EFFECT OF WASTE PLASTIC ON THE STRENGTH CHARACTERISTICS OF THE SUBGRADE FOR THE FLEXIBLE PAVEMENT

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DECLARATION

I, Kartik jindal, hereby declare that this thesis entitled **"Effect of Waste Plastic on the Strength Characteristics of the Subgrade for the Flexible Pavement"** is an authentic record of my study carried out as requirements for the award of degree of **Master of Engineering** in **Infrastructure Engineering** in the Civil Engineering Department, Thapar University, Patiala under the supervision of **Mr. Rajesh Pathak, Associate Professor and Mr. Tanuj Chopra, Assistant Professor,** Department of Civil Engineering, Thapar University, Patiala during July 2012 to July 2014 . This matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

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CERTIFICATE

This is to certify that above statement made by the student concerned is correct and true to the best of my knowledge and belief.

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ABSTRACT

The Biggest challenge in a developing country like India is to build a full network of road system with limited financial source available. Use of local materials can considerably lower down the construction cost. If the stability of local soil is not adequate for supporting wheel loads, the properties are improved by soil stabilization techniques e.g. use of geogrids, using randomly distributed fiber, or waste plastic in the subgrade soil, this can help in improving strength of subgrade. Research has been done in this area to improve engineering performance of subgrade soil by adding different types of waste plastic content.

In this study different types of waste plastic were randomly mixed with the soil, then a series of California Bearing Ratio (CBR) tests were conducted to evaluate the strength of subgrade soil. High density polyethylene (HDPE), Low density polyethylene (LDPE) and Polypropylene (PP) at various percentages were used for improving soil strength. Results from the CBR tests established that addition of these materials in subgrade soil gives efficient strength to subgrade soil. It was observed that the CBR value increases with increase in fiber content upto a certain percentage but decreases with further addition of waste plastic content.

The pavement sections has been designed with the modified subgrade using HDPE, LDPE & PP and the critical strain values at the top of the subgrade and at the bottom of the bituminous layer has been analysed and compared with the allowable values as per IRC: 37-2012 for the traffic loading of 150 msa for the four lane divided state highway project. The reduction in the crust thickness and saving in the project cost has been compared for the different subgrade with different waste plastics and by varying plastic contents.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER – 1

INTRODUCTION

In developing countries like India, the biggest handicap to provide a complete network of road system is the limited finances available to build roads. Use of local materials, including local soils, can considerably lower down the construction cost. If the stability of local soil is not adequate for supporting wheel loads, the properties are improved by soil stabilization techniques. The stabilization of soil for use in subgrade for pavement is an economic substitute of costly paving materials. There are many techniques for soil stabilization either mechanical or chemical, but all of them require skilled manpower and equipment to ensure adequate performance.

Randomly distributed fibre, when used an insertion in highway subgrade, can produce a high performance in the stabilization of weak roads. Many investigators have used various types of fibres under different test conditions. The most important findings of the previous research work is that the use of certain fibre, such as synthetic and natural, in road construction can significantly increase pavement resistant to rutting as compared to the resistance of non stabilized pavement over a weak subgrade. Permanent deformation in each layer is the indicator of rut formation at the road surface. Consequently this is used as a criterion of pavement performance. However, it is difficult to comprehensively include permanent deformation. There are problems in assessing the contribution made by each individual layer to the total rut depth visible at the pavement surface. Hence, the deformation that appears at the surface of a pavement is the sum of deformation of each of the pavement layers, together with that in the subgrade

1.1 Definition

The standard fiber-reinforced soil is defined as a soil mass that contains randomly distributed, discrete elements, i.e. fibers, which provide an improvement in the mechanical behavior of the soil composite. Fiber reinforced soil behaves as a composite material in which fibers of relatively high tensile strength are embedded in a matrix of soil. Shear stresses in the soil mobilize tensile resistance in the fibers, which in turn imparts greater strength to the soil.

1.2 Classification of Fibre

There are two types of fibre i.e. natural and synthetic (man made fibre)

1.2.1 Natural fibres

At the present time, there is a greater awareness that landfills are filling up, resources are being used up, the planet is being polluted and that non-renewable resources will not last forever. So, there is a need to have more environmentally friendly materials. That is why there have been many experimental investigations and a great deal of interest has been created worldwide on potential applications of natural fibers for soil reinforcement in recent years. The term ''eco-composite'' shows the important role of natural fibers in the modern industry. Mainly, what part of the plant the fiber came from, the age of the plant; and how the fiber was isolated, are some of the factors which affect the performance of natural fibers in a natural fibre reinforced soil. It is necessary to mention that natural fibres have been used for a long time in many developing countries in cement composites and earth blocks because of their availability and low cost. At this point, some natural fibres and their features in soil projects are briefly described

(i) Coconut (coir) fibre

The outer covering of fibrous material of a matured coconut, termed coconut husk, is the reject of coconut fruit. The fibres are normally 50–350 mm long and consist mainly of lignin, tannin, cellulose, pectin and other water soluble substances. However, due to its high lignin content, coir degradation takes place much more slowly than in other natural fibres. So, the fibre is also very long lasting, with infield service life of 4–10 years. The water absorption of that is about 130–180% and diameter is about 0.1–0.6 mm .Coir retains much of its tensile strength when wet. It has low tenacity but the elongation is much higher. The degradation of coir depends on the medium of embedment, the climatic conditions and is found to retain 80% of its tensile strength after 6 months of embedment in clay. Coir geo-textiles are presently available with wide ranges of properties which can be economically utilized for temporary reinforcement purposes. Mainly, coir fibre shows better resilient response against synthetic fibres by higher coefficient of friction.

(ii) Sisal fibre

Sisal is a lingo-cellulosed fibre in which its traditional use is as reinforcement for gypsum plaster sheets in building industry with 60–70% of water absorption and diameter about 0.06– 0.4 mm. Sisal fibres are extracted from the leaves of the plants, which vary in size, between 6–10 cm in width and 50–250 cm in length. In general, Brazil, Indonesia and East African countries are the world's main producers of sisal fibres

(iii) Palm fibre

The palm fibres in date production have filament textures with special properties such as low costs, plenitude in the region, durability, lightweight, tension capacity and relative strength against deterioration. Fibres extracted from decomposed palm trees are found to be brittle, having low tensile strength and modulus of elasticity and very high water absorption.

(iv) Jute fibre

Jute is abundantly grown in Bangladesh, China, India and Thailand. Jute fibres are extracted from the fibrous bark of jute plants which grow as tall as 2.5 m with the base stem diameter of around 25 mm. There are different varieties of jute fibres with varying properties. Jute is mainly environmental-friendly fibre that is used for producing porous textiles which are widely used for filtration, drainage, and soil stabilization. For instance, geojute is the commercial name of a product woven from jute fibres used for soil stabilization in pavement engineering

(v) Flax fibre

Flax is probably the oldest textile fibre known to mankind. It has been used for the production of linen cloth since ancient times. Flax is a slender, blue flowered plant grown for its fibres and seeds in many parts of the world.

(vi) Barely straw

Barley straw is widely cultivated and harvested once or twice annually in almost all rural areas in all over the world and could be used in producing composite soil blocks with better characteristics but relatively few published data is available on its performance as reinforcement to soil or earth blocks. It is important to know that during the Egyptian times, straws or horsehairs were added to mud bricks, while straw mats were used as reinforcements in early Chinese and Japanese housing construction. From the late 1800s, straw was also used in the United States as bearing wall elements. Barely straw is claimed to be the most cost-effective much practice to retain soil in artificial rainfall tests.

(vii) Bamboo fibre

Bamboo fibre is a regenerated cellulose fibre. It is a common fact that bamboo can thrive naturally without using any pesticide. The fibre is seldom eaten by pests or infected by pathogens. So, scientists found that bamboo owns a unique anti-bacteria and bacteriostatic bio-agent named ‘‘Bamboo Kun’’. It is important to know that the root rhizomes of bamboo are excellent soil binders which can prevent erosion. Bamboo fibres are remarkably strong in tension but have low modulus of elasticity about 33–40 KN/mm^2 and high water absorption about 40–45%.

(viii) Cane fibre

Cane or sugarcane belongs to grass family and grows up to 6 m high and has a diameter up to 6 cm and bagasse is the fibrous residue which is obtained in sugarcane production after extraction of the juice from the cane stalk. The fibre diameter is up to 0.2– 0.4 mm. However, waste cane fibre has limited use in most typical waste fibre applications because of the residual sugars and limited structural properties within the fibre. But, the residual sugars can result a detrimental impact on the finished product, i.e. a stiffer bonding phase generates in the composite structure.

1.2.2 Synthetic (man-made) fibres

i) Polypropylene (PP) fibres

It is the most widely used inclusion in the laboratory testing of soil reinforcement. Currently, PP fibres are used to enhance the soil strength properties, to reduce the shrinkage properties and to overcome chemical and biological degradation.

ii) Polyester (PET) fibres

Polyesters include naturally occurring chemicals, such as in the cutting of plant cuticles, as well as synthetics through step-growth polymerization such as polycarbonate and polybutyrate. Natural polyesters and a few synthetic ones are biodegradable, but most synthetic polyesters are not. Depending on the chemical structure, polyester can be a thermoplastic or thermoset, there are also polyester resins cured by hardeners; however, the most common polyesters are thermoplastics.

iii) Polyethylene (PE) fibres

It is a subset of the thermoplastic polyethylene. Also known as high-modulus polyethylene, (HMPE), or high-performance polyethylene (HPPE), it has extremely long chains, with a molecular mass usually between 2 and 6 million u. The longer chain serves to transfer load more effectively to the polymer backbone by strengthening intermolecular interactions. This result in a very tough material, with the highest impact strength of any thermoplastic presently made.

iv) Glass fibres

It is a material consisting of numerous extremely fine fibres of glass. Glassmakers throughout history have experimented with glass fibres, but mass manufacture of glass fibre was only made possible with the invention of finer machine tooling. Glass fibre has roughly comparable properties to other fibres such as polymers and carbon fibre. Although not as strong or as rigid as carbon fibre, it is much cheaper and significantly less brittle.

v) Nylon fibres

Nylon is one of the most commonly used polymers. Nylon is a generic designation for a family of synthetic polymers known generically as polyamides.

vi) Polyvinyl alcohol (PVA) fibres

Polyvinyl alcohol (PVA) fibre is a synthetic fibre that has recently been used in fibre-reinforced concrete, since its weather resistance, chemical resistance (especially alkaline resistance), and tensile strength are superior to that of PP fiber. PVA fibre has a significantly lower shrinkage from heat than nylon and/or polyester.

1.3 Outline of Thesis

In this study different types of waste plastic material (i.e. High density Polyethylene, Low density Polyethylene, Polypropylene etc.) were used which are generally available from Rag pickers. Various engineering properties were studied on the locally available soil. A series of CBR tests were conducted on soil reinforced with waste plastic content ranging from 1% to 9 % (HDPE,LDPE,PP).After getting improved CBR values, possible changes in the design of flexible pavements were studied. The thesis has been divided into six chapters:

- Ist chapter is about General introduction of fibres and their classification.
- 2nd chapter is about the thorough literature review on use of natural fibre, synthetic fibre, waste plastic for improving strength of subgrade soil.
- 3rd chapter deals with the experimental programme wherein all test procedures are explained in detail.
- 4th chapter deals with the results and discussions where findings of experimental programme are discussed.
- 5th chapter includes the design of flexible pavement.
- 6th chapter is a concluding chapter.

CHAPTER-2
LITERATURE REVIEW

2.1 Literature Review on Natural Fibre

Ghavami et al. (1999) found that inclusion of 4% sisal, or coconut fiber, imparted considerable ductility and slightly increased the compressive strength. It was also found that introduction of bitumen emulsion did not improve the bonding between the soil and fibers; but did significantly improve soil durability.

Prabakar and Siridihar (2002) used 0.25%, 0.5%, 0.75% and 1% of sisal fibers by weight of raw soil with four different lengths of 10, 15, 20 and 25 mm to reinforce a local problematic soil. They concluded that sisal fibers reduce the dry density of the soil. The increase in the fiber length and fiber content also reduces the dry density of the soil. As well it was found that the shear stress is increased non-linearly with increase in length of fiber up to 20 mm and beyond, where an increase in length reduces the shear stress. The percentage of fiber content also improves the shear strength. But beyond 0.75% fiber content, the shear stress reduces with increase in fiber content.

Ravishankar and Raghavan (2004) confirmed that for coir-stabilized lateritic soils, the maximum dry density (MDD) of the soil decreases with addition of coir and the value of optimum moisture content (OMC) of the soil increases with an increase in percentage of coir. The compressive strength of the composite soil increases up to 1% of coir content and further increase in coir quantity results in the reduction of the values. The percentage of water absorption increases with an increase in the percentage of coir. Tensile strength of coir-reinforced soil (oven dry samples) increases with an increase in the percentage of coir.

Bouhicha et al. (2005) proved the positive effects of adding straw in decreasing shrinkage, reducing the curing time and enhancing compressive strength if an optimized reinforcement ratio is used. Flexural and shear strengths were also increased and a more ductile failure was obtained with the reinforced specimen. A mixture of barely straw with cement can form a sustainable low-cost building material, which also reduces atmospheric pollution. In addition to these benefits, the straw could act as a thermal insulation material for the unpleasant weather conditions to create pleasant indoor temperatures.

Khedari et al. (2005) introduced a new type of soil–cement block reinforced with coir fibers with low thermal conductivity. Black cotton soil treated with 4% lime and reinforced with coir fiber shows ductility behavior before and after failure. An optimum fiber content of 1% (by weight) with aspect ratio of 20 for fiber was recommended for strengthening the black cotton soil.

Segetin et al. (2007) improved the ductility of the soil–cement composite with the addition of flax fibers. An enamel paint coating was applied to the fiber surface to increase its interfacial bond strength with the soil. Fiber length of 85 mm along with fiber content levels of 0.6% was recommended by the authors. ‘‘Uku’’ is a low-cost flax fiber-reinforced stabilized rammed earth walled housing system that has been recently designed as a building material. In this way, a mobile flax machine is used enabling the fast and mobile processing of flax leaves into flax fibers.

Ahmad et al. (2010) mixed palm fibers with silty sand soil to investigate the increase of shear strength during triaxial compression. The specimens were tested with 0.25% and 0.5% content of palm fibers of different lengths (i.e. 15 mm, 30 mm and 45 mm). Reinforced silty sand containing 0.5% coated fibers of 30 mm length exhibited approximately 25% increase in friction angle and 35% in cohesion compared to those of unreinforced silty sand. In addition, palm fibres coated with acrylic butadiene styrene thermoplastic increased the shear strength of silty sand much more compared to uncoated fibres.

Aggarwal and Sharma (2010) used different lengths (5–20 mm) of jute fibers in different percentages (0.2–1.0%) to reinforce soil. Bitumen was used for coating fibers to protect them from microbial attack and degradation. They concluded that jute fiber reduces the MDD while increases the OMC. Maximum CBR value is observed with 10 mm long and 0.8% jute fiber, an increase of more than 2.5 times of the plain soil CBR value.

Sallehan and Yaacob (2011) found that the addition of 3% palm fibers improve the compressive strength of composite bricks. Water absorption test results indicated a small increase in water absorption with the increase in the palm fiber content.

2.2 Literature Review on Synthetic Fibre

Puppala and Musenda (2000) indicated that PP fibre reinforcement enhanced the unconfined compressive strength (UCS) of the soil and reduced both volumetric shrinkage strains and swell pressures of the expansive clays.

Gosavi et al. (2000) reported that by mixing nylon fibers and jute fibres, the CBR value of soil is enhanced by about 50% of that of unreinforced soil, whereas coconut fiber increases the value by as high as 96%. The optimum quantity of fiber to be mixed with soil is found to be 0.75% and any addition of fiber beyond this quantity does not have any significant increase in the CBR value.

Consoli et al. (2003) investigated the load–settlement response carried out on a thick homogeneous stratum of compacted sandy soil reinforced with PP fibres. The PP-reinforced specimens showed a marked hardening behavior up to the end of the tests, at axial strains larger than 20%, whereas the non-reinforced specimens demonstrated an almost perfectly plastic behavior at large strain. This improvement suggests the potential application of fiber reinforcement in shallow foundations, embankments over soft soils, and other earthworks that may suffer excessive deformation.

Consoli et al. (2004) indicated that inclusion of glass fibers in silty sand effectively improves peak strength. They examined the effect of PP, PET and glass fibers on the mechanical behavior of fiber-reinforced cemented soils. Their results showed that the inclusion of PP fiber significantly improved the brittle behavior of cemented soils, whereas the deviator stresses at failure slightly decreased. Unlike the case of PP fiber, the inclusion of PET and glass fibers slightly increased the deviator stresses at failure and slightly reduced the brittleness.

Murray et al. (2004) conducted a laboratory test program to evaluate the properties of nylon carpet waste fiber reinforced sandy silt soil. Increasing the triaxial compressive strength by 204% with 3% carpet fibers and ductility of soil were reported by the authors. Also field trials have showed that shredded carpet waste fibers (to 70 mm long) can be blended into soil with conventional equipment. The availability of low cost fibers from carpet waste could lead to wider use of fiber reinforced soil and more cost-effective construction. But this improvement is not compared with the case of using other types of fibers.

Kumar et al. (2006) tested highly compressible clay in UCS test with 0%, 0.5%, 1.0%, 1.5% and 2.0% flat and crimped polyester fibers. Three lengths of 3 mm, 6 mm and 12 mm were chosen for flat fibres, while crimped fibers were cut to 3 mm long. The results indicate that as the fiber length and/or fiber content increases, the UCS value will improve**.**

Kim et al. (2008) used PE waste fishing net (0%, 0.25%, 0.5%, 0.75%, and 1%) to reinforce lightweight soil derived from dredging process. They found that the maximum increase in compressive strength was obtained for a waste fishing net content of about 0.25%.

Park et al. (2009) found that the addition of 1% polyvinyl alcohol (PVA) fiber to 4% cemented sand resulted in a two times increase in both the UCS and the axial strain at peak strength when compared to non-fiber-reinforced specimen. As well, Park reported that at 1% fiber dosage, the values of ductility are greater than four, regardless of cement ratios.

Choudhary et al. (2010) reported that the addition of reclaimed HDPE strips to local sand increases the CBR value and secant modulus. The maximum improvement in CBR and secant modulus is obtained when the strip content is 4% with the aspect ratio of 3, approximately three times that of an unreinforced system.

Zaimoglu (2010) found that the mass loss in PP reinforced soils (12 mm, 0.75% of total dry soil) was almost 50% lower than that in the un-reinforced soil. It was also illustrated that the unconfined compressive strength of specimens subjected to freezing–thawing cycles generally increased with the increasing fiber content.

Ghazavi and Roustaie (2010) showed that the addition of 3% polypropylene fibers (12 mm) results in the increase of UCS of the soil before and after applying freeze - thaw cycles by 60 -160% and decrease of frost heave by 70%.

Tang et al. (2010) investigated the micromechanical interaction behavior between soil particles and reinforcing PP fibers. They concluded that the interfacial shear resistance of fiber/soil depends primarily on the rearrangement resistance of soil particles, effective interface contact area, fiber surface roughness and soil composition. As well, a soil–fiber pull out test apparatus was made by the authors.

Maheshwari (2011) mixed polyester fibers of 12 mm in length with highly compressible clayey soil vary from 0% to 1%. The results indicated that reinforcement of highly compressible clayey soil with randomly distributed fibers caused an increase in the ultimate bearing capacity and decrease in settlement at the ultimate load. They concluded that the soil bearing capacity and the safe bearing pressure (SBP) both increase with increase in fiber content up to 0.50% and then it decreases with further inclusion of fibres. Japanese scientists have been found that short PET fiber (64 mm) reinforced soil had high piping resistance, and that the short fiber reinforced soil layer increased the stability of levee against seepage of rainfall and flood.

2.3 Literature Review on Fibre Reinforced Subgrade

Mehndiratta et al (2005) presents the effect of inclusion of polypropylene fibres with fly ash. Laboratory CBR tests, triaxial shear tests, plate load and field CBR tests were carried out to investigate the effect of fibre inclusion on the strength behavior of fly ash. Tests were conducted on fly ash with different percentages of polypropylene fibres. Laboratory CBR tests were conducted on fly ash in both soaked and unsoaked conditions.

The CBR value of fly ash increases with increase in fibre content in both soaked and unsoaked conditions as shown in Figure. 2.1. The percentage increase in CBR value is higher at lower percentage of fibre content in Table 2.1. Triaxial tests were conducted at optimum moisture content with 0.7 kg/cm², 1.2 kg/cm² and 1.8 kg/cm² confining pressures. Based on the CBR values and shear strength parameters, 0.5% fibre content is seen to be the optimum. Plate load and field CBR tests were conducted on fly ash and fly ash with 0.5% fibre content. The addition of fibre to fly ash shows significant improvement in CBR value, angle of internal friction and modulus subgrade reaction. Variation of major principal stress at failure with different confining pressures and fibre contents are shown in Figure. 2.2 and Table 2.2.

