msa and 125 msa traffic.

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