Table 2.1: **Percentage increase in CBR values of fly ash for unsoaked condition compared to soaked condition *(Mehndiratta et al 2005)***

Fibre content %	CBR values %		Increase in CBR, value %
	Soaked condition	Unsoaked condition	
0.0	8.57	29.52	244.40
0.5	31.50	44.76	42.09
1.0	36.66	54.28	48.00
1.5	39.00	59.00	51.28
2.0	39.00	62.80	61.00

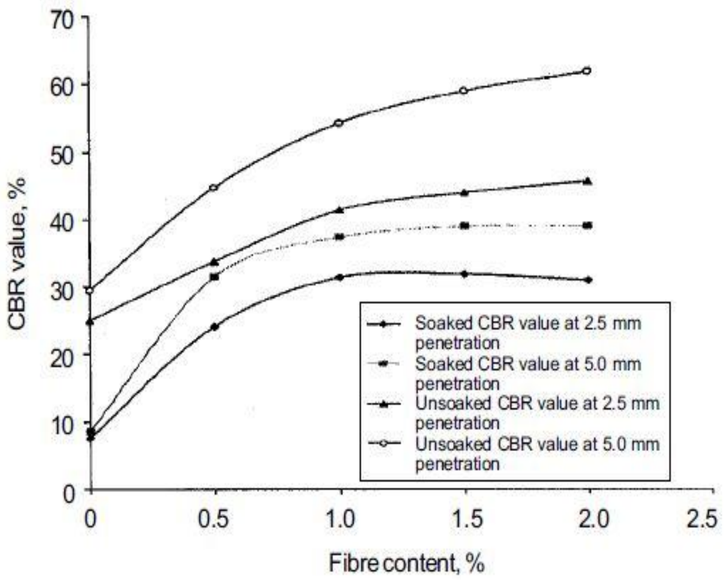


Figure 2.1: **Variation of CBR of fly ash with fibre content for soaked and unsoaked conditions *(Mehndiratta et al 2005)***

Table 2.2: **Variation of major principal stress at failure with fibre content and confining pressure *(Mehndiratta et al 2005)***

Fibre content, %	Major principal stress at failure, kg/cm^2 at confining pressure, kg/cm^2		
	0.70	1.20	1.80
0.0	4.50	5.95	7.50
0.5	4.90	7.45	9.30
1.0	5.45	8.05	10.80
1.5	5.85	8.70	12.10
2.0	7.00	9.20	13.90

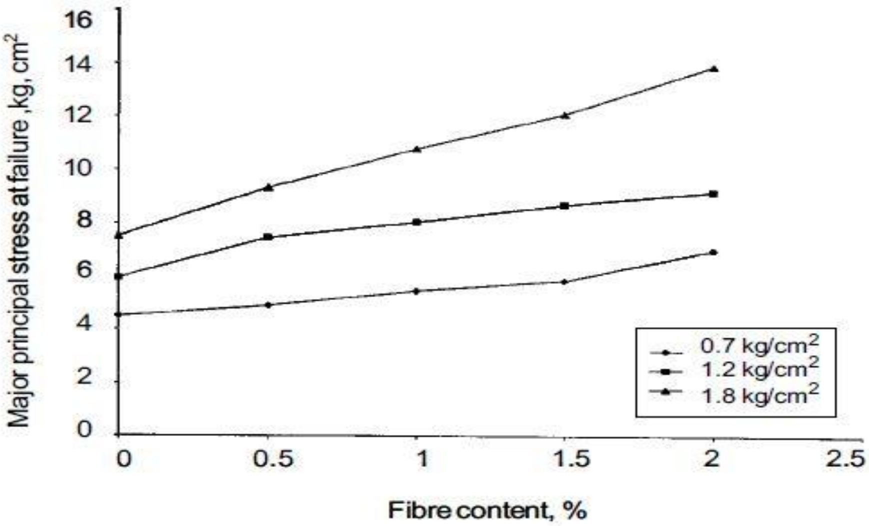


Figure 2.2 **Variation of major principal stress at failure with different confining pressures and fibre contents (*Mehndiratta et al (2005)*)**

Kumar et al. (2006) studied admixtures and geogrids are frequently used in practice to stabilize soils and to improve their load carrying capacity. In this study, polyester fibers were mixed with soft clay soil to investigate the relative strength gain in terms of unconfined compression. Samples were tested in unconfined compression with 0%, 0.5%, 1.0%, 1.5% and 2.0% plain and crimped polyester fibres. The results presented show that the degree of compaction affected the relative benefits of fiber reinforcement for the subject soil. Samples compacted after mixing various proportions of sand into clay (varying from 0% to 12% of clay) was also tested. It was observed that unconfined compressive strength of clay increases with the addition of fibers and it further increases when fibers are mixed in clay sand mixture. Verification tests performed revealed that even though the fibers were randomly oriented, tests results can be reproduced with reasonable accuracy. Cut length of polyester fibre is 3,6,12 mm plain and 6 mm crimped.

Chauhan et al. (2008) studied the effectiveness of fibre reinforcement (coir fibre and synthetic fibre) in subgrade soil has been studied from the point of view of strength. The permanent strain, resilient strain behavior and resilient modulus of subgrade soil have been determined in the laboratory. A value of 10% (20 mm) strain is taken as the failure criterion for the subgrade for pavement in rural area. A subgrade soil of silty sand mixed with optimum content of fly ash and two different types of fibres varying in their tensile strength and coefficient of frictions were used. Repeated triaxial tests on samples, unreinforced and reinforced at the optimum content of fibre, were carried out at a confining pressure of 25, 50 and 75 kN/m² and the stress levels of 153 and 204 kN/m², producing six different deviator stresses. It is concluded from this study that both the permanent and resilient strains in all materials decrease with confining pressure but increase with the number of load cycles and deviator stress in reinforced and unreinforced conditions. Further, the resilient modulus decreases with the number of load cycles and deviator stress increases with the confining pressure. Coir fibre shows better resilient response against synthetic fibre by higher coefficient of friction. Fly ash is also used in this study and for maximum dry density, the 30% fly ash and 70% sand mix is tested for various parameters. Aspect ratio L/d of fibre is 400. Table 2.3 gives value of deviator stress at failure for different test conditions. Figure. 2.3 shows typical stress–strain plots for 70% silty sand (SM) +30% fly ash at confining pressure of 50 kN/m² under different reinforcement conditions.

Table2.3: **Deviator stress (kN/m²) at failure on 70 % silty sand (SM) + 30 % fly ash for different test conditions (*Chauhan et al. 2008)***

Deviator stress (kN/m²) at failure on 70 % silty sand (SM) + 30 % fly ash for different test conditions			
	Deviator stress (kN/m²)		
Test condition			
Confining stress (kN/m²)	25	50	75
70 % Silty sand + 30 % fly ash	720	1441	1976
70 % Silty sand + 30 % fly ash + synthetic fibre	984	1968	2657
70 % Silty sand + 30 % fly ash + coir fibre	1166	2332	3148

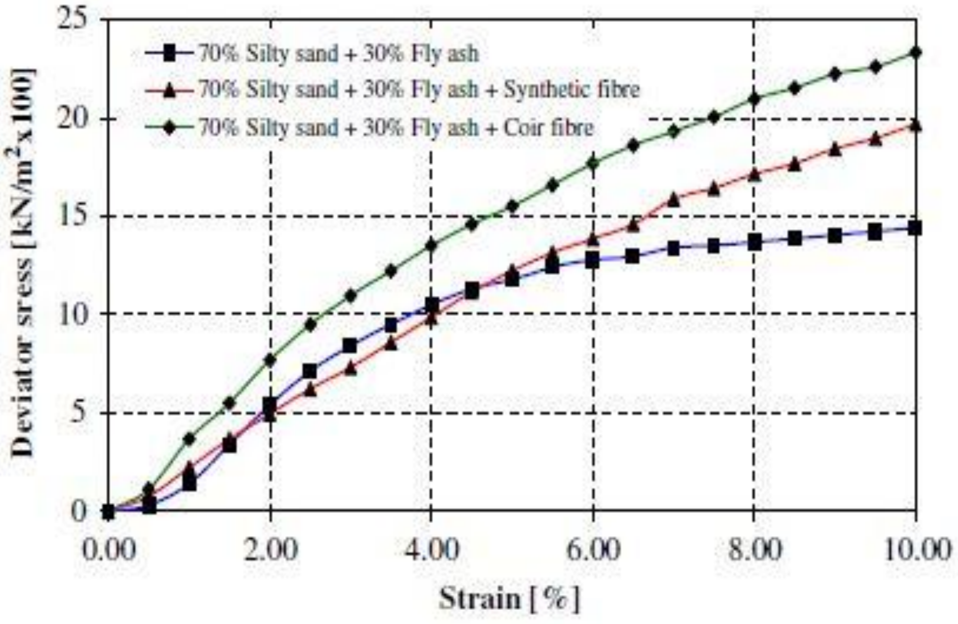


Figure 2.3: **Typical stress–strain plots for 70% silty sand (SM) +30% fly ash at confining pressure of 50 kN/m² under different reinforcement conditions (*Chauhan et al. 2008).***

Rao et al. (2010) studies strengthening of soil subgrade with polymeric reinforcements was carried out. Polyester fibres with two aspect ratios in the range of 150-200 and 300-400 were used in the study.CBR tests were conducted in accordance with IS 2720 Part 16: 1987 on the locally available soil. Soil was reinforced with two different types of fibres and CBR values were ascertained.

While performing direct shear test, the results reveal that cohesion value increases, mean while angle of internal friction decreases and then increases as shown in Figure 2.4-2.6. The results reveal that the inclusion of fiber reinforcement in the soil subgrade enhances the CBR as can be seen in Figure. 2.7. The addition of 1% polyester fiber of aspect ratios (AR) 200 & 400 increases the CBR by 1.54 and 1.25 times respectively than the unreinforced soil samples. Diameter 0.03 to 0.04 mm and length 6 and 12mm of fibre were used.

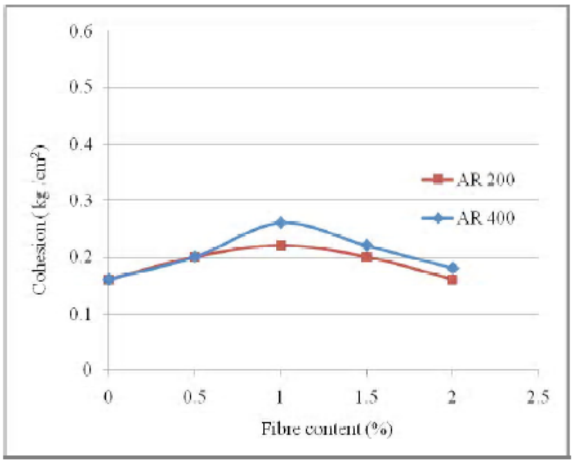


Fig2.4: **Variations of Cohesion with Fibre Content (*Rao et al. 2010)***

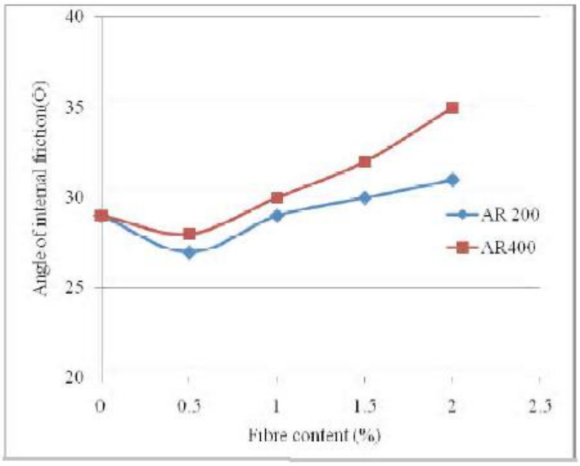


Fig2.5: **Angle of Internal Friction vs. Fibre Content *(Rao et al. 2010)***

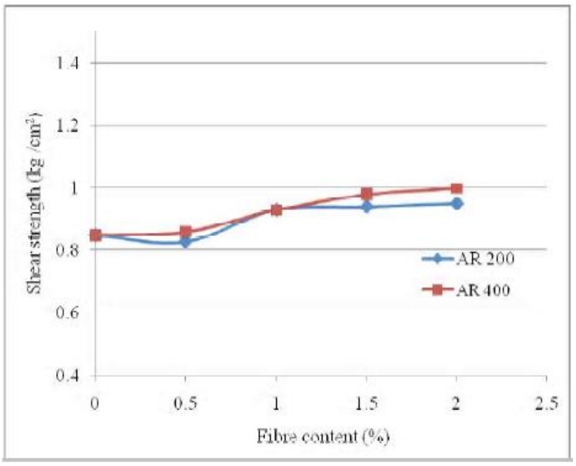


Fig. 2.6: **Shear Strength vs. Fibre Content (*Rao et al. 2010)***

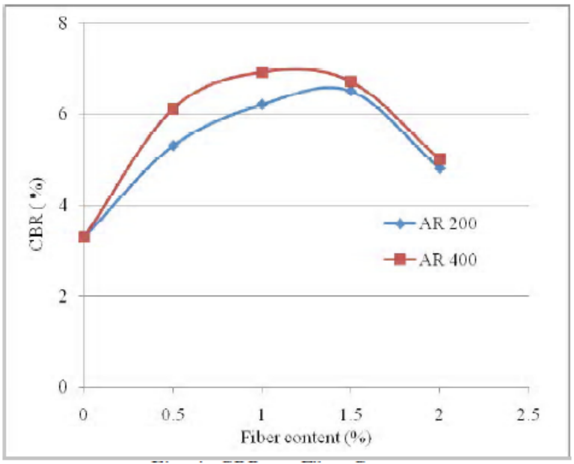


Fig.2. 7: **CBR vs. Fibre Content (*Rao et al. 2010)***

Kamel et al. (2011) presents a comparative laboratory study for optimization and quantification of the beneficial effects of stabilization of subgrade soils in flexible pavement systems. Two types of soils namely inorganic silt and clayey sand were selected. A total of six different groups of stabilizers were added to the two soils. They are, cement, lime, a mixture of cement and polystyrene fibers, a mixture of lime and polystyrene fibers, a mixture of lime and fly ash and finally a mixture of lime, cement and fly ash. Unconfined compressive strength tests were performed on all combinations of variable ratios of stabilizers to evaluate the unconfined compressive strength and the moduli of elasticity (E-values).It was found that the unconfined compressive strength increases with the increase of the stabilizer content. However, E-values increased till certain percentage of the stabilizer and then decreased. A procedure is outlined to quantify the beneficial effects of subgrade soils stabilization based on the extension of pavement service life or reduction in the pavement thickness. It was found that cement content of 7% by dry weight of the soil is the best stabilizing group and the mixture of 7% lime and 15% fly ash is the poorest group amongst the selected groups of stabilizers.

Mohammad M. Khabiri (2011) studies solid waste materials can be left out of environment in different ways or can be used again. As an example of waste fiber materials is the fibers reselling from producing carpet which are made in Iran in largest quantity. These materials are added to soil and granular materials and improve their various properties as compressive and tensile strengths. It analyses the effect of using from waste materials in subgrade on highway pavement performance. By using analytical software and results of testing, tensile strain under asphalt layer and compressive strain on subgrade of pavement containing these materials are calculated and after that they are compared together. Increasing the waste fiber of soil leads to increase in soil UCS. Increasing 1% of fiber to soil, its UCS increase on average 10% as shown in Figure. 2.8.The most suitable length of waste fiber, in which the most quantity of strength for mixed soil is possible is 40 mm.

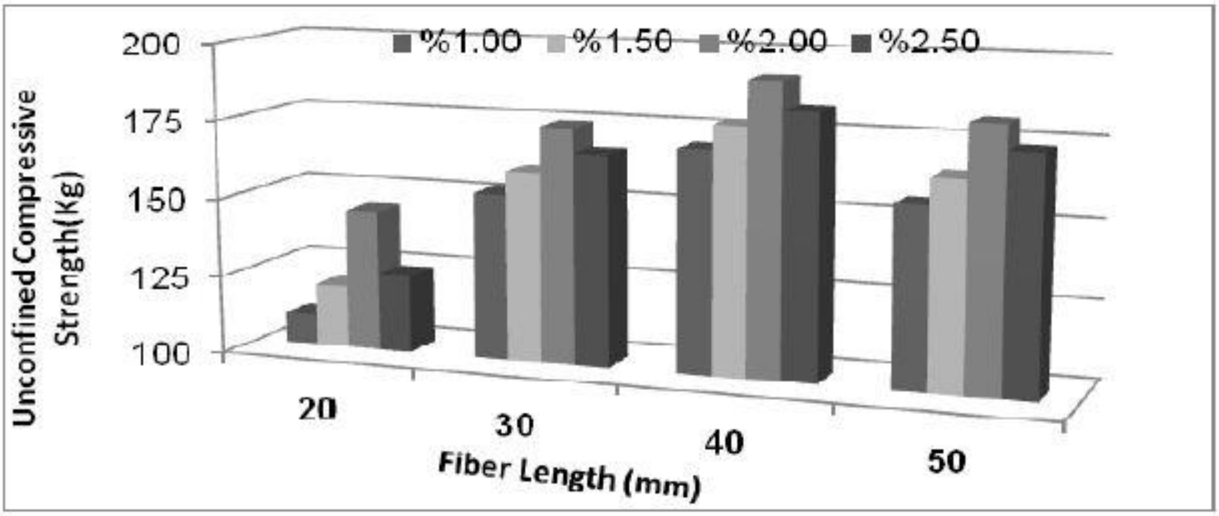


***Figure 2.8:* The effect of fiber length and fiber content on soil strength (*Mohammad M. Khabiri 2011*)**

Chegenizadeh et al. (2011) study aims to investigate effect of fiber inclusion on CBR ratio. A series of laboratory investigation were carried out to evaluate effects of reinforcing the sub grade soil in pavement system with randomly distributed plastic fibres and natural fibres.

CBR test were conducted on unreinforced samples as well as reinforced ones at different fiber contents (i.e. 0.1%, 0.3%) and different fiber length (i.e. 10mm, 25 mm and 50mm) as shown in Figure. 2.9 and Figure. 2.10.The results of CBR test showed that the CBR ratio for reinforced clay increased even more than two times in some cases as fiber content and fiber length increased.

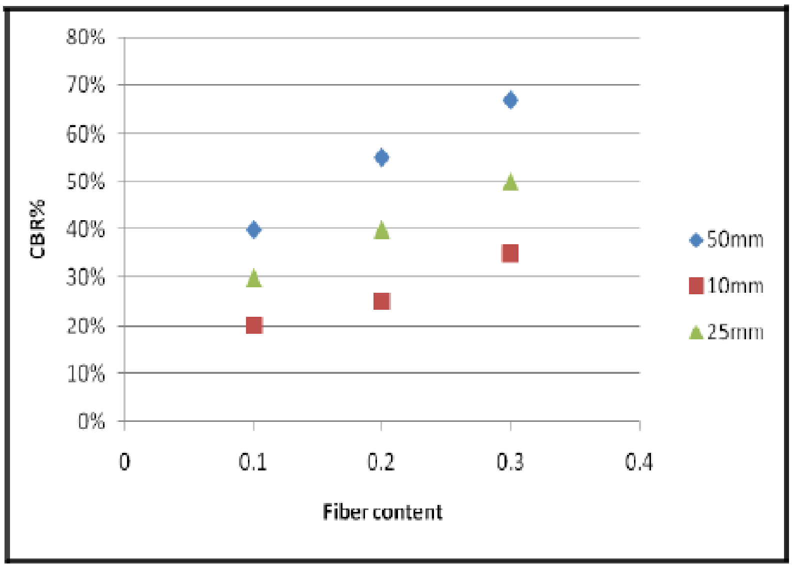


Figure 2.9: **Results of CBR test for plastic fibre (*Chegenizadeh et al. 2011)***

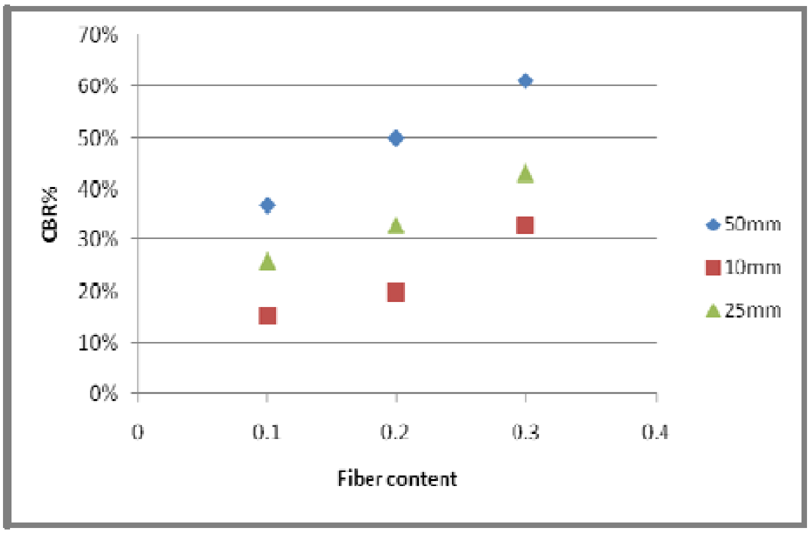


Figure 2.10: **Results of CBR test for natural fibre (*Chegenizadeh et al. 2011)***

Aggarwal et al. (2011) study a series of Proctor Compaction tests and California Bearing Ratio tests have been carried out on soil mixed with jute fiber. Jute fibers of different diameters (2 to 8mm) and lengths (0.5 to 2.0 mm) are mixed in the subgrade in different percentage (0.2 to 1.0%) to find out the optimal quantity.

It can be concluded that jute fiber reinforcement reduces the maximum dry density and increases the optimum moisture content of the subgrade soil. The CBR value of the subgrade soil increases up to 250% with the inclusion of bitumen coated jute fiber as shown in Figure. 2.11. CBR value of unreinforced and jute Fibre reinforced soil at respective MDD given in Table 2.4.

***Table 2.4:* CBR value of unreinforced and jute Fibre reinforced soil at respective MDD *(Aggarwal et al. (2011))*.**

JUTE(%)	0.2 %	0.4 %	0.6 %	0.8 %	1.0 %
LENGTH	Without reinforcement at MDD- 1.82 gm/cc				
5mm	2.48	2.72	4.03	3.74	2.93
10mm	3.11	3.16	3.26	4.62	3.61
15mm	2.40	2.57	3.06	3.11	3.05
20mm	2.84	3.26	3.99	2.96	2.81

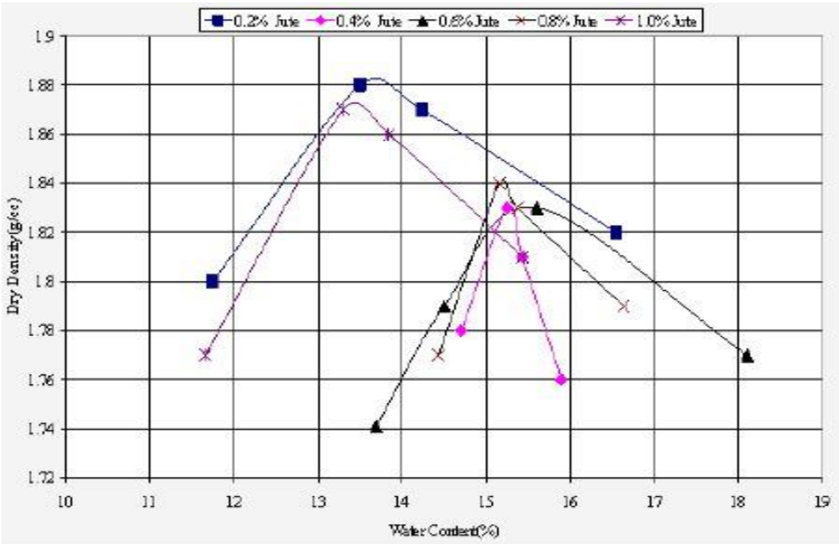


Figure 2.11:* Proctor test results on soil mixed with 2-3mm diameter 10mm length jute fiber in different percentages (*Aggarwal et al. 2011)

Pasupuleti et al. (2012) in this study revealed that the fiber reinforcement improves the CBR values in admixture stabilized soil. An attempt is made to compare the quantity of the earth required for the sub grade with and without fly ash stabilization. For 1.5% of fiber and 15 % of fly ash the thickness of the pavement is decreased by 60%. Aspect Ratio (L/d) of fibre is 300 and Length 12 mm. Variation of CBR for unsoaked and soaked condition with and without addition of fibers to the fly ash Soil shown in Figure 2.12 and Figure 2.13.

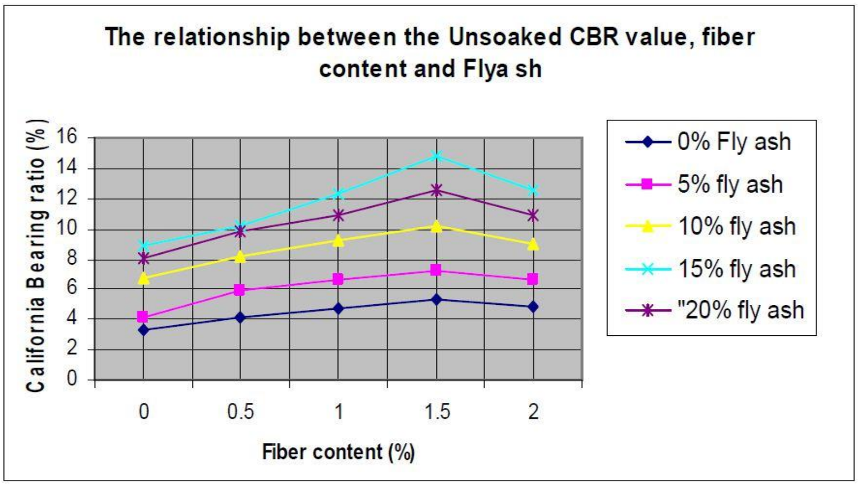


Figure 2.12: **Variation of CBR for unsoaked condition with and without addition of fibres to the fly ash Soil (*Pasupuleti et al. 2012)***

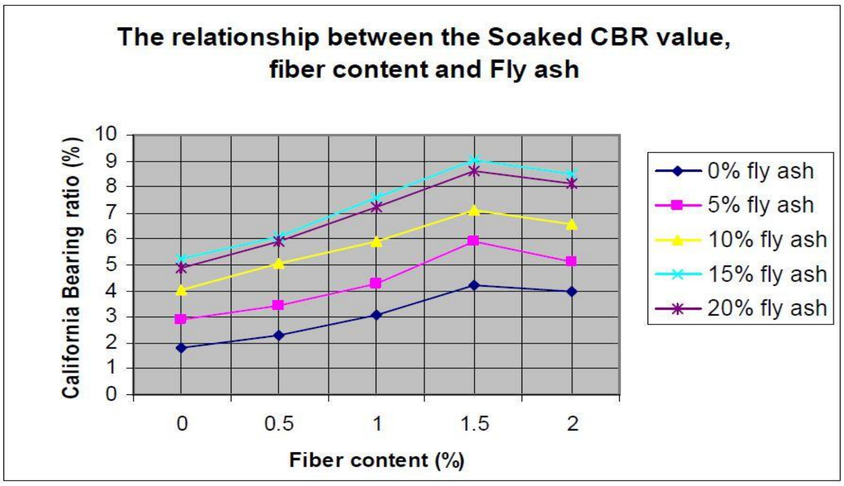


Figure 2.13: **Variation of CBR for soaked condition with and without addition of fibres to the fly- ash Soil (*Pasupuleti et al. 2012)***

Singh et al. (2012) studies about the effect of geo-grid reinforcement on maximum dry density (MDD), Optimum Moisture Content (OMC), California Bearing Ratio (CBR) and E-Value of sub-grade soil. The clayey type of soil and one type of geo-grid were selected for this study. From the study it is clear that there is considerable improvement in California Bearing Ratio (CBR) of sub-grade due to geo-grid reinforcement. In case of without reinforcement (Geo-grid) the soaked CBR value was 2.9% and when geo-grid was placed at 0.2 H from the top of the specimen the CBR increases to 9.4%.

2.4 Literature Review on Waste Plastic Reinforced Soil

Choudhary et al (2010) studies to demonstrate the potential of reclaimed high density polyethylene strips (HDPE) as soil reinforcement for improving engineering performance of subgrade soil. A series of California Bearing Ratio (CBR) tests were carried out on randomly reinforced soil by varying percentage of HDPE strips (i.e 0.25%, 0.50%, 1%, 2%, 4%) with different lengths and proportions as shown in Figure 2.14-2.17. It increases the CBR value and Secant Modulus which is maximum when strip content is 4% and aspect ratio 3. The maximum CBR value of reinforced system is 3 times that of a unreinforced system. Base course thickness can be significantly reduced if HDPE strip reinforced sand is used as sub-grade material.

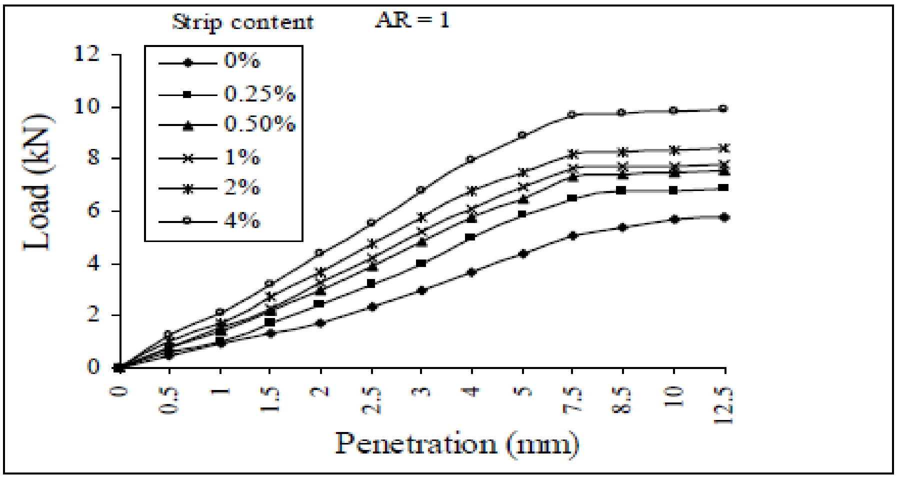


Figure 2.14: **Load penetration curve for varying strip content having AR= 1** ***(Choudhary et al 2010)***

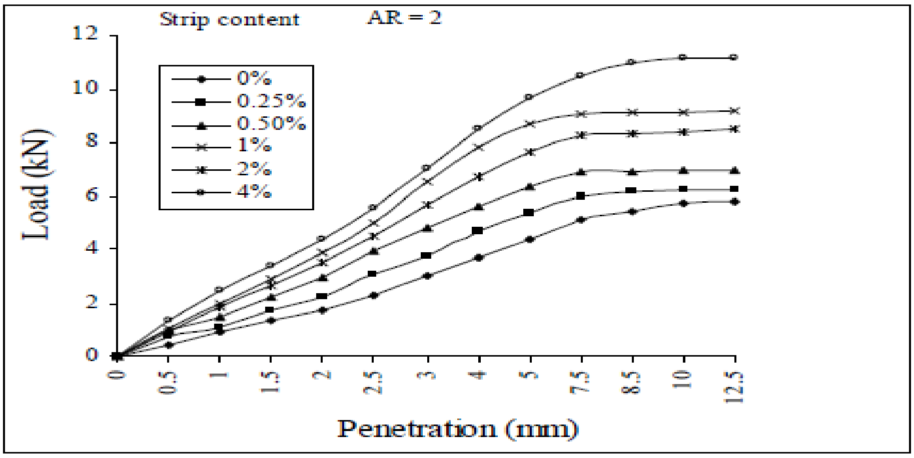


Figure 2.15: **Load penetration curve for varying strip content having AR= 2** ***(Choudhary et al 2010)***

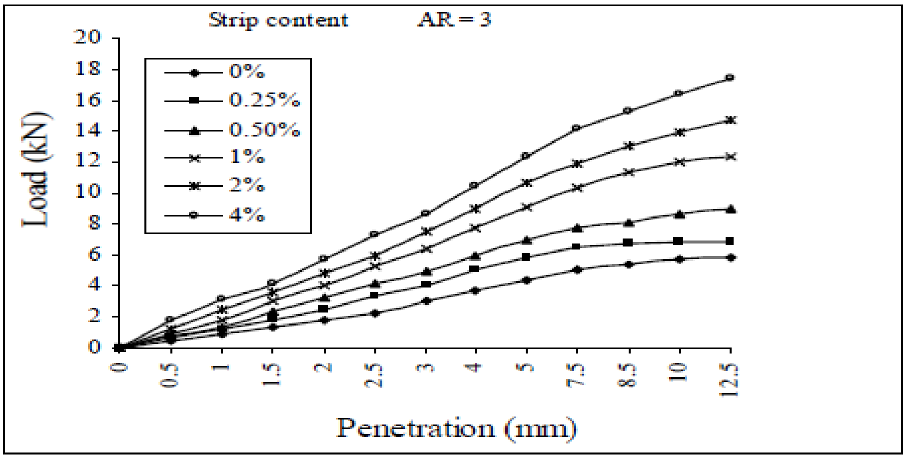


Figure 2.16: **Load penetration curve for varying strip content having AR= 3** ***(Choudhary et al 2010)***

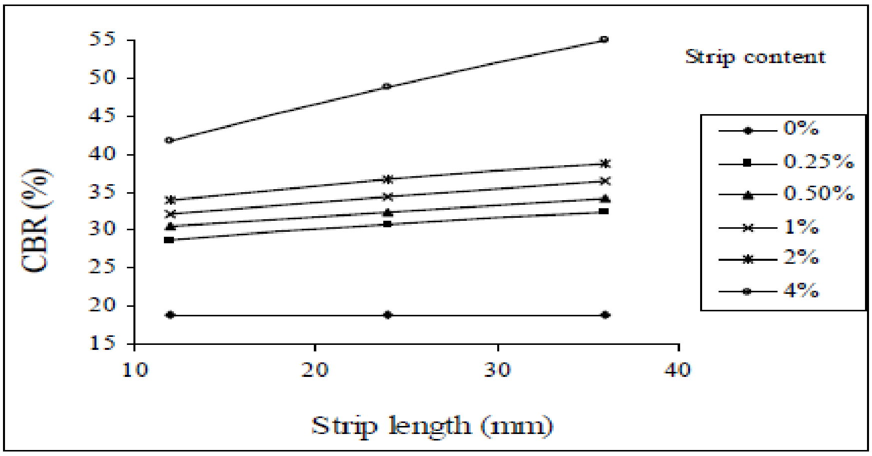


Figure 2.17: **Variation of California Bearing Ratio (CBR) with strip length at different strip content** ***(Choudhary et al 2010)***

Dasari et al (2013) used waste medical capsule plastic packing as a reinforcing material and its effect on dry density , California Bearing Ratio and Permeability of three soil types viz., sand , moorum and expansive soil with different percentage of randomly distributed reinforcing elements in the form of waste medical packing polythene strips. Different percentages of reinforcement considered are 1,2,4 and 7 and the sizes of strips being 7*7mm, 20*7mm and 35*7mm as shown in Table 2.5. CBR values to an extent of 7 times, in case of sandy soils reinforced with medical waste strips compared to the improvements with similar mixes with moorum and expansive soil.

Table 2.5: **Effect of fiber content on CBR value *(Dasari et al 2013).***

Type of Soil	Strip Size	Fiber Content, %				
		0	1	2	4	7
Sandy Soil D_r = 25%	7 mm × 7 mm	4.8	5.6	6.8	9.9	26.6
	20 mm × 7 mm	4.8	5.6	15.2	21.3	35.7
	35 mm × 7 mm	4.8	3.3	3.1	3.6	6.1
Sandy Soil D_r= 45%	7 mm × 7 mm	5.8	6.6	11.9	26.9	33.2
	20 mm × 7 mm	5.8	6.9	12.2	29.5	33.2
	35 mm × 7 mm	5.8	3.4	3.6	4.2	6.5
Moorum Soil	7 mm × 7 mm	4.8	3.3	3.7	4.0	4.1
	20 mm × 7 mm	4.8	3.4	3.1	3.5	3.6
	35 mm × 7 mm	4.8	3.1	3.8	4.1	4.9
Expansive Soil	7 mm × 7 mm	3.0	2.7	2.6	2.4	1.3
	20 mm × 7 mm	3.0	2.9	2.7	2.2	1.2
	35 mm × 7 mm	3.0	1.6	1.5	1.2	1.0

Medical waste reinforced sandy soils exhibited no improvement in permeability while those with moorum and expansive soil samples showed slight improvement. The 7 mm by 7 mm and 20 mm by 7 mm sizes were effective in improving CBR values as compared to 35 mm by 7 mm size.

CHAPTER-3
EXPERIMENTAL PROGRAMME

3.1 Materials

A brief description of the materials and methods used in this investigation is given as following.

3.1.1 Sand

Soil taken is locally available in the region of Bhawanigarh, Patiala, Punjab (India). The investigation of Soil is done by Indian Standard code. The index properties of soil such as Liquid limit, Plastic limit, and Plastic index were determined.

Grain size: It is done to determine the percentage of various grain sizes. The grain size distribution helps in determining the textural classification of soils whether it is gravel, sand, silt, clay, etc. which is then useful in evaluating the engineering characteristics. IS: 2720- Part iv (2006) is used. The sieves for soil tests used are 4.75 mm to 75 microns and grain size distribution is shown in Figure. 3.1.

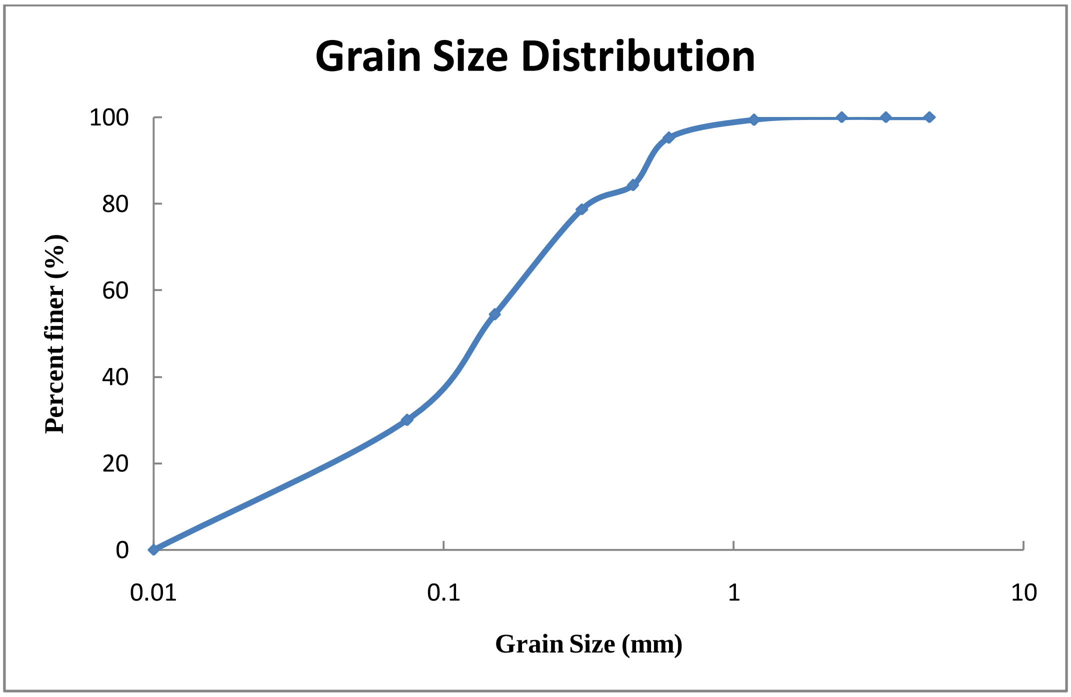


Figure 3.1: **Grain Size Distribution of Sand**

Table 3.1: **Engineering Properties of Soil**

S. No.	Property	Result
1	Liquid Limit	18.58 %
2	Plastic Limit	13.33 %
3	Plastic Index	5.25%
4	Coefficient of Curvature (C_c)	0.42
5	Uniformity Coefficient (C_u)	5.3

3.1.2 Waste Plastic:

Three types of waste plastic used were High density Polyethylene (HDPE), Low density Polyethylene (LDPE) and Polypropylene (PP). These waste materials were purchased from waste plastic recycle industries, where rag picker supplies the waste plastic which they collect from waste dump around Patiala. Different types of waste plastic were crushed into irregular strip which were further converted into granular particles which were used in this study. The cost of different waste plastic varies from INR 40 to INR 65 per kg.

High Density Polyethylene (HDPE)

It has little branching, giving it stronger intermolecular forces and tensile strength than LDPE. The difference in strength exceeds the difference in density, giving HDPE a higher specific strength. It is also harder and more opaque and can withstand somewhat higher temperatures (120 °C/ 248 °F for short periods, 110 °C /230 °F continuously).Although the density of HDPE is only marginally higher than that of low density polyethylene. The cost of HDPE is 55 Rs per kg.

Figure 3.2: **High Density Polyethylene (HDPE)**

Low Density Polyethylene (LDPE)

It is a thermoplastic made from the monomer ethylene. It was the first grade of polyethylene . LDPE has more branching (on about 2% of the carbon atoms) than HDPE, so its intermolecular forces are weaker, its tensile strength is lower, and its resilience is higher. It can withstand temperatures of 80 °C continuously and 95 °C for a short time. Made in translucent or opaque variations, it is quite flexible, and tough but breakable. The cost of LDPE waste plastic is 65 Rs per kg.

Figure 3.3: **Low Density Polyethylene (LDPE)**

Polypropylene (PP)

It is also known as **polypropene**, is a thermoplastic polymer used in a wide variety of applications including packaging and labeling, textiles , plastic parts and reusable containers of various types . An addition polymer made from the monomer propylene, it is rugged and unusually resistant to many chemical solvents, bases and acids. The cost of PP waste plastic is 45 Rs per kg

Figure 3.4: **Polypropylene (PP)**

3.2 Compaction Test

This test is done to determine the maximum dry density and the optimum moisture content of soil using by proctor test as per IS: 2720-Part viii (1995).
Compaction is the process of densification of soil mass by reducing air voids. The degree of compaction of a soil is measured in terms of its dry density. For a given compaction energy every soil attains the maximum dry density at a particular water content which is known as optimum moisture content.

3.2.1 Applications

Compaction of soils increases their density, shear strength, bearing capacity but reduces their void ratio, porosity, permeability and settlements. The results of this test are useful in the stability of field problems like earthen dams, embankments, roads and airfields, In such constructions, the soil are compacted.

3.2.2 Apparatus

i) Cylindrical metal mould- It should be either of 100mm dia. and 1000cc volume or 150mm dia. and 2250cc volume and should conform to IS: 10074 - 1982.
ii) Balances - one of 10kg capacity, sensitive to 1g and the other of 200g capacity, sensitive to 0.01g
iii) Oven - thermostatically controlled with an interior of non corroding material to maintain temperature between 105 and 110˚C

iv) Rammer for light compaction (face diameter 50 mm , mass of 2.6 kg , free drop 310 mm) or Rammer for heavy compaction (face diameter 50 mm , mass of 4.89 kg , free drop 450 mm)

v) IS Sieves of sizes - 4.75mm, 19mm.

Figure 3.5: **Automatic Compactor**

3.2.3 Procedure:

1. Take about 20 kg for 1000 cc mould or 45 kg for 2250 cc mould of air dried and mixed soil.
2. Sieve this soil through 20 mm and 4.75 mm sieves.
3. Take about 2.5 kg of the soil for 1000 cc mould or 6 kg for 2250 cc mould for light compaction
4. Clean, dry and grease lightly the mould and base plate. Weigh the mould with base plate. Fit the collar and place the mould on a solid base.
5. For light compaction, compact the wet soil in three equal layers by rammer of mass 2.6 kg and free fall 31 cm with 25 evenly distributed blows in each layer for 10 cm diameter mould and 56 blows for 15 cm diameter mould

6. Remove the collar and trim off the soil flush with the top of the mould. In removing the collar rotate it to break the bond between it and the soil before lifting it off the mould.
7. Remove the soil from mould and obtain a representative soil sample from the bottom, middle and top for water content determination.
8. Weigh the dry crucible with sample and put in the drying oven at temperature 105˚C to 110˚C for 24 hours.
9. Repeat the above procedure with 7, 10, 13, 16, 19, and 22 % of water content on Coarse grained fresh soil samples and 11, 14,17,20,23 and 26 % of water contents of fine grained fresh soil samples approx.
10. Next day weight crucibles with dry soil samples and then the empty crucibles.

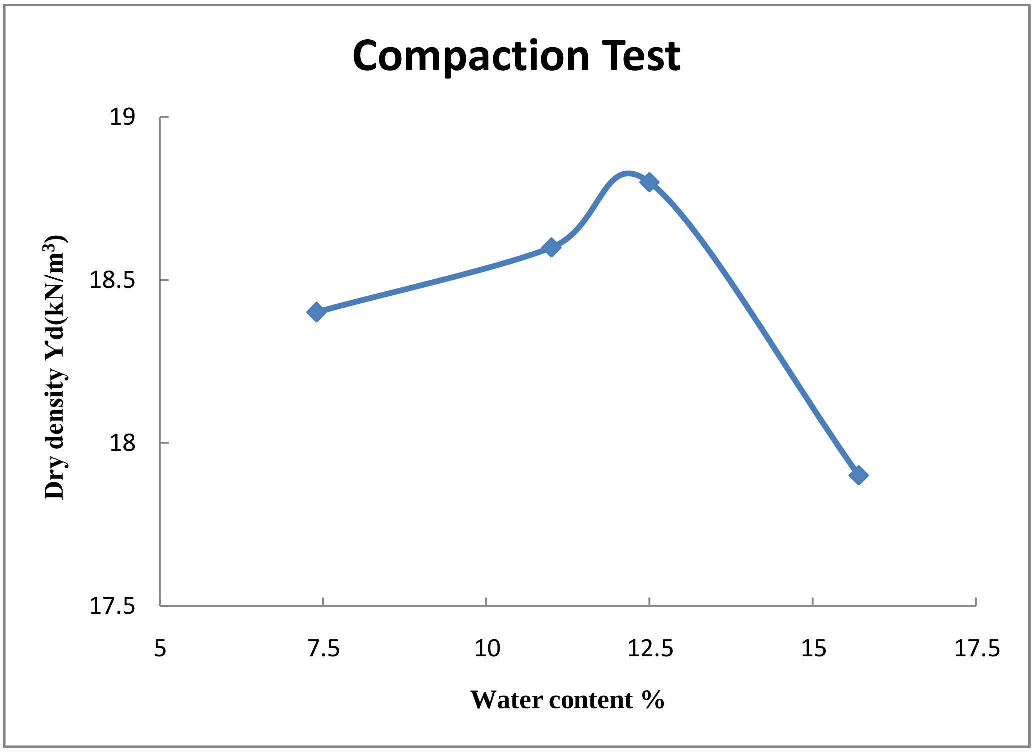


Figure 3.6: **Compaction Test on Unreinforced Soil**

Optimum Moisture Content: 12.5 %

Maximum Dry Density: 18.8 kN/m^3

Compaction Test were performed on Polypropylene waste plastic content 1%,2% and 4% as shown in Figure 3.7-3.9. It was found that there is no. change in Dry Density. There is small change in water content 1% to 2%.

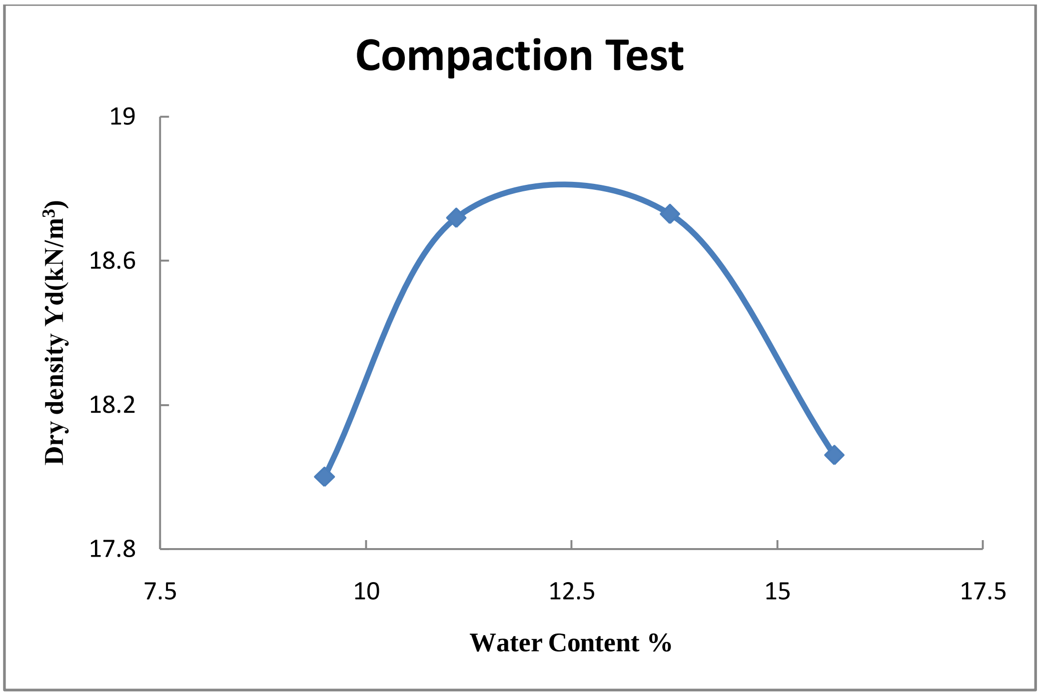


Figure 3.7: **Compaction Test on 1% Polypropylene**

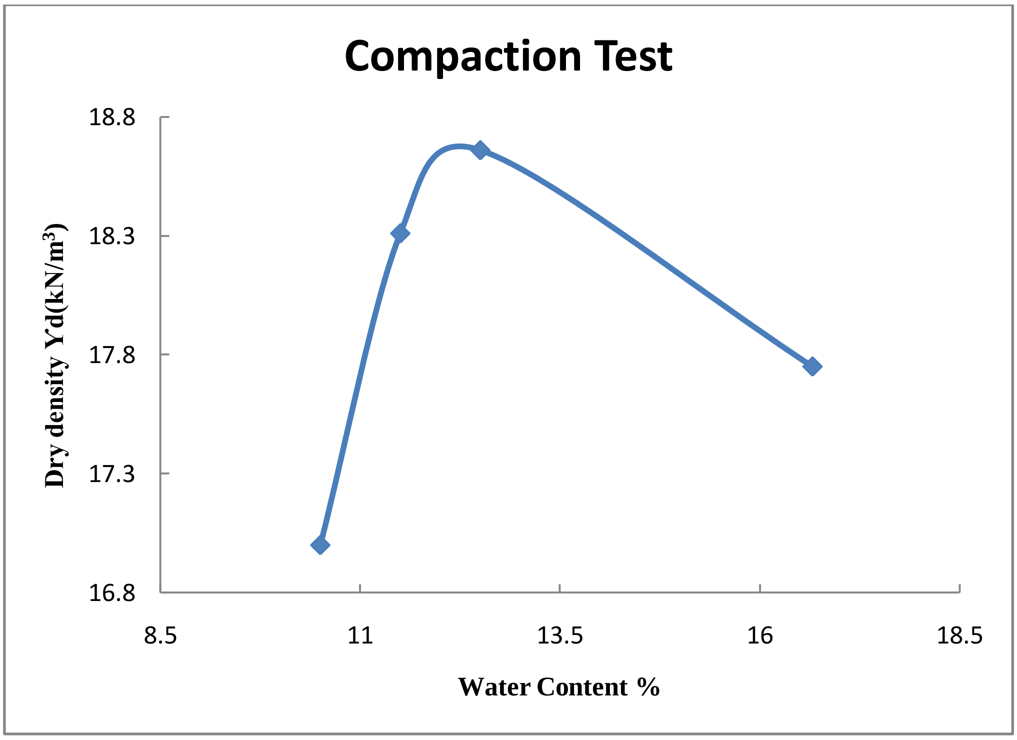


Figure 3.8: **Compaction Test on 2% Polypropylene**

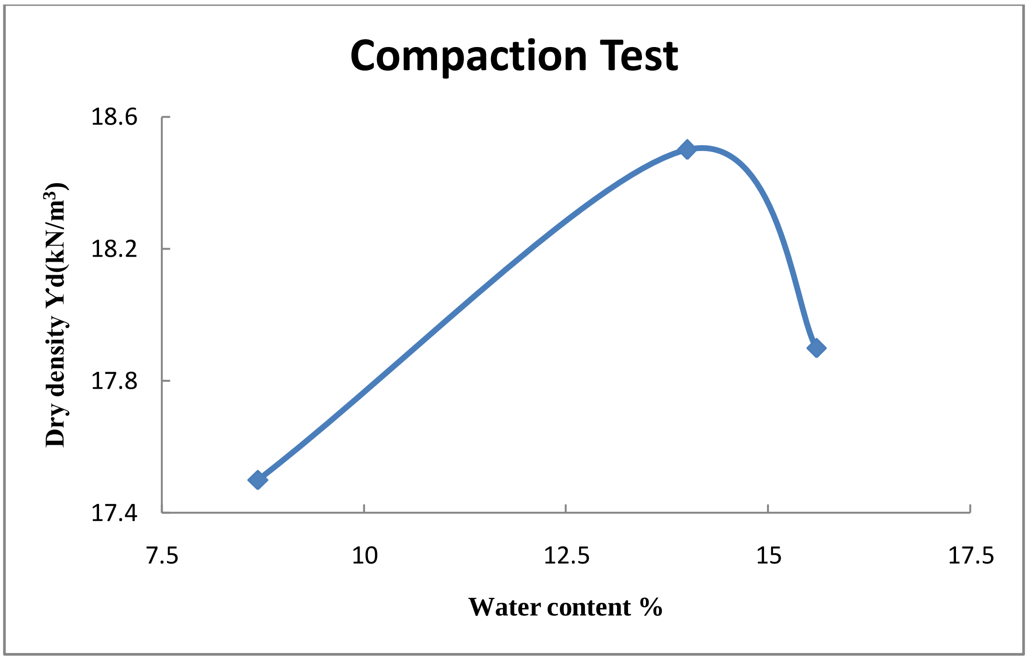


Figure 3.9: **Compaction Test on 4% Polypropylene**

3.3 California bearing ratio test:

It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material. IS 2720- Part xvi (2002) is used for this test.

$$\text{C.B.R.} = \frac{Test\ Load\ (kg)}{Standard\ \ Load\ (kg)} \times 100$$

The following table gives the standard loads adopted for different penetrations for the standard material with a C.B.R. value of 100%

Table 3.2: **Standard Loads adopted for different Penetrations**

Penetration of Plunger (mm)	Standard Load (kg)
2.5	1370
5	2055
7.5	2630
10	3180
12.5	3600

The test may be performed on undisturbed specimens and on remolded specimens which may be compacted either statically or dynamically. This test is done to determine the California bearing ratio by conducting a load penetration test in the laboratory. The California bearing ratio test is penetration test meant for the evaluation of sub grade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

3.3.1 Equipments and tool required

1. Cylindrical mould with inside dia 150 mm and height 175 mm, provided with a detachable extension collar 50 mm height and a detachable perforated base plate 10 mm thick.
2. Spacer disc 148 mm in dia and 47.7 mm in height along with handle.
3. Metal rammers. Weight 2.6 kg with a drop of 310 mm (or) weight 4.89 kg a drop 450 mm.
4. Weights. One annular metal weight and several slotted weights weighing 2.5 kg each, 147 mm in dia, with a central hole 53 mm in diameter.
5. Loading machine. With a capacity of at least 5000 kg and equipped with a movable head or base that travels at an uniform rate of 1.25 mm/min. Complete with load indicating device.
6. Metal penetration piston 50 mm dia and minimum of 100 mm in length.

Figure 3.10: **California bearing ratio testing Machine**

3.3.2 Preparation of test specimen

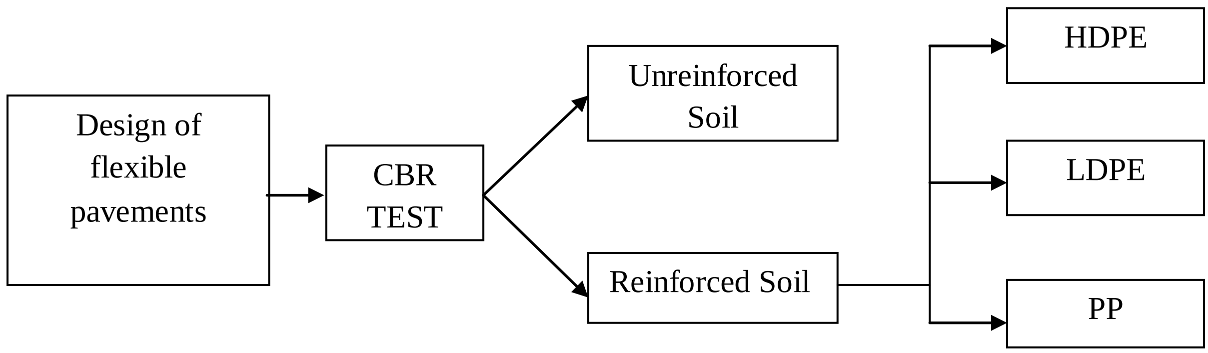
1. Take about 4.5 to 5.5 kg of soil and mix thoroughly with the required water.
2. Fix the extension collar and the base plate to the mould. Insert the spacer disc over the base .Place the filter paper on the top of the spacer disc.
3. Compact the mix soil in the mould using either light compaction or heavy compaction. For light compaction, compact the soil in 3 equal layers, each layer being given 55 blows by the 2.6 kg rammer. For heavy compaction compact the soil in 5 layers, 56 blows to each layer by the 4.89 kg rammer.

4. Remove the collar and trim off soil.
5. Turn the mould upside down and remove the base plate and the displacer disc.
6. Weigh the mould with compacted soil and determine the bulk density and dry density.
7. Put filter paper on the top of the compacted soil (collar side) and clamp the perforated base plate on to it.

3.3.3 Procedure

1. Place the mould assembly with the surcharge weights on the penetration test machine.
2. Seat the penetration piston at the center of the specimen with the smallest possible load, but in no case in excess of 4 kg so that full contact of the piston on the sample is established.
3. Set the stress and strain dial gauge to read zero. Apply the load on the piston so that the penetration rate is about 1.25 mm/min.
4. Record the load readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10 and 12 mm. Note the maximum load and corresponding penetration if it occurs for a penetration less than 12.5 mm.
5. Detach the mould from the loading equipment. Take about 20 to 50 g of soil from the top 3 cm layer and determine the moisture content.

This experimental study involved a series of laboratory CBR tests on unreinforced and randomly distributed reinforced different waste plastic (i.e. with different %) . Specimens were prepared by compacting soil in three equal layers to a dry density of 18.8 kN/m^3.Design of flexible pavement is done thereafter.



CHAPTER-4
RESULT AND DISCUSSION

4.1 California Bearing Ratio

Various load penetration curves obtained from the CBR tests for unreinforced and randomly distributed reinforced samples with different waste plastic (i.e. HDPE, LDPE and PP.) content were as below:

4.1.1 Load Penetration curves for unreinforced sample

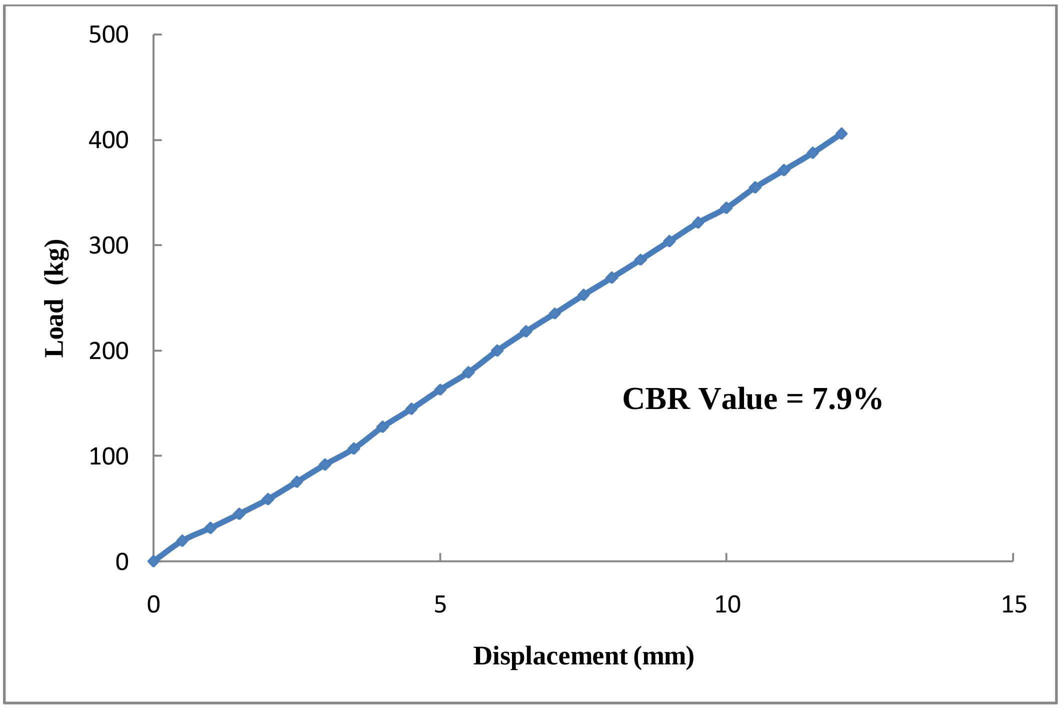


Figure 4.1: **Load Penetration curves for unreinforced soil.**

In this study different percentage of HDPE, LDPE, PP. waste plastic were randomly mixed with soil for CBR testing. After the mixing, water is added and sample is prepared by Compacting the soil into three layers. Load penetration curves obtained by adding various percentages are as follows:

4.1.2 Load Penetration curves for HDPE waste plastic:

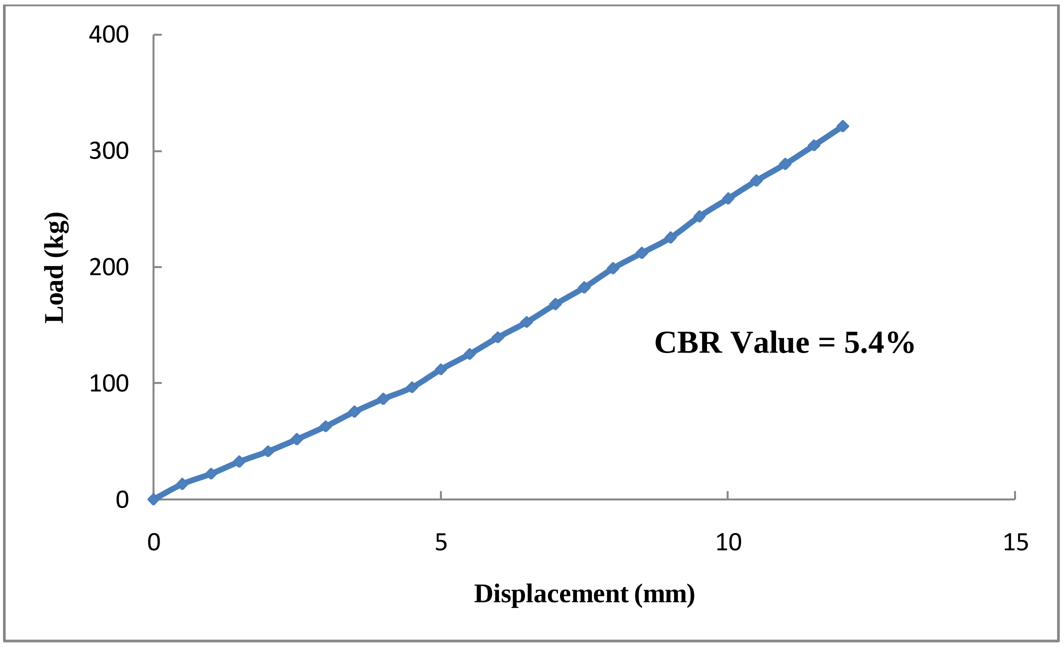


Figure 4.2: **Load Penetration curve for Soil having 1% HDPE waste plastic**.

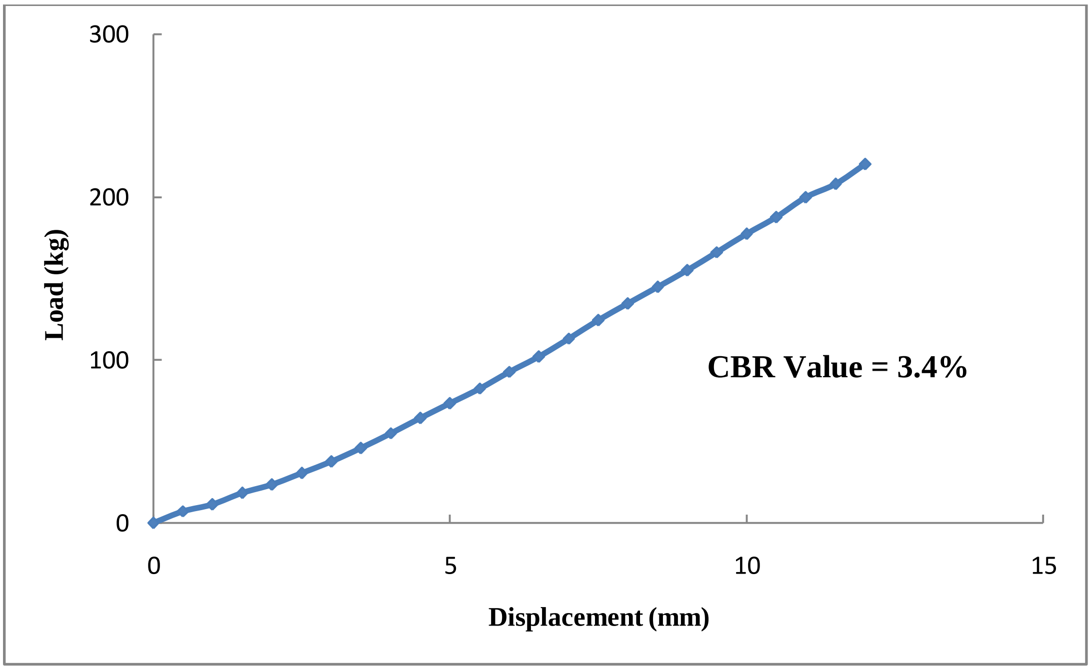


Figure 4.3: **Load Penetration curve for Soil having 2% HDPE waste plastic**

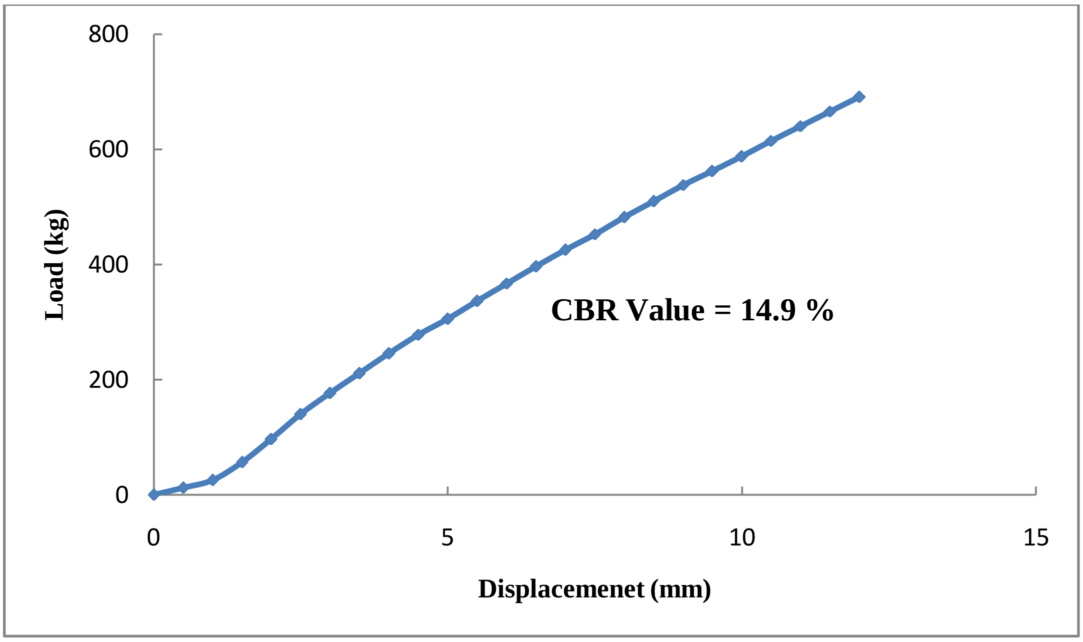


Figure 4.4: **Load Penetration curve for Soil having 3% HDPE waste plastic**

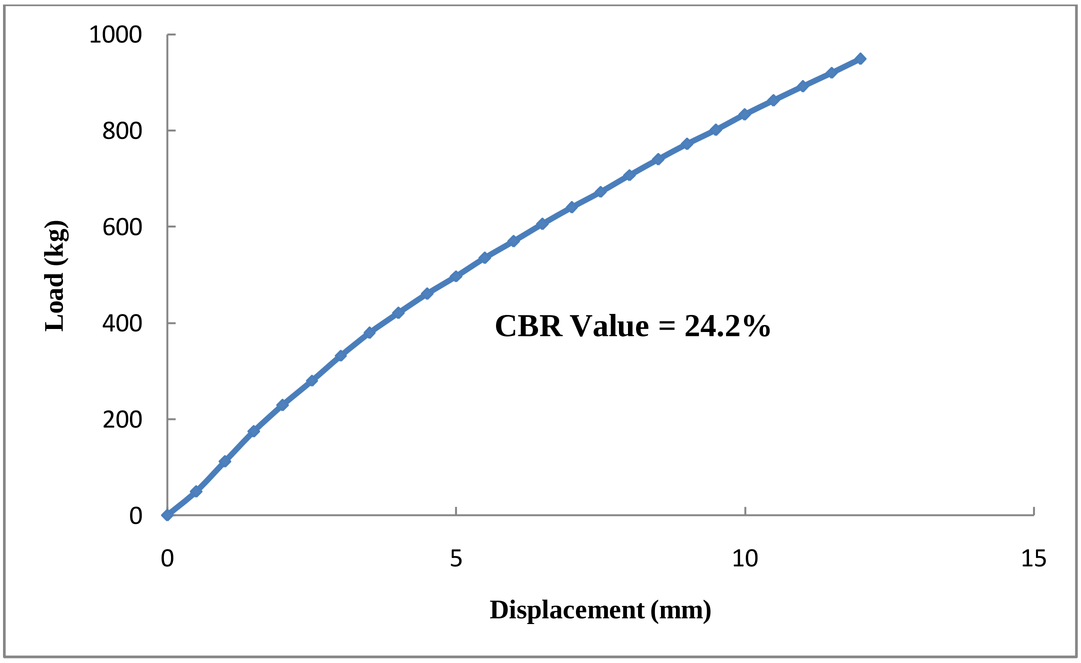


Figure 4.5: **Load Penetration curve for Soil having 4% HDPE waste plastic**

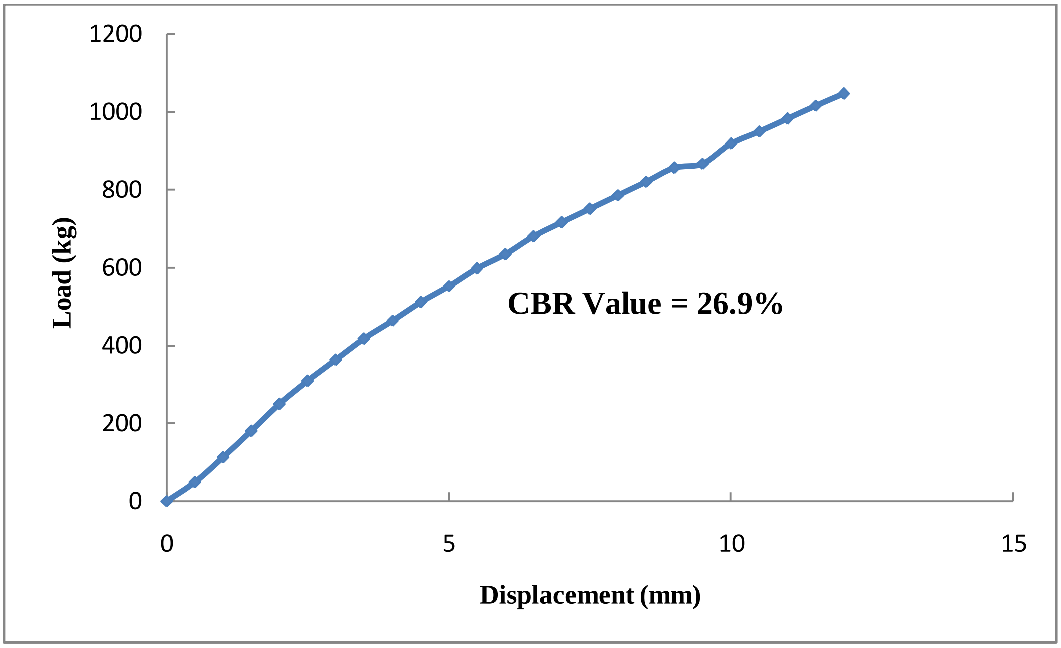


Figure 4.6: **Load Penetration curve for Soil having 5% HDPE waste plastic**

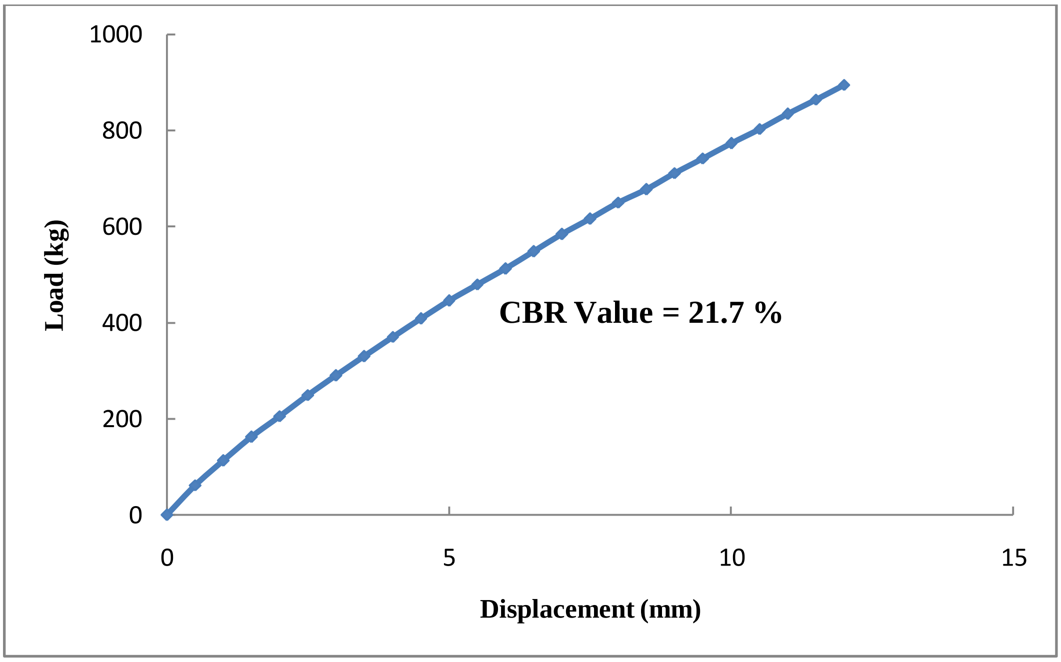


Figure 4.7: **Load Penetration curve for Soil having 6% HDPE waste plastic**

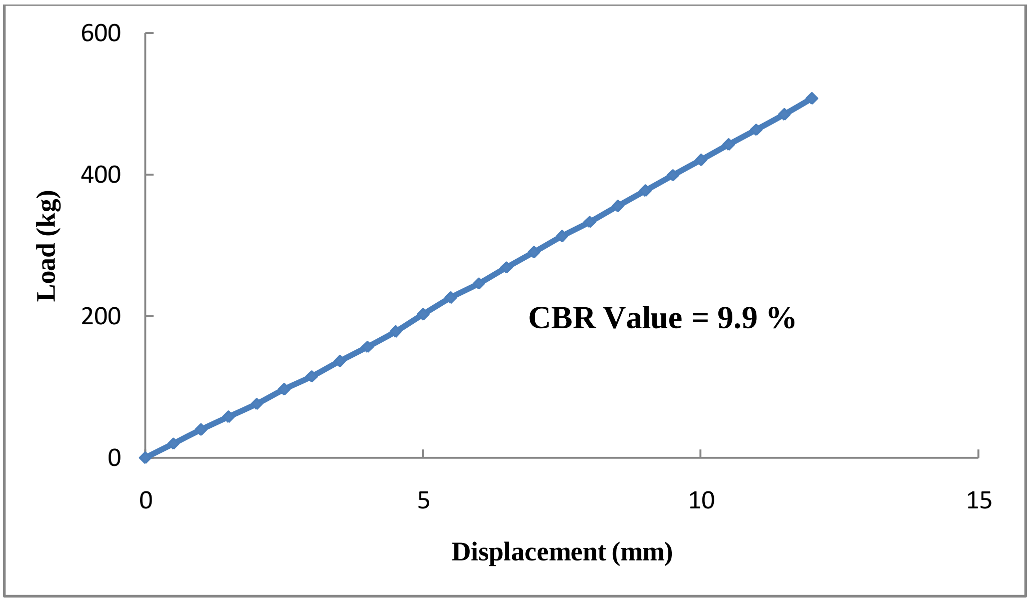


Figure 4.8: **Load Penetration curve for Soil having 7% HDPE waste plastic**

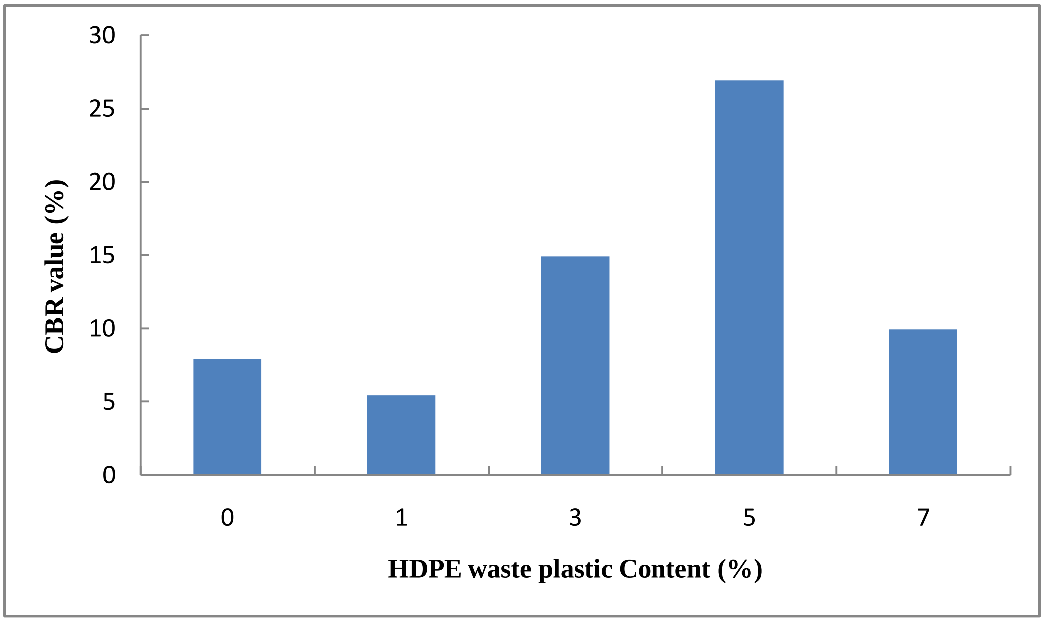


Figure 4.9: **CBR value with different HDPE content**

Table 4.1: **Values of CBR at different HDPE waste Plastic content**

HDPE waste plastic content	0%	1%	2%	3%	4%	5%	6%	7%
CBR value(%)	7.9	5.4	3.5	14.9	24.2	26.9	21.7	9.9

From Table 4.1 and Figure 4.9 it shows that CBR value increases with increase in HDPE content and it is maximum at 5%. After that it decreases with increase in content. Maximum value of CBR is 26.9 %.

4.1.3 Load Penetration curves for LDPE waste plastic

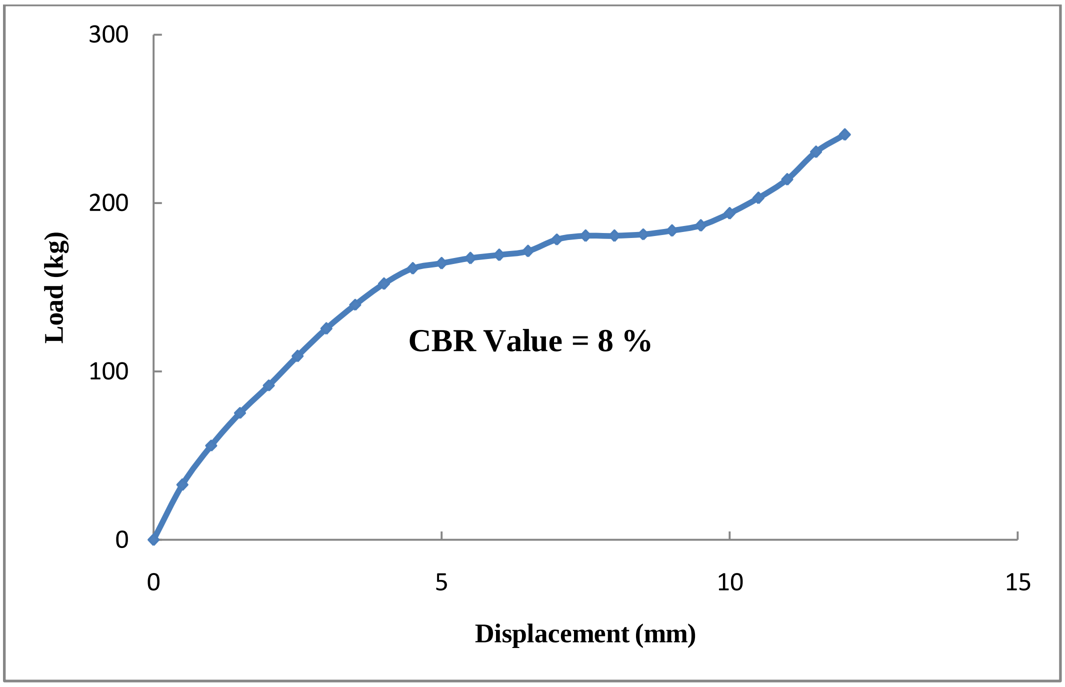


Figure 4.10: **Load Penetration curve for Soil having 1% LDPE waste plastic**

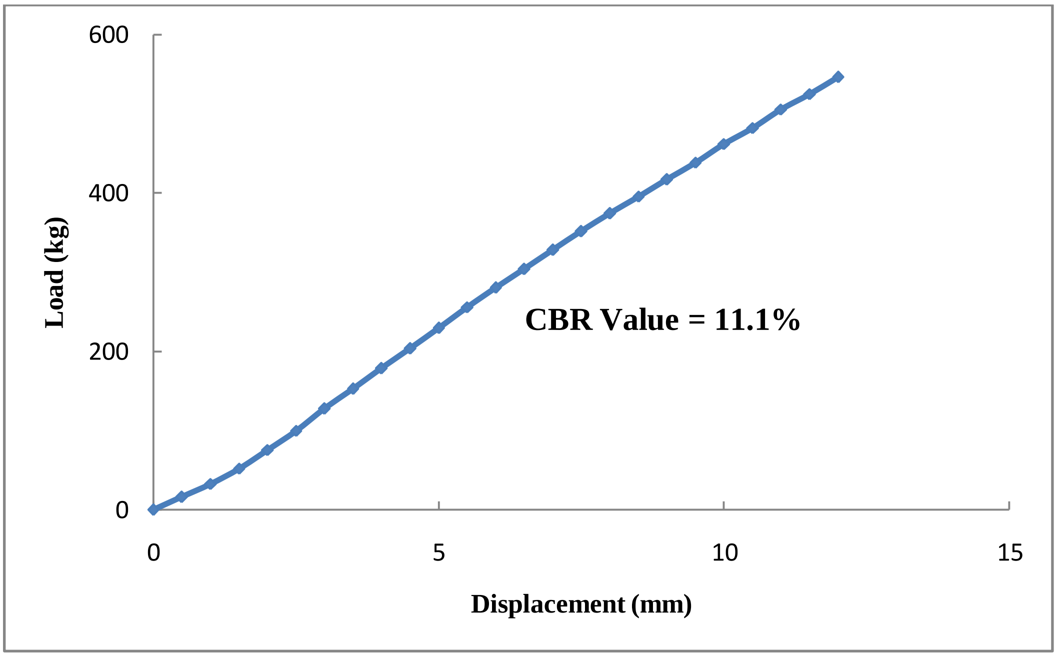


Figure 4.11: **Load Penetration curve for Soil having 3% LDPE waste plastic**

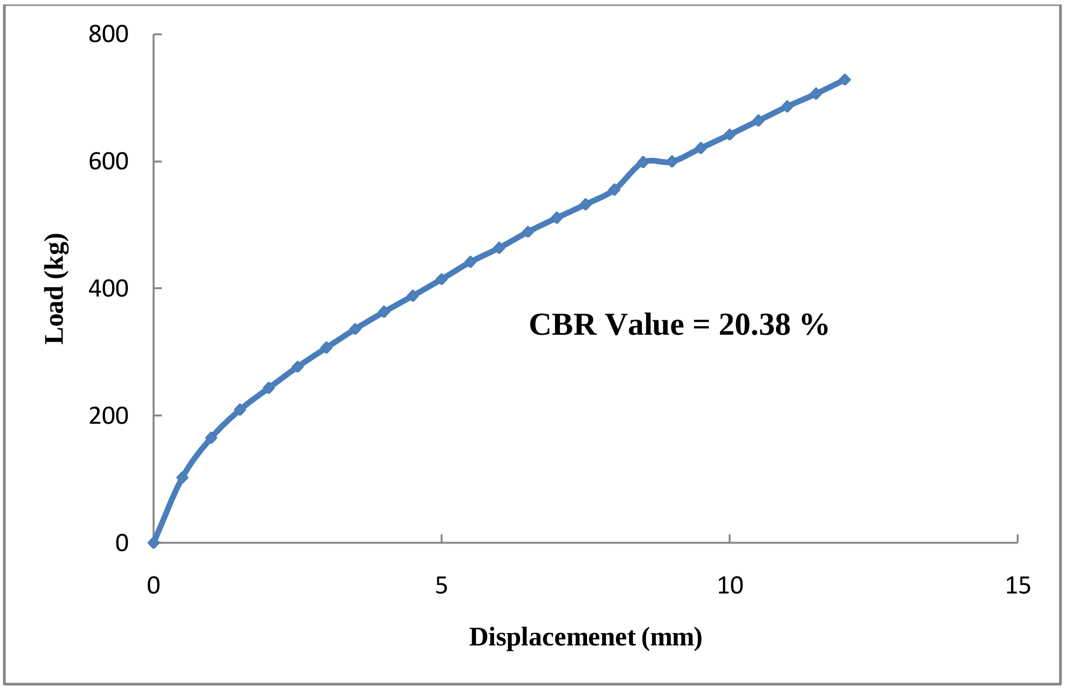


Figure 4.12: **Load Penetration curve for Soil having 5% LDPE waste plastic**

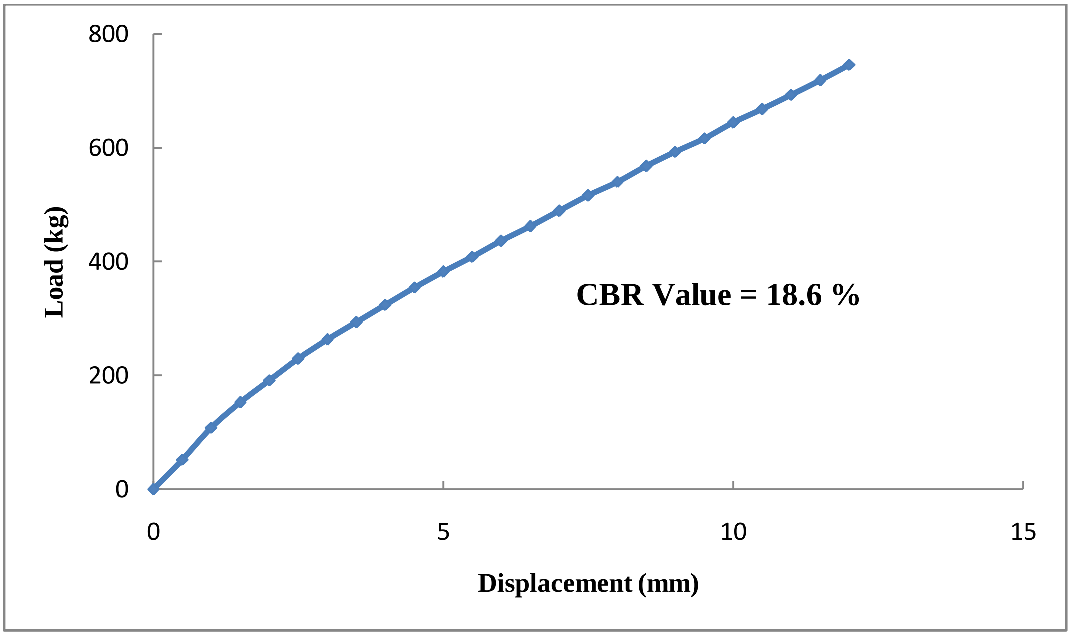


Figure 4.13: **Load Penetration curve for Soil having 7% LDPE waste plastic**

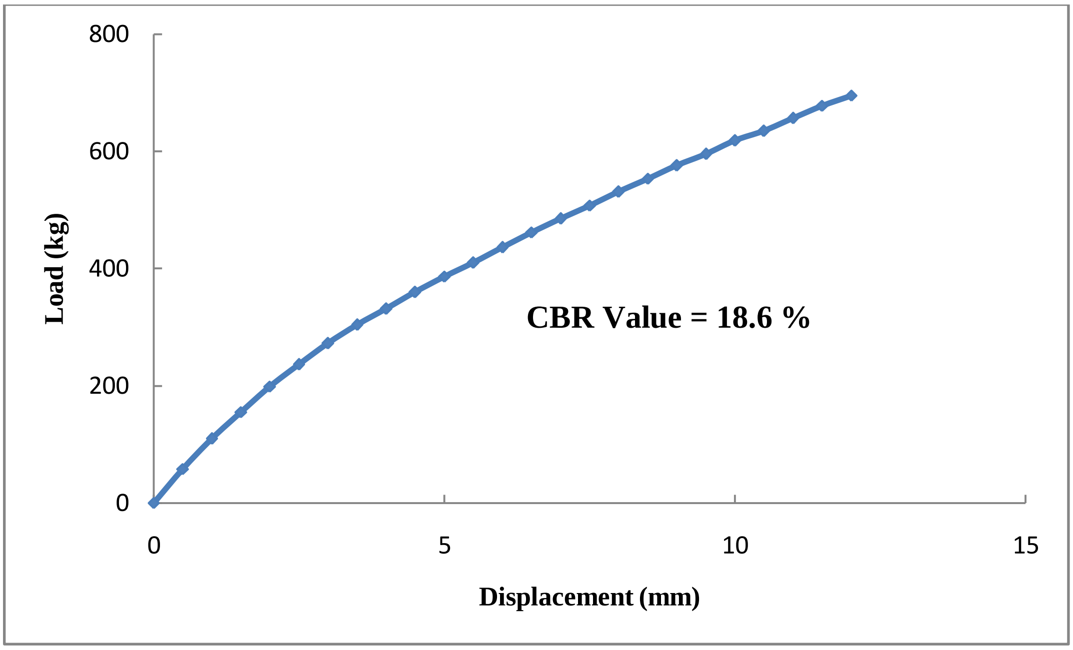


Figure 4.14: **Load Penetration curve for Soil having 9% LDPE waste plastic**

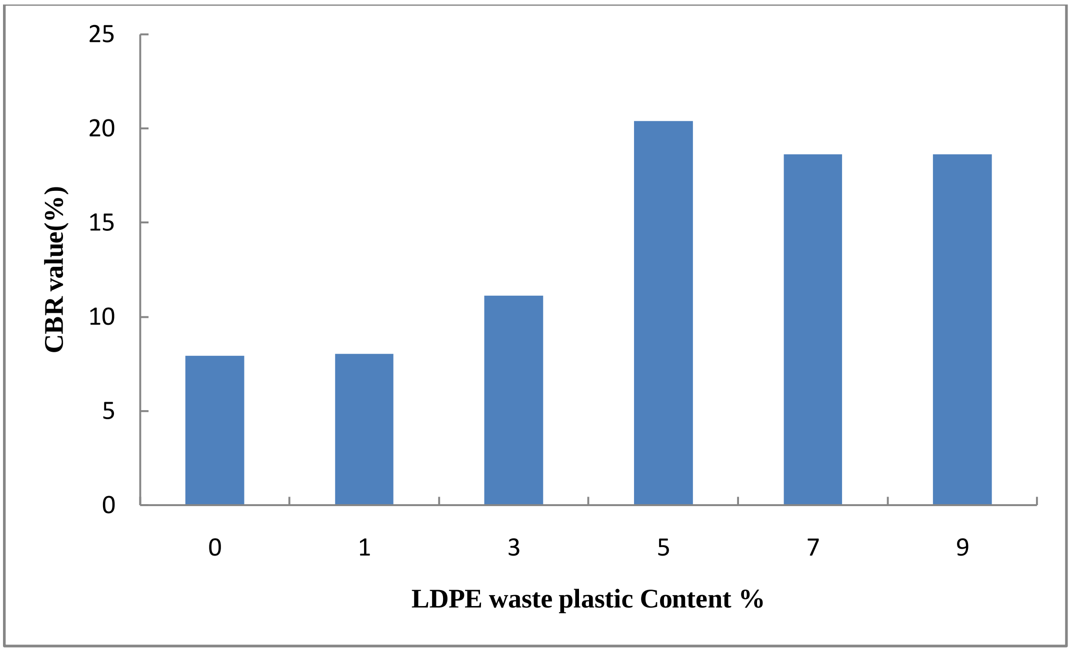


Figure 4.15: **CBR value with different LDPE content**

Table 4.2: **Values of CBR at different LDPE waste Plastic content**

LDPE waste plastic content	0%	1%	3%	5%	7%	9%
CBR value(%)	7.9	8.0	11.1	20.38	18.6	18.6

It is found that increase in CBR value when LDPE content is added but it is less than as compared to HDPE. From Table 4.2 and Figure 4.15 it is observed that CBR value is 20.38% at 5% LDPE content which is maximum after 5% content it again decreases.

4.1.4 Load Penetration curves for PP waste plastic

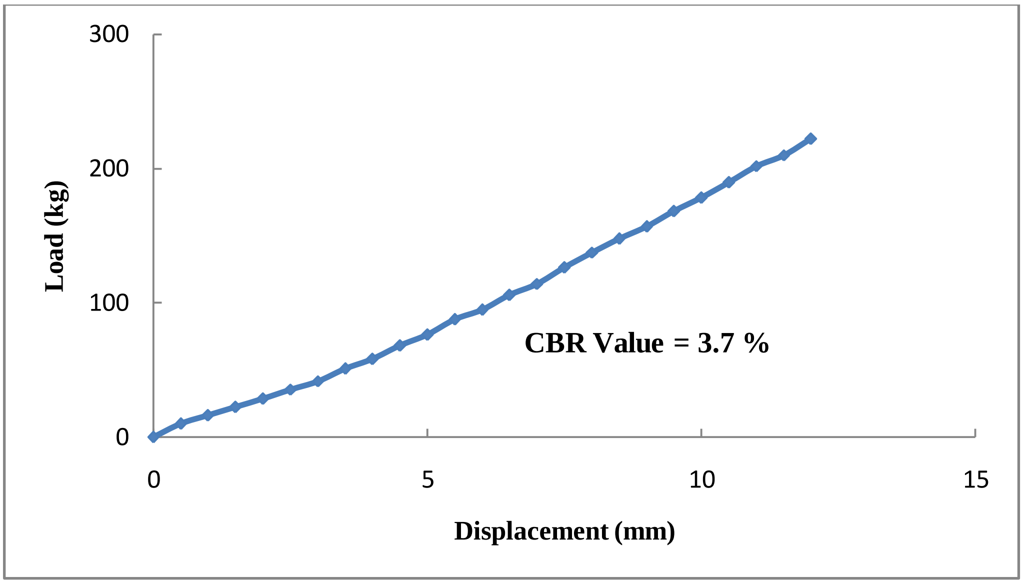


Figure 4.16: **Load Penetration curve for Soil having 1% PP waste plastic**

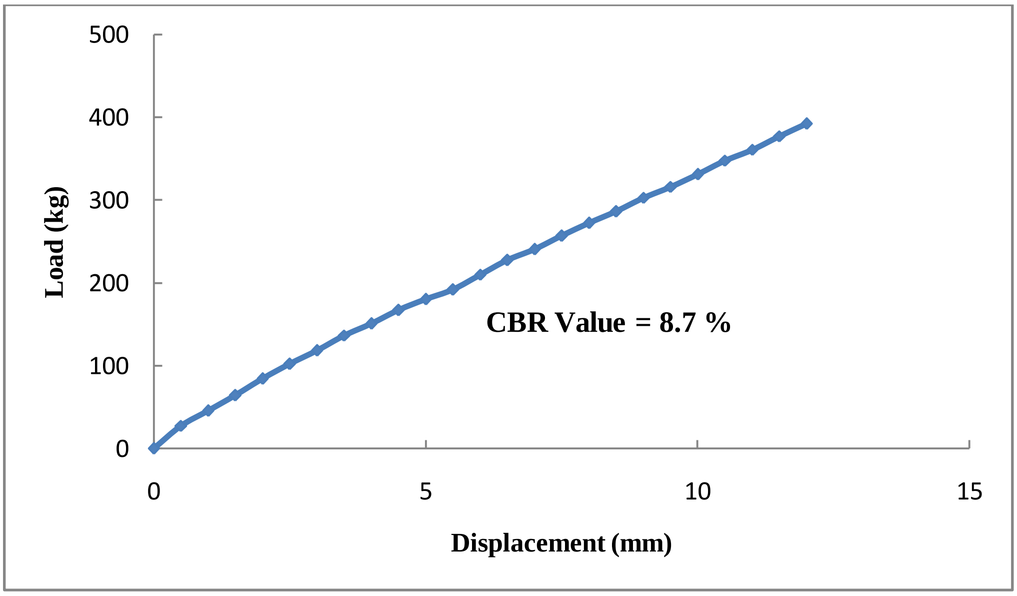


Figure 4.17: **Load Penetration curve for Soil having 3% PP waste plastic**

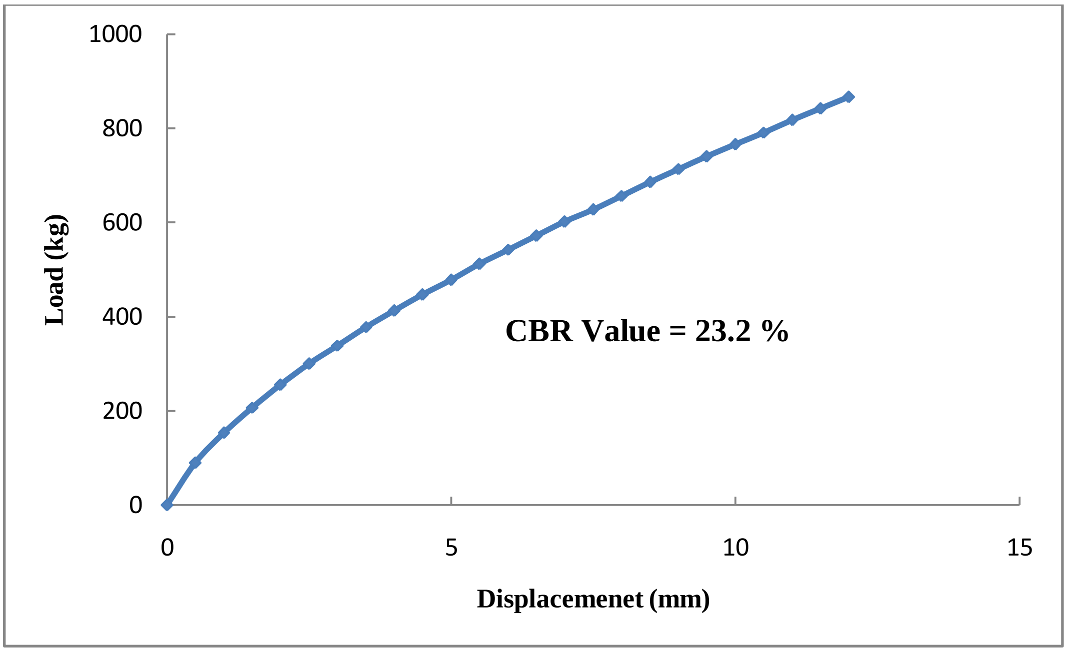


Figure 4.18: **Load Penetration curve for Soil having 5% PP waste plastic**

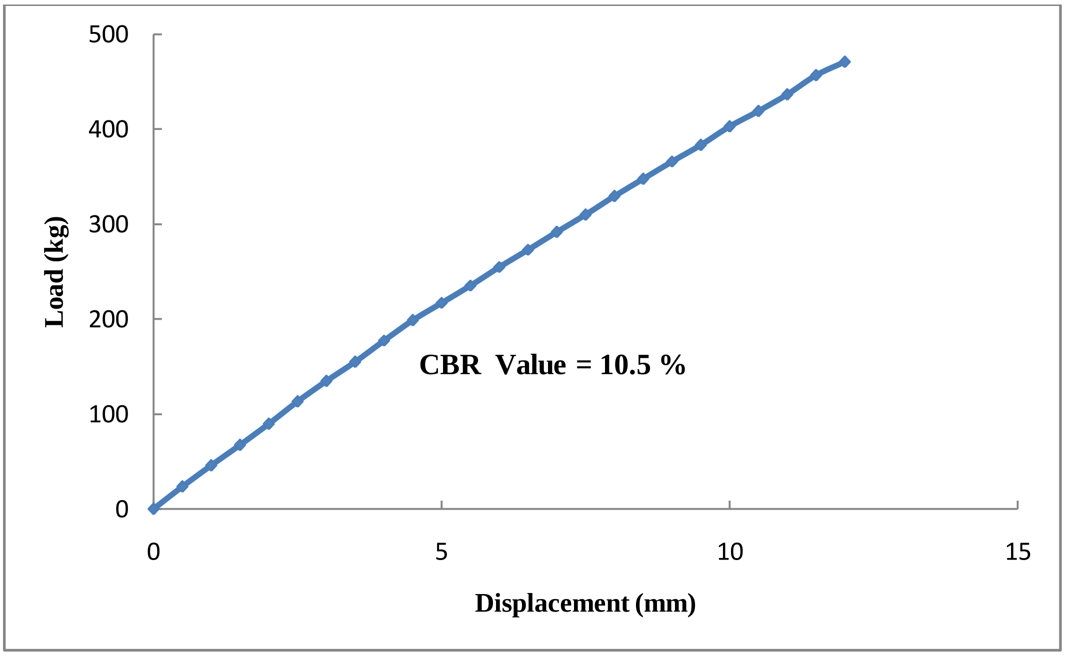


Figure 4.19: **Load Penetration curve for Soil having 7% PP waste plastic**

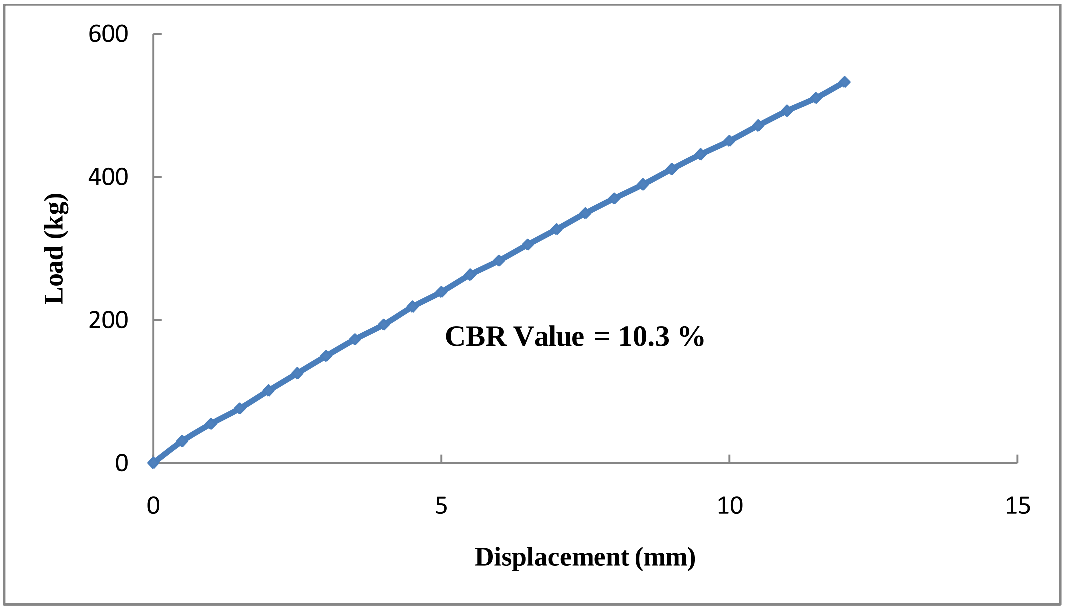


Figure 4.20: **Load Penetration curve for Soil having 9% PP waste plastic**

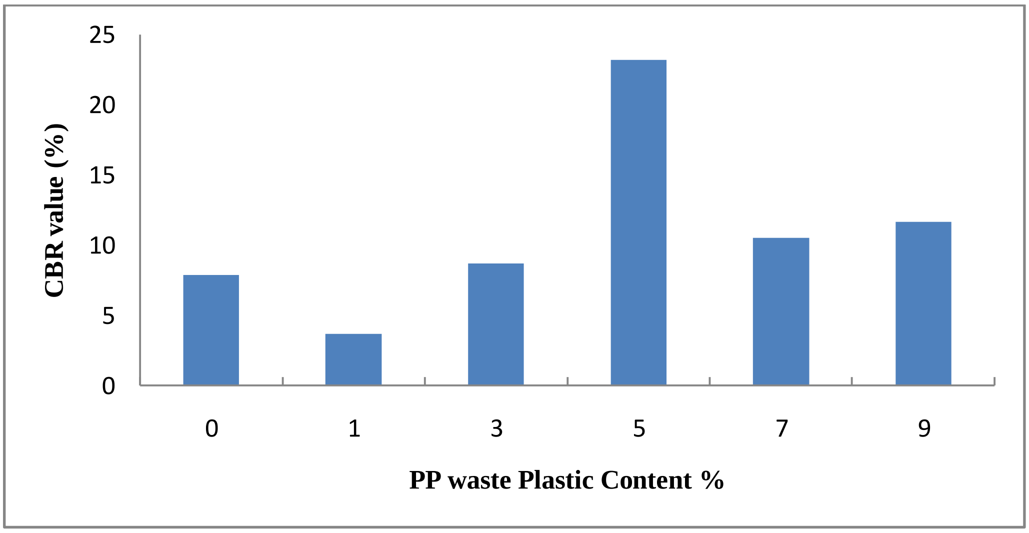


Figure 4.21: **CBR value with different PP content**

Table 4.3: **Values of CBR at different PP waste Plastic content**

PP waste plastic content	0%	1%	3%	5%	7%	9%
CBR value(%)	7.9	3.7	8.7	23.2	10.5	10.3

CBR values for various PP waste plastic are as shown in Table 4.3 and Figure 4.21.It is found that at 5% CBR value is 23.2 %. It is less than HDPE content and greater than LDPE.

4.1.5 Comparison of CBR value For different waste plastic content

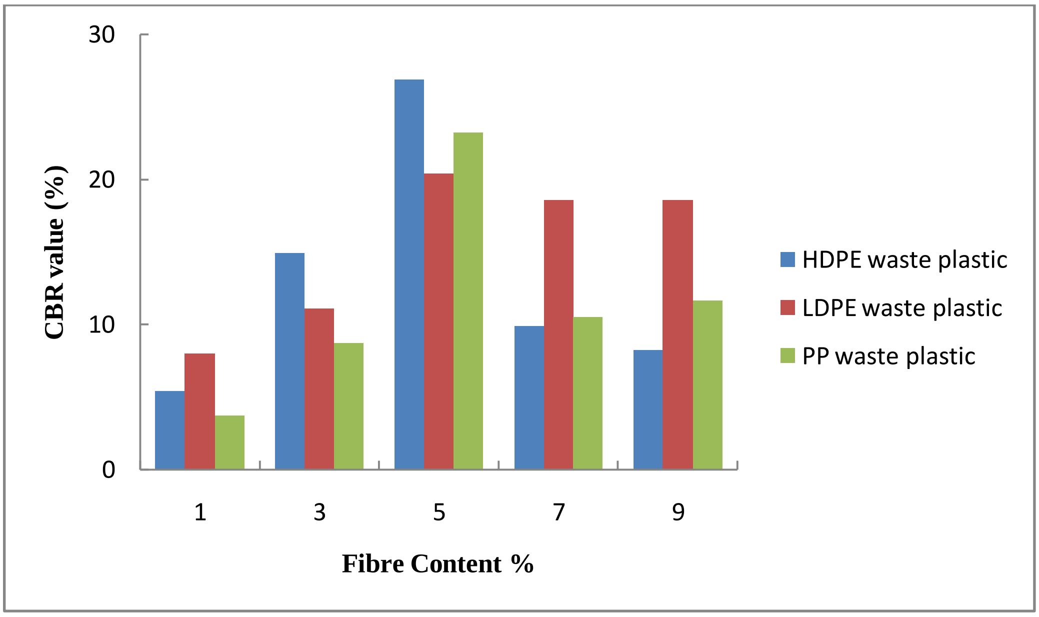


Figure 4.22: **Comparison of CBR value for different waste plastic content**

It was observed mixing of randomly distributed HDPE, LDPE, PP waste plastic increased the CBR value. The CBR value of the unreinforced soil was 7.9 % which were increased to 26.9 %(i.e. 240 % increased) for 5% HDPE waste plastic content. It was found that increase in CBR value is maximum for different waste plastic having 5%. The CBR value for HDPE is maximum and for PP it was in between HDPE & LDPE. Increase in the CBR value due to the presence of waste plastic content by a dimensionless term Bearing Ratio Index (BRI) and has been defined as the ratio of the CBR value of reinforced soil (CBR_r) to the CBR value of unreinforced soil (CBR_u)

$$BRI = \frac{CBR\,r}{CBR\,u}$$

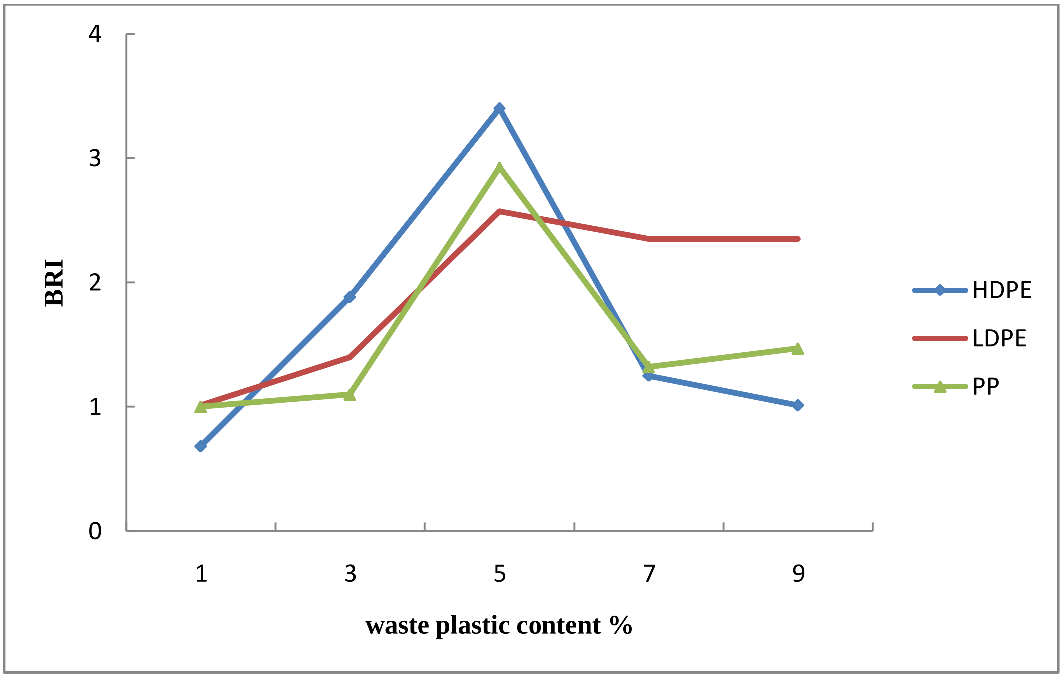


Figure 4.23: **Bearing Ratio Index with different waste plastic content**

Figure 4.23 shows that Bearing Ratio Index (BRI) value was found approximately 3.40 for HDPE waste plastic whereas for LDPE and PP, BRI was 2.57 and 2.93.

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CHAPTER 5

DESIGN OF FLEXIBLE PAVEMENT AS PER IRC:37-2012

5.1 Axle load Survey

Axle load survey has been carried out on the random sampling bases. Selected categories of commercial vehicles were stopped. The enumerators guided the front wheel of the vehicle slowly on the calibrated Axle Load Pad and the readings were recorded on the specially designed format once the readings got stabilized. The vehicle was directed to move ahead slowly till the rear wheel properly mounted on the axle pad. The procedure was repeated while recording the readings on the meter. Axle load survey and Axle load survey coding schedule is shown in ANNEXURE-1

5.2 Calculation of Vehicle Damage Factor (VDF) for Different Vehicles based upon Axle load Survey

The objective of analysis is to estimate the Vehicle Damage Factor (Mode wise) in either direction. The aim of estimating mode wise VDF is to judge the extent of damage by different categories of goods vehicle, having varying load patterns. In order to convert the axle load data into number of Equivalent Standard Axle loads (ESAL's) the axle loads were grouped in the interval of 0.9 Metric Tonnes. The Equivalency factor derived from the **"fourth power rule"** was multiplied with the frequency of that class interval to achieve the Equivalent Standard Axle Load for the weight class of the sample by using the following formulae as per (IRC : 37-2012)

Single axle with single wheel on either side $= \left(\frac{\text{axle load in kN}}{65}\right)^4$

Single axle with dual wheels on either side $= \left(\frac{\text{axle load in kN}}{80}\right)^4$

Tandem axle with dual wheels on either side $= \left(\frac{\text{axle load in kN}}{148}\right)^4$

Tridem axles with dual wheels on either side $= \left(\frac{\text{axle load in kN}}{224}\right)^4$

The summation of ESAL's of all categories giving the total number of ESAL's for total vehicles has been considered. The VDF was obtained by dividing the Total

ESAL’s by the number of vehicles surveyed. The VDF of Bus, LCV, Truck 2 Axle, Truck 3 Axle, Truck 4 Axle, Truck 5 Axle, and Truck 6 Axle are calculated as shown in the Tables from 5.1 to 5.7.

Table 5.1: **VDF for Bus**

Mode: Bus

Axle load category (in tonnes)	No. of axles in each weight range	Load equivalency factors	Equivalent standard axle loads (ESAL's)
< 0.9	0	0.0001	0.000
0.9-1.81	0	0.0024	0.000
1.81-2.72	0	0.0123	0.000
2.72-3.63	3	0.0392	0.117
3.63-4.54	9	0.0958	0.862
4.54-5.44	5	0.1975	0.988
5.44-6.35	7	0.3667	2.567
6.35-7.26	1	0.6266	0.627
7.26-8.16	0	1.0000	0.000
8.16-9.07	0	1.5264	0.000
9.07-9.98	0	2.2375	0.000
9.98-10.89	0	3.1721	0.000
10.89-11.79	1	4.3581	4.358
11.79-12.7	0	5.8675	0.000
12.7-13.61	0	7.7388	0.000
13.61-14.52	0	10.0255	0.000
14.52-15.42	0	12.7520	0.000
15.42-16.32	0	16.0000	0.000
16.32-17.23	0	19.8784	0.000
17.23-18.14	0	24.4224	0.000
18.14-19.051	0	29.7105	0.000

19.051-19.958	0	35.7855	0.000
19.958-20.865	0	42.7477	0.000
20.865-21.772	0	50.6795	0.000
21.772-22.680	0	59.6776	0.000
22.680-23.587	0	69.8120	0.000
23.587-24.494	0	81.1855	0.000
24.494-25.401	0	93.8950	0.000
Total	**26**		**9.519**
No. of Vehicles	**13**		
VDF	**0.73**		

Table 5.2: **VDF for LCV**

Mode: LCV

Axle load category (in tonnes)	**No. of axles in each weight range**	**Load equivalency factors**	**Equivalent standard axle loads (ESAL's)**
< 0.9	0	0.0001	0.000
0.9-1.81	0	0.0024	0.000
1.81-2.72	1	0.0123	0.012
2.72-3.63	12	0.0392	0.470
3.63-4.54	4	0.0958	0.383
4.54-5.44	3	0.1975	0.593
5.44-6.35	8	0.3667	2.934
6.35-7.26	4	0.6266	2.506
7.26-8.16	2	1.0000	2.000
8.16-9.07	0	1.5264	0.000
9.07-9.98	2	2.2375	4.475
9.98-10.89	0	3.1721	0.000

10.89-11.79	1	4.3581	4.358
11.79-12.7	0	5.8675	0.000
12.7-13.61	0	7.7388	0.000
13.61-14.52	0	10.0255	0.000
14.52-15.42	0	12.7520	0.000
15.42-16.32	0	16.0000	0.000
16.32-17.23	0	19.8784	0.000
17.23-18.14	0	24.4224	0.000
18.14-19.051	0	29.7105	0.000
19.051-19.958	0	35.7855	0.000
19.958-20.865	0	42.7477	0.000
20.865-21.772	0	50.6795	0.000
21.772-22.680	0	59.6776	0.000
22.680-23.587	0	69.8120	0.000
23.587-24.494	0	81.1855	0.000
24.494-25.401	0	93.8950	0.000
Total	**37**		**17.731**
No. of Vehicles	**19**		
VDF	**0.93**		

Table 5.3: **VDF for Truck 2 Axle**

Mode: Truck 2 Axle

Axle load category (in tonnes)	No. of axles in each weight range	Load equivalency factors	Equivalent standard axle loads (ESAL's)
< 0.9	0	0.0001	0.000
0.9-1.81	0	0.0024	0.000
1.81-2.72	0	0.0123	0.000

2.72-3.63	0	0.0392	0.000
3.63-4.54	5	0.0958	0.479
4.54-5.44	20	0.1975	3.951
5.44-6.35	44	0.3667	16.136
6.35-7.26	20	0.6266	12.532
7.26-8.16	6	1.0000	6.000
8.16-9.07	0	1.5264	0.000
9.07-9.98	8	2.2375	17.900
9.98-10.89	9	3.1721	28.549
10.89-11.79	19	4.3581	82.803
11.79-12.7	35	5.8675	205.363
12.7-13.61	3	7.7388	23.216
13.61-14.52	1	10.0255	10.025
14.52-15.42	0	12.7520	0.000
15.42-16.32	0	16.0000	0.000
16.32-17.23	0	19.8784	0.000
17.23-18.14	0	24.4224	0.000
18.14-19.051	0	29.7105	0.000
19.051-19.958	0	35.7855	0.000
19.958-20.865	0	42.7477	0.000
20.865-21.772	0	50.6795	0.000
21.772-22.680	0	59.6776	0.000
22.680-23.587	0	69.8120	0.000
23.587-24.494	0	81.1855	0.000
24.494-25.401	0	93.8950	0.000
Total	**170**		**406.955**
No. of Vehicles	**93**		
VDF	**4.38**		

Table 5.4: **VDF for Truck 3 Axle**

Mode: Truck 3 Axle

1) **No. of axles in each weight range Single Axle.**
2) **No. of axles in each weight range Tandem Axle.**
3) **Load equivalency factors Single Axle.**
4) **Load equivalency factors Tandem Axle.**

Axle load category (in tonnes)	(1)	(2)	(3)	(4)	Equivalent standard axle loads (ESAL's)
< 0.9	0	0	0.0001	0.0000	0.000
0.9-1.81	1	0	0.0024	0.0002	0.002
1.81-2.72	0	0	0.0123	0.0011	0.000
2.72-3.63	1	0	0.0392	0.0035	0.039
3.63-4.54	6	0	0.0958	0.0085	0.575
4.54-5.44	24	1	0.1975	0.0174	4.758
5.44-6.35	106	10	0.3667	0.0324	39.196
6.35-7.26	59	2	0.6266	0.0553	37.080
7.26-8.16	16	7	1.0000	1.0000	23.000
8.16-9.07	0	0	1.5264	0.1348	0.000
9.07-9.98	38	37	2.2375	0.1976	92.337
9.98-10.89	35	47	3.1721	0.2802	124.194
10.89-11.79	26	29	4.3581	0.3849	124.473
11.79-12.7	25	18	5.8675	0.5183	156.017
12.7-13.61	10	4	7.7388	0.6836	80.122
13.61-14.52	7	9	10.0255	0.8855	78.148
14.52-15.42	5	3	12.7520	1.1264	67.139
15.42-16.32	0	0	16.0000	1.4133	0.000

16.32-17.23	1	2	19.8784	1.7558	23.390
17.23-18.14	1	0	24.4224	2.1572	24.422
18.14-19.051	0	0	29.7105	2.6243	0.000
19.051-19.958	0	0	35.7855	3.1609	0.000
19.958-20.865	0	0	42.7477	3.7759	0.000
20.865-21.772	0	0	50.6795	4.4765	0.000
21.772-22.680	0	0	59.6776	5.2713	0.000
22.680-23.587	0	0	69.8120	6.1665	0.000
23.587-24.494	0	0	81.1855	7.1711	0.000
24.494-25.401	0	0	93.8950	8.2937	0.000
25.401-26.308	0	0	108.0415	9.5432	0.000
26.308-27.216	0	0	123.7475	10.9306	0.000
27.216-28.123	0	0	141.0867	12.4621	0.000
28.123-29.03	0	0	160.1871	14.1492	0.000
29.03-29.937	0	0	181.1642	16.0021	0.000
29.937-30.844	0	0	204.1372	18.0313	0.000
30.844-31.752	0	0	229.2576	20.2502	0.000
31.752-32.66	0	0	256.6280	22.6678	0.000
32.66-33.566	0	0	286.3108	25.2897	0.000
33.566-34.473	0	0	319.5330	28.2242	0.000
Total	**361**	**169**			**874.893**
No. of Vehicles		**192**			
V D F		**4.56**			

Table 5.5: **VDF for Truck 4 Axle**

Mode: Truck 4 Axle

Axle load category (in tonnes)	**(1)**	**(2)**	**(3)**	**(4)**	**Equivalent standard axle loads (ESAL's)**
< 0.9	0	0	0.0001	0.0000	0.000
0.9-1.81	0	0	0.0024	0.0002	0.000
1.81-2.72	0	0	0.0123	0.0011	0.000
2.72-3.63	0	0	0.0392	0.0035	0.000
3.63-4.54	3	1	0.0958	0.0085	0.296
4.54-5.44	15	1	0.1975	0.0174	2.980
5.44-6.35	15	1	0.3667	0.0324	5.533
6.35-7.26	4	1	0.6266	0.0553	2.562
7.26-8.16	6	7	1.0000	1.0000	13.000
8.16-9.07	0	0	1.5264	0.1348	0.000
9.07-9.98	4	24	2.2375	0.1976	13.693
9.98-10.89	5	9	3.1721	0.2802	18.382
10.89-11.79	1	3	4.3581	0.3849	5.513
11.79-12.7	3	0	5.8675	0.5183	17.603
12.7-13.61	0	1	7.7388	0.6836	0.684
13.61-14.52	0	0	10.0255	0.8855	0.000
14.52-15.42	0	0	12.7520	1.1264	0.000
15.42-16.32	0	0	16.0000	1.4133	0.000
16.32-17.23	0	0	19.8784	1.7558	0.000
17.23-18.14	0	0	24.4224	2.1572	0.000
18.14-19.051	0	0	29.7105	2.6243	0.000
19.051-19.958	0	0	35.7855	3.1609	0.000
19.958-20.865	0	0	42.7477	3.7759	0.000

20.865-21.772	0	0	50.6795	4.4765	0.000
21.772-22.680	0	0	59.6776	5.2713	0.000
22.680-23.587	0	0	69.8120	6.1665	0.000
23.587-24.494	0	0	81.1855	7.1711	0.000
24.494-25.401	0	0	93.8950	8.2937	0.000
25.401-26.308	0	0	108.0415	9.5432	0.000
26.308-27.216	0	0	123.7475	10.9306	0.000
27.216-28.123	0	0	141.0867	12.4621	0.000
28.123-29.03	0	0	160.1871	14.1492	0.000
29.03-29.937	0	0	181.1642	16.0021	0.000
29.937-30.844	0	0	204.1372	18.0313	0.000
30.844-31.752	0	0	229.2576	20.2502	0.000
31.752-32.66	0	0	256.6280	22.6678	0.000
32.66-33.566	0	0	286.3108	25.2897	0.000
33.566-34.473	0	0	319.5330	28.2242	0.000
Total	**56**	**48**			**80.246**
No. of Vehicles		**32**			
V D F		**2.51**			

Table 5.6: **VDF for Truck 5 Axle**

Mode: Truck 5 Axle

Axle load category (in tonnes)	**(1)**	**(2)**	**(3)**	**(4)**	**Equivalent standard axle loads (ESAL's)**
< 0.9	0	0	0.0001	0.0000	0.000
0.9-1.81	0	0	0.0024	0.0002	0.000
1.81-2.72	0	0	0.0123	0.0011	0.000
2.72-3.63	0	0	0.0392	0.0035	0.000

3.63-4.54	0	0	0.0958	0.0085	0.000
4.54-5.44	5	0	0.1975	0.0174	0.988
5.44-6.35	2	0	0.3667	0.0324	0.733
6.35-7.26	0	0	0.6266	0.0553	0.000
7.26-8.16	0	0	1.0000	1.0000	0.000
8.16-9.07	0	0	1.5264	0.1348	0.000
9.07-9.98	0	3	2.2375	0.1976	0.593
9.98-10.89	1	0	3.1721	0.2802	3.172
10.89-11.79	4	4	4.3581	0.3849	18.972
11.79-12.7	0	14	5.8675	0.5183	7.256
12.7-13.61	1	0	7.7388	0.6836	7.739
13.61-14.52	1	0	10.0255	0.8855	10.025
14.52-15.42	0	0	12.7520	1.1264	0.000
15.42-16.32	0	0	16.0000	1.4133	0.000
16.32-17.23	0	0	19.8784	1.7558	0.000
17.23-18.14	0	0	24.4224	2.1572	0.000
18.14-19.051	0	0	29.7105	2.6243	0.000
19.051-19.958	0	0	35.7855	3.1609	0.000
19.958-20.865	0	0	42.7477	3.7759	0.000
20.865-21.772	0	0	50.6795	4.4765	0.000
21.772-22.680	0	0	59.6776	5.2713	0.000
22.680-23.587	0	0	69.8120	6.1665	0.000
23.587-24.494	0	0	81.1855	7.1711	0.000
24.494-25.401	0	0	93.8950	8.2937	0.000
25.401-26.308	0	0	108.0415	9.5432	0.000
26.308-27.216	0	0	123.7475	10.9306	0.000
27.216-28.123	0	0	141.0867	12.4621	0.000
28.123-29.03	0	0	160.1871	14.1492	0.000
29.03-29.937	0	0	181.1642	16.0021	0.000
29.937-30.844	0	0	204.1372	18.0313	0.000

30.844-31.752	0	0	229.2576	20.2502	0.000
31.752-32.66	0	0	256.6280	22.6678	0.000
32.66-33.566	0	0	286.3108	25.2897	0.000
33.566-34.473	0	0	319.5330	28.2242	0.000
Total	**14**	**21**			**49.478**
No. of Vehicles		**7**			
V D F		**7.07**			

Table 5.7: **VDF for Truck 6 Axle**

Mode: Truck 6 Axle

Axle load category (in tonnes)	**(1)**	**(2)**	**(3)**	**(4)**	**Equivalent standard axle loads (ESAL's)**
< 0.9	0	0	0.0001	0.0000	0.000
0.9-1.81	0	0	0.0024	0.0002	0.000
1.81-2.72	0	0	0.0123	0.0011	0.000
2.72-3.63	0	0	0.0392	0.0035	0.000
3.63-4.54	0	0	0.0958	0.0085	0.000
4.54-5.44	1	0	0.1975	0.0174	0.198
5.44-6.35	0	0	0.3667	0.0324	0.000
6.35-7.26	0	0	0.6266	0.0553	0.000
7.26-8.16	0	0	1.0000	1.0000	0.000
8.16-9.07	0	0	1.5264	0.1348	0.000
9.07-9.98	0	3	2.2375	0.1976	0.593
9.98-10.89	0	0	3.1721	0.2802	0.000
10.89-11.79	0	0	4.3581	0.3849	0.000
11.79-12.7	0	0	5.8675	0.5183	0.000

12.7-13.61	0	0	7.7388	0.6836	0.000
13.61-14.52	0	0	10.0255	0.8855	0.000
14.52-15.42	0	0	12.7520	1.1264	0.000
15.42-16.32	0	0	16.0000	1.4133	0.000
16.32-17.23	0	0	19.8784	1.7558	0.000
17.23-18.14	0	0	24.4224	2.1572	0.000
18.14-19.051	0	0	29.7105	2.6243	0.000
19.051-19.958	0	0	35.7855	3.1609	0.000
19.958-20.865	0	0	42.7477	3.7759	0.000
20.865-21.772	0	0	50.6795	4.4765	0.000
21.772-22.680	0	0	59.6776	5.2713	0.000
22.680-23.587	0	0	69.8120	6.1665	0.000
23.587-24.494	0	0	81.1855	7.1711	0.000
24.494-25.401	0	0	93.8950	8.2937	0.000
25.401-26.308	0	0	108.0415	9.5432	0.000
26.308-27.216	0	0	123.7475	10.9306	0.000
27.216-28.123	0	0	141.0867	12.4621	0.000
28.123-29.03	0	0	160.1871	14.1492	0.000
29.03-29.937	0	0	181.1642	16.0021	0.000
29.937-30.844	0	0	204.1372	18.0313	0.000
30.844-31.752	0	0	229.2576	20.2502	0.000
31.752-32.66	0	0	256.6280	22.6678	0.000
32.66-33.566	0	0	286.3108	25.2897	0.000
33.566-34.473	0	0	319.5330	28.2242	0.000
Total	**1**	**3**			**0.790**
No. of Vehicles		**1**			
V D F		**0.79**			

Table 5.8: **VDF for Different Modes**

Sr. No.	Mode	V.D.F.
1	Bus	0.73
2	LCV	0.93
3	Truck (2- Axle)	4.38
4	Truck(3-Axle)	4.56
5	Multi Axle	10.37

5.3 MSA Calculation

MSA has been calculated from the axle survey data and VDF for different modes according to IS specification. For the year 2029 MSA calculated was 141×10^{6} but for the design of flexible pavement value of MSA considered were 150×10^{6}. Calculations for MSA are shown in ANNEXURE-II

5.4 Calculation of Crust Thickness as per IRC: 37-2012

Thickness was calculated according to IRC: 37- 2012 in which CBR plates were given and MSA has been calculated from Axle survey load. Using IITPAVE software various pavement composition was done by comparing calculated strain with the allowable strain as shown in Table 5.9-5.13.

1. Allowable Horizontal Tensile Strain in Bituminous Layer is 153×10^{-6} for VG 40 mixes
2. Allowable Vertical Compressive Strain on Subgrade is 291×10^{-6}

***Table 5.9:* Pavement Composition for Soil Sample CBR 8% without waste plastic content**

PAVEMENT COMPOSITION AS PER IRC:37-2012					
Soil Sample CBR 8% Without waste plastic content					
CASE – I		CBR	8%	MSA	150
		DESIGN YEAR	2029	VDF	As Per VDF Calculations
Pavment Thickness & Composition					
MSA	PAVEMENT THICKNESS (mm)				
150	635	(Required Pavement Thickness)			
Proposed Pavement Thickness					
GSB	**WMM**	**DBM**	**BC**	**TOTAL PAVEMENT**	
200	**250**	**135**	**50**	**635**	
Calculated: **Horizontal Tensile Strain is 150 × 10^{-6}** **Vertical Compressive Strain is 270× 10^{-6}**					

***Table 5.10:* Pavement Composition for Soil Sample CBR 26.9 % with 5% HDPE waste plastic content**

PAVEMENT COMPOSITION AS PER IRC:37-2012					
With 5% HDPE waste plastic					
CASE – II		CBR	26.9%	MSA	150
		DESIGN YEAR	2029	VDF	As Per VDF Calculations
Pavment Thickness & Composition					
MSA	PAVEMENT THICKNESS (mm)				
150	455	(Required Pavement Thickness)			
Proposed Pavement Thickness					
GSB	**WMM**	**DBM**	**BC**	**TOTAL PAVEMENT**	
150	**200**	**70**	**35**	**455**	
Calculated: **Horizontal Tensile Strain is 125 × 10^{-6}** **Vertical Compressive Strain is 281× 10^{-6}**					

***Table 5.11:* Pavement Composition for Soil Sample CBR 20.38 % with 5% LDPE waste plastic content**

PAVEMENT COMPOSITION AS PER IRC:37-2012					
With 5% LDPE waste plastic					
CASE – III		CBR	20.38%	MSA	150
		DESIGN YEAR	2029	VDF	As Per VDF Calculations
Pavement Thickness & Composition					
MSA	PAVEMENT THICKNESS (mm)				
150	490	(Required Pavement Thickness)			
Proposed Pavement Thickness					
GSB	**WMM**	**DBM**	**BC**	**TOTAL PAVEMENT**	
150	**200**	**90**	**50**	**490**	
Calculated: **Horizontal Tensile Strain is 132 × 10^{-6}** **Vertical Compressive Strain is 275× 10^{-6}**					

***Table 5.12:* Pavement Composition for Soil Sample CBR 23.20 % with 5% PP waste plastic content**

PAVEMENT COMPOSITION AS PER IRC:37-2012					
With 5% PP waste plastic					
CASE – IV		CBR	23.20%	MSA	150
		DESIGN PERIOD	16 YEARS	VDF	As Per VDF Calculations
Pavement Thickness & Composition					
MSA	PAVEMENT THICKNESS (mm)				
150	470	(Required Pavement Thickness)			
Proposed Pavement Thickness					
GSB	**WMM**	**DBM**	**BC**	**TOTAL PAVEMENT**	
150	**200**	**80**	**40**	**470**	
Calculated: **Horizontal Tensile Strain is 131 × 10^{-6}** **Vertical Compressive Strain is 283× 10^{-6}**					

Table 5.13: **Crust thickness with different Percentages of Waste plastic**

S.No	Description	Layers	Layer Thickness (mm)
1	Soil Sample without waste plastic content ,CBR 8%	GSB	200
		G. Base	250
		DBM	135
		BC	50
		TOTAL	**635**
2	With 5% HDPE waste plastic content, CBR 26.9%	GSB	150
		G. Base	200
		DBM	70
		BC	35
		TOTAL	**455**
3	With 5% LDPE waste plastic content , CBR 20.38%	GSB	150
		G. Base	200
		DBM	90
		BC	50
		TOTAL	**490**
4	With 5% PP waste plastic content, CBR 23.2%	GSB	150
		G. Base	200
		DBM	80
		BC	40
		TOTAL	**470**

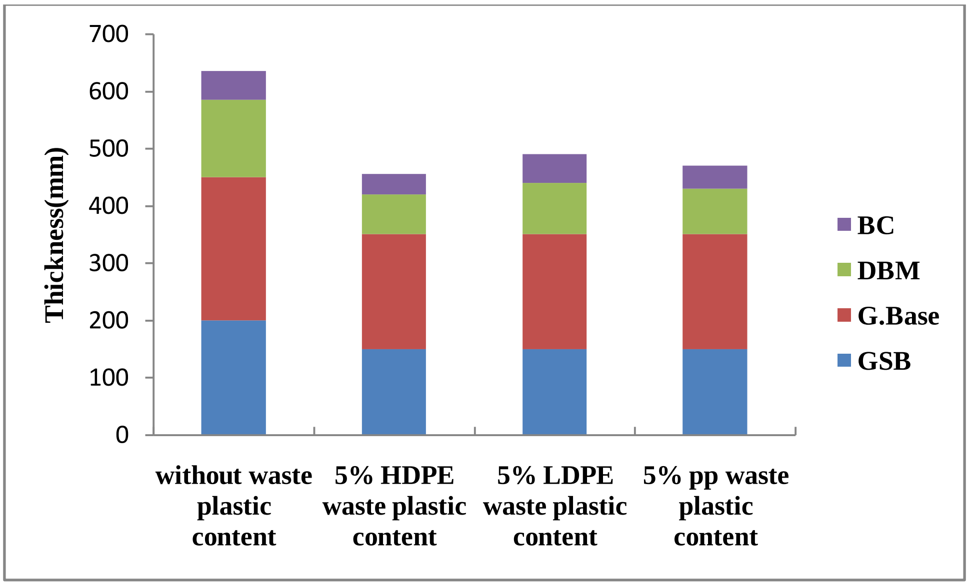

Figure 5.1: **Pavement thickness with various waste plastic content**

Pavement composition has been done with various waste plastic content. It was observed that there is large decrease in pavement thickness with the addition of material. In 5% HDPE waste plastic content the total thickness is reduced from 635mm to 455mm which is maximum as compared to other waste plastic content. Whereas in LDPE and PP it has been reduced 490mm and 470 mm. Pavement compositions for different layer has been shown in Figure 5.1. Strain analysis has been done for all percentages by using IITPAVE software. Horizontal tensile and vertical compressive strain obtained by software was less than the allowable stain as shown in figure 5.2.

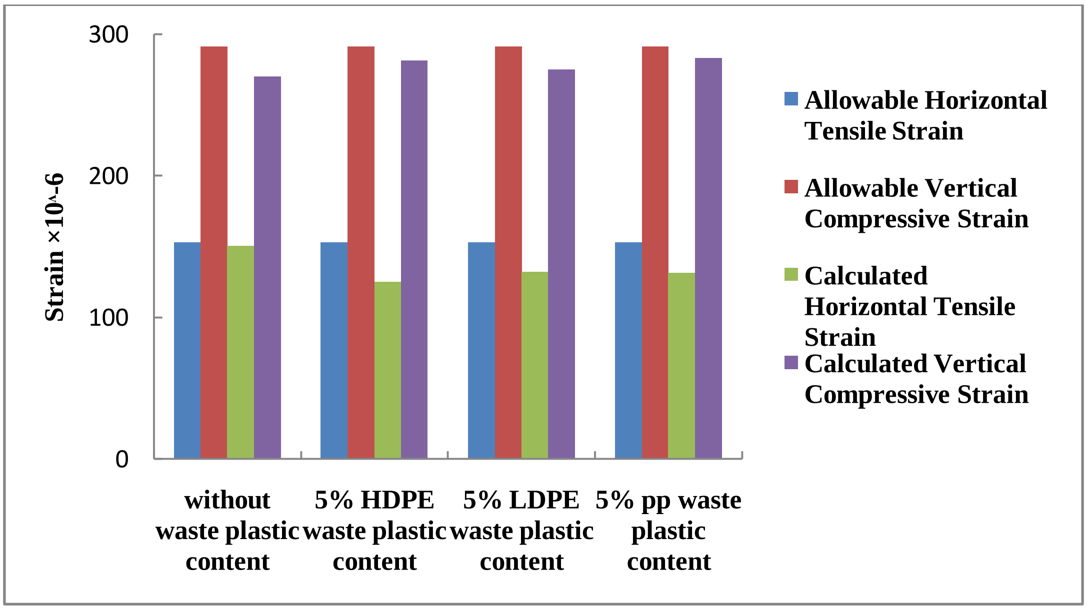

Figure 5.2: **Comparison of Calculated Strain with Allowable Strain**

5.5 Cost Analysis

Cost analysis has been done for road having 1 km length , 8.5 m width as shown in Table 5.14. Cost of different layer has been taken from present rates.

Table 5.14: **Cost analysis**

S.No	Description	Layers	Layer Thickness (mm)	Cost of layer/km (Rs)	Total cost of layer/km (Rs)
1	Soil Sample without waste plastic content	GSB	200	1427	24,25,900
		G. Base	250	1671	35,50,875
		DBM	135	6619	75,95,303
		BC	50	7451	31,66,675
		Waste plastic	-	-	-
		Total Cost of Road per km (Rs)			**1,67,38,753**
2	With 5% HDPE waste plastic content	GSB	150	1427	18,19,425
		G. Base	200	1671	28,50,900
		DBM	70	6619	39,38,305
		BC	35	7451	22,16,673
		Waste plastic	-	-	22,85,965
		Total Cost of Road per km (Rs)			**1,31,11,268**
3	With 5% LDPE waste plastic content	GSB	150	1427	18,19,425
		G. Base	200	1671	28,50,900
		DBM	90	6619	50,63,535
		BC	50	7451	31,66,675
		Waste plastic	-	-	27,01,595
		Total Cost of Road per km (Rs)			**1,56,02,130**
4	With 5% PP waste plastic content	GSB	150	1427	18,19,425
		G. Base	200	1671	28,50,900
		DBM	80	6619	45,00,920
		BC	40	7451	25,33,340

		Waste plastic	-	-	18,70,335
		Total Cost of Road per km (Rs)			**1,35,74,920**

From Table 5.14 it can be observed that Pavement construction cost of 21.6% can be saved by using 5% of HDPE content in the subgrade of the four lane divided carriageway whereas 6.7 % & 18.9% of pavement cost can be saved with 5% of LDPE & PP content in the similar crust section.

CHAPTER 6

CONCLUSION

The feasibility of reinforcing soil with different waste plastic content (i.e. HDPE, LDPE, PP) was investigated in this study. Granular size materials were randomly mixed with locally available soil and tested to determine CBR values. Design of flexible pavement with different material and cost analysis of road was done. Based on the results, the following conclusions can be drawn:

1. Addition of HDPE, LDPE, PP waste plastic, to local soil increases the CBR value.
2. The CBR value of the unreinforced soil was 7.9 % which were increased to 26.9 % for 5% HDPE waste plastic content, 20.38 % for 5% LDPE and 23.2% for 5% PP.
3. The maximum improvement in CBR value was obtained when waste plastic content was 5%. Bearing Ratio Index (BRI) value was found approximately 3.40 for HDPE waste plastic whereas for LDPE and PP, BRI was 2.57 and 2.93.
4. It was observed that there is large decrease in pavement crust thickness with the addition of HDPE, LDPE & PP in the subgrade soil. With 5% HDPE waste plastic content, the total crust thickness was reduced from 635mm to 455mm as compared to LDPE and PP where the reduction in crust is 490mm and 470 mm respectively.
5. Pavement construction cost of 21.6% can be saved by using 5% of HDPE content in the subgrade of the four lane divided carriageway whereas 6.7 % & 18.9% of pavement cost can be saved with 5% of LDPE & PP content in the similar crust section.

Future scope of work

By using these waste plastics in the subgrade, a trial pavement sections can be constructed and the performance of these pavements can be evaluated under the repetitive loading for the rutting and the fatigue distresses.

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ANNEXURE - 1

Axle load survey

S.No.	Vehicle type	Commodity type	Axle Load (Kg) - Single Sides						Axle Load (Tonnes) - Both Sides						Gross Vehicle weight
			FRONT AXLE	REAR AXLE 1	REAR AXLE 2	REAR AXLE 3	REAR AXLE 4	REAR AXLE 5	FRONT AXLE	REAR AXLE 1	REAR AXLE 2	REAR AXLE 3	REAR AXLE 4	REAR AXLE 5	
			Front Axle Single/ Tandem	Axle no 2 S-T	Axle no 3 S-T	Axle no 4 S-T	Axle no 5 S-T	Axle no 65 S-T	Front Axle Single/ Tandem	Axle no 2 S-T	Axle no 3 S-T	Axle no 4 S-T	Axle no 5 S-T	Axle no 6 S-T	
1	6	5	3400	6100					6.800	12.200	0.000	0.000	0.000	0.000	**19.000**
2	6	4	3200	6200					6.400	12.400	0.000	0.000	0.000	0.000	**18.800**
3	8	11	2950	2800	5850	5650			5.900	5.600	11.700	11.300	0.000	0.000	**34.500**
4	7	7	3200	5900	5200				6.400	11.800	10.400	0.000	0.000	0.000	**28.600**
5	7	1	2900	5350	5550				5.800	10.700	11.100	0.000	0.000	0.000	**27.600**
6	5	4	1700	3450					3.400	6.900	0.000	0.000	0.000	0.000	**10.300**
7	7	11	2750	4150	4500				5.500	8.300	9.000	0.000	0.000	0.000	**22.800**
8	7	11	2450	6150	6350				4.900	12.300	12.700	0.000	0.000	0.000	**29.900**

9	7	11	2500	6500	6350				5.000	13.000	12.700	0.000	0.000	0.000	**30.700**
10	7	8	4200	4850	4250				8.400	9.700	8.500	0.000	0.000	0.000	**26.600**
11	4	12	1800	2050					3.600	4.100	0.000	0.000	0.000	0.000	**7.700**
12	10	2	2550	4350	4550	4450	4600	4550	5.100	8.700	9.100	8.900	9.200	9.100	**50.100**
13	8	8	2350	3400	4050	4400			4.700	6.800	8.100	8.800	0.000	0.000	**28.400**
14	6	11	3300	6200					6.600	12.400	0.000	0.000	0.000	0.000	**19.000**
15	5	11	2100	3050					4.200	6.100	0.000	0.000	0.000	0.000	**10.300**
16	5	8	2800	4950					5.600	9.900	0.000	0.000	0.000	0.000	**15.500**
17	7	11	3550	3800	3950				7.100	7.600	7.900	0.000	0.000	0.000	**22.600**
18	5	8	2400	4400					4.800	8.800	0.000	0.000	0.000	0.000	**13.600**
19	7	11	3500	5650	5400				7.000	11.300	10.800	0.000	0.000	0.000	**29.100**
20	6	8	3550	6300					7.100	12.600	0.000	0.000	0.000	0.000	**19.700**
21	5	8	3050	3300					6.100	6.600	0.000	0.000	0.000	0.000	**12.700**
22	7	11	2750	5650	5800				5.500	11.300	11.600	0.000	0.000	0.000	**28.400**
23	6	4	3850	6500					7.700	13.000	0.000	0.000	0.000	0.000	**20.700**

24	6	8	3300	4500					6.600	9.000	0.000	0.000	0.000	0.000	**15.600**
25	7	11	3500	4200	4800				7.000	8.400	9.600	0.000	0.000	0.000	**25.000**
26	7	11	3800	5050	4950				7.600	10.100	9.900	0.000	0.000	0.000	**27.600**
27	6	8	4050	6050					8.100	12.100	0.000	0.000	0.000	0.000	**20.200**
28	6	4	3250	6050					6.500	12.100	0.000	0.000	0.000	0.000	**18.600**
29	7	7	3450	6150	6000				6.900	12.300	12.000	0.000	0.000	0.000	**31.200**
30	6	4	3100	4550					6.200	9.100	0.000	0.000	0.000	0.000	**15.300**
31	5	11	1600	1650					3.200	3.300	0.000	0.000	0.000	0.000	**6.500**
32	7	8	3050	4950	4700				6.100	9.900	9.400	0.000	0.000	0.000	**25.400**
33	8	8	3150	3800	5050	5150			6.300	7.600	10.100	10.300	0.000	0.000	**34.300**
34	6	8	3950	5800					7.900	11.600	0.000	0.000	0.000	0.000	**19.500**
35	6	8	3450	5800					6.900	11.600	0.000	0.000	0.000	0.000	**18.500**
36	6	8	3500	5600					7.000	11.200	0.000	0.000	0.000	0.000	**18.200**
37	7	5	3250	6150	6050				6.500	12.300	12.100	0.000	0.000	0.000	**30.900**
38	7	11	2950	5500	5400				5.900	11.000	10.800	0.000	0.000	0.000	**27.700**

39	7	5	3100	5500	5400				6.200	11.000	10.800	0.000	0.000	0.000	**28.000**
40	7	7	3050	4800	4450				6.100	9.600	8.900	0.000	0.000	0.000	**24.600**
41	7	2	3200	6100	5050				6.400	12.200	10.100	0.000	0.000	0.000	**28.700**
42	7	2	3400	6150	5150				6.800	12.300	10.300	0.000	0.000	0.000	**29.400**
43	7	1	2950	5350	5250				5.900	10.700	10.500	0.000	0.000	0.000	**27.100**
44	7	11	3200	5700	6050				6.400	11.400	12.100	0.000	0.000	0.000	**29.900**
45	4	13	1600	2950					3.200	5.900	0.000	0.000	0.000	0.000	**9.100**
46	8	11	2550	4500	4600	6700			5.100	9.000	9.200	13.400	0.000	0.000	**36.700**
47	6	11	2050	4500					4.100	9.000	0.000	0.000	0.000	0.000	**13.100**
48	6	7	3100	6050					6.200	12.100	0.000	0.000	0.000	0.000	**18.300**
49	6	8	3350	6100					6.700	12.200	0.000	0.000	0.000	0.000	**18.900**
50	6	8	3150	4500					6.300	9.000	0.000	0.000	0.000	0.000	**15.300**
51	6	8	3100	6200					6.200	12.400	0.000	0.000	0.000	0.000	**18.600**
52	7	8	2750	5800	5550				5.500	11.600	11.100	0.000	0.000	0.000	**28.200**
53	4	13	1950	2800					3.900	5.600	0.000	0.000	0.000	0.000	**9.500**

54	7	8	2550	3000	3100				5.100	6.000	6.200	0.000	0.000	0.000	**17.300**
55	7	7	3050	5350	6200				6.100	10.700	12.400	0.000	0.000	0.000	**29.200**
56	7	7	2900	5100	4950				5.800	10.200	9.900	0.000	0.000	0.000	**25.900**
57	7	7	2650	5200	4800				5.300	10.400	9.600	0.000	0.000	0.000	**25.300**
58	8	3	2500	6150	4000	4600			5.000	12.300	8.000	9.200	0.000	0.000	**34.500**
59	7	1	3150	5250	5050				6.300	10.500	10.100	0.000	0.000	0.000	**26.900**
60	7	11	3100	5350	5150				6.200	10.700	10.300	0.000	0.000	0.000	**27.200**
61	7	11	2800	5250	5500				5.600	10.500	11.000	0.000	0.000	0.000	**27.100**
62	7	11	3200	6100	5950				6.400	12.200	11.900	0.000	0.000	0.000	**30.500**
63	7	2	2900	5250	5600				5.800	10.500	11.200	0.000	0.000	0.000	**27.500**
64	7	7	3400	4850	5280				6.800	9.700	10.560	0.000	0.000	0.000	**27.060**
65	7	11	2800	2700	3000				5.600	5.400	6.000	0.000	0.000	0.000	**17.000**
66	7	7	3000	4800	4650				6.000	9.600	9.300	0.000	0.000	0.000	**24.900**
67	7	11	3550	5050	5350				7.100	10.100	10.700	0.000	0.000	0.000	**27.900**
68	7	8	3050	4650	4500				6.100	9.300	9.000	0.000	0.000	0.000	**24.400**

69	7	6	4150	8700	8450				8.300	17.400	16.900	0.000	0.000	0.000	**42.600**
70	7	11	3400	6150	6200				6.800	12.300	12.400	0.000	0.000	0.000	**31.500**
71	6	8	2650	5800					5.300	11.600	0.000	0.000	0.000	0.000	**16.900**
72	7	11	3100	4450	4300				6.200	8.900	8.600	0.000	0.000	0.000	**23.700**
73	7	8	4200	4250	4100				8.400	8.500	8.200	0.000	0.000	0.000	**25.100**
74	7	7	3400	5450	5350				6.800	10.900	10.700	0.000	0.000	0.000	**28.400**
75	7	7	3700	5700	5350				7.400	11.400	10.700	0.000	0.000	0.000	**29.500**
76	7	11	3100	6250	6100				6.200	12.500	12.200	0.000	0.000	0.000	**30.900**
77	7	8	3050	3400	3200				6.100	6.800	6.400	0.000	0.000	0.000	**19.300**
78	5	11	1750	5750					3.500	11.500	0.000	0.000	0.000	0.000	**15.000**
79	6	11	2550	4550					5.100	9.100	0.000	0.000	0.000	0.000	**14.200**
80	7	9	3500	7100	6850				7.000	14.200	13.700	0.000	0.000	0.000	**34.900**
81	7	11	3150	6300	6400				6.300	12.600	12.800	0.000	0.000	0.000	**31.700**
82	6	8	2850	4500					5.700	9.000	0.000	0.000	0.000	0.000	**14.700**
83	5	11	2550	4850					5.100	9.700	0.000	0.000	0.000	0.000	**14.800**

84	6	11	3000	6050					6.000	12.100	0.000	0.000	0.000	0.000	**18.100**
85	6	6	3200	6550					6.400	13.100	0.000	0.000	0.000	0.000	**19.500**
86	7	11	3050	3900	4350				6.100	7.800	8.700	0.000	0.000	0.000	**22.600**
87	7	11	2800	4300	4500				5.600	8.600	9.000	0.000	0.000	0.000	**23.200**
88	5	5	2050	3150					4.100	6.300	0.000	0.000	0.000	0.000	**10.400**
89	7	6	4500	8250	8450				9.000	16.500	16.900	0.000	0.000	0.000	**42.400**
90	5	11	1100	1750					2.200	3.500	0.000	0.000	0.000	0.000	**5.700**
91	4	13	2050	2650					4.100	5.300	0.000	0.000	0.000	0.000	**9.400**
92	7	7	3400	4400	5050				6.800	8.800	10.100	0.000	0.000	0.000	**25.700**
93	6	11	2250	3100					4.500	6.200	0.000	0.000	0.000	0.000	**10.700**
94	9	2	2950	6850	6200	5700	5850		5.900	13.700	12.400	11.400	11.700	0.000	**55.100**
95	8	3	2550	5050	3050	3200			5.100	10.100	6.100	6.400	0.000	0.000	**27.700**
96	6	8	3050	5950					6.100	11.900	0.000	0.000	0.000	0.000	**18.000**
97	6	8	2250	6300					4.500	12.600	0.000	0.000	0.000	0.000	**17.100**
98	7	8	3850	4850	4700				7.700	9.700	9.400	0.000	0.000	0.000	**26.800**

99	7	8	3200	5050	4900				6.400	10.100	9.800	0.000	0.000	0.000	**26.300**
100	7	8	3800	4850	4750				7.600	9.700	9.500	0.000	0.000	0.000	**26.800**
101	8	8	2200	4600	4950	4900			4.400	9.200	9.900	9.800	0.000	0.000	**33.300**
102	7	7	3450	4950	4900				6.900	9.900	9.800	0.000	0.000	0.000	**26.600**
103	6	11	3050	6050					6.100	12.100	0.000	0.000	0.000	0.000	**18.200**
104	7	11	2950	6250	6100				5.900	12.500	12.200	0.000	0.000	0.000	**30.600**
105	8	8	2400	4700	5200	5150			4.800	9.400	10.400	10.300	0.000	0.000	**34.900**
106	6	11	2750	6200					5.500	12.400	0.000	0.000	0.000	0.000	**17.900**
107	6	3	3500	5850					7.000	11.700	0.000	0.000	0.000	0.000	**18.700**
108	7	1	2850	4900	5200				5.700	9.800	10.400	0.000	0.000	0.000	**25.900**
109	7	11	3400	485	4900				6.800	0.970	9.800	0.000	0.000	0.000	**17.570**
110	6	8	2300	6150					4.600	12.300	0.000	0.000	0.000	0.000	**16.900**
111	7	7	3050	5200	5300				6.100	10.400	10.600	0.000	0.000	0.000	**27.100**
112	7	1	2800	4050	4200				5.600	8.100	8.400	0.000	0.000	0.000	**22.100**
113	6	11	3200	6350					6.400	12.700	0.000	0.000	0.000	0.000	**19.100**

114	6	8	3100	5400					6.200	10.800	0.000	0.000	0.000	0.000	**17.000**
115	7	7	3500	5900	5800				7.000	11.800	11.600	0.000	0.000	0.000	**30.400**
116	5	7	1600	3850					3.200	7.700	0.000	0.000	0.000	0.000	**10.900**
117	6	8	3150	4500					6.300	9.000	0.000	0.000	0.000	0.000	**15.300**
118	8	3	2700	4150	4500	4150			5.400	8.300	9.000	8.300	0.000	0.000	**31.000**
119	6	8	2650	4500					5.300	9.000	0.000	0.000	0.000	0.000	**14.300**
120	7	11	3300	4850	5650				6.600	9.700	11.300	0.000	0.000	0.000	**27.600**
121	7	7	3350	4750	4850				6.700	9.500	9.700	0.000	0.000	0.000	**25.900**
122	6	11	2900	6200					5.800	12.400	0.000	0.000	0.000	0.000	**18.200**
123	8	3	2950	4500	4900	5450			5.900	9.000	9.800	10.900	0.000	0.000	**35.600**
124	7	11	3150	5250	5100				6.300	10.500	10.200	0.000	0.000	0.000	**27.000**
125	7	8	2950	4800	4900				5.900	9.600	9.800	0.000	0.000	0.000	**25.300**
126	7	4	2650	2750	2800				5.300	5.500	5.600	0.000	0.000	0.000	**16.400**
127	7	11	2550	4800	5300				5.100	9.600	10.600	0.000	0.000	0.000	**25.300**
128	7	11	2700	5200	5100				5.400	10.400	10.200	0.000	0.000	0.000	**26.000**

129	6	6	3950	7250					7.900	14.500	0.000	0.000	0.000	0.000	**22.400**
130	7	7	3300	5050	4950				6.600	10.100	9.900	0.000	0.000	0.000	**26.600**
131	6	8	3000	5850					6.000	11.700	0.000	0.000	0.000	0.000	**17.700**
132	6	8	2800	5900					5.600	11.800	0.000	0.000	0.000	0.000	**17.400**
133	7	7	3650	4000	4150				7.300	8.000	8.300	0.000	0.000	0.000	**23.600**
134	7	7	2950	4600	4800				5.900	9.200	9.600	0.000	0.000	0.000	**24.700**
135	7	11	2450	2850	3050				4.900	5.700	6.100	0.000	0.000	0.000	**16.700**
136	7	11	2300	4050	4050				4.600	8.100	8.100	0.000	0.000	0.000	**20.800**
137	5	7	1800	3050					3.600	6.100	0.000	0.000	0.000	0.000	**9.700**
138	7	2	3150	5050	4850				6.300	10.100	9.700	0.000	0.000	0.000	**26.100**
139	6	3	2750	5800					5.500	11.600	0.000	0.000	0.000	0.000	**17.100**
140	4	13	2100	2650					4.200	5.300	0.000	0.000	0.000	0.000	**9.500**
141	7	7	2900	7200	7050				5.800	14.400	14.100	0.000	0.000	0.000	**34.300**
142	7	8	2150	2350	2500				4.300	4.700	5.000	0.000	0.000	0.000	**14.000**
143	7	6	3350	4850	5000				6.700	9.700	10.000	0.000	0.000	0.000	**26.400**

144	6	8	3450	5800					6.900	11.600	0.000	0.000	0.000	0.000	**18.500**
145	5	7	1700	2250					3.400	4.500	0.000	0.000	0.000	0.000	**7.900**
146	4	13	1750	3050					3.500	6.100	0.000	0.000	0.000	0.000	**9.600**
147	4	13	2050	2900					4.100	5.800	0.000	0.000	0.000	0.000	**9.900**
148	7	11	2700	4800	4900				5.400	9.600	9.800	0.000	0.000	0.000	**24.800**
149	7	11	1750	3750	3800				3.500	7.500	7.600	0.000	0.000	0.000	**18.600**
150	7	11	3450	4600	5000				6.900	9.200	10.000	0.000	0.000	0.000	**26.100**
151	7	11	3400	5000	5700				6.800	10.000	11.400	0.000	0.000	0.000	**28.200**
152	6	8	2950	5400					5.900	10.800	0.000	0.000	0.000	0.000	**16.700**
153	7	4	2850	3350	4200				5.700	6.700	8.400	0.000	0.000	0.000	**20.800**
154	7	11	3200	4850	4650				6.400	9.700	9.300	0.000	0.000	0.000	**25.400**
155	6	11	2350	5600					4.700	11.200	0.000	0.000	0.000	0.000	**15.900**
156	8	8	2150	2350	1850	2600			4.300	4.700	3.700	5.200	0.000	0.000	**17.900**
157	6	3	2850	6650					5.700	13.300	0.000	0.000	0.000	0.000	**19.000**
158	6	8	3050	6050					6.100	12.100	0.000	0.000	0.000	0.000	**18.200**

159	7	3	3250	4700	4950				6.500	9.400	9.900	0.000	0.000	0.000	**25.800**
160	6	3	2900	6050					5.800	12.100	0.000	0.000	0.000	0.000	**17.900**
161	7	11	3100	6350	6100				6.200	12.700	12.200	0.000	0.000	0.000	**31.100**
162	7	7	2750	5050	5650				5.500	10.100	11.300	0.000	0.000	0.000	**26.900**
163	6	8	2800	5900					5.600	11.800	0.000	0.000	0.000	0.000	**17.400**
165	7	2	2800	4200	4600				5.600	8.400	9.200	0.000	0.000	0.000	**23.200**
166	7	7	3000	4850	5000				6.000	9.700	10.000	0.000	0.000	0.000	**25.700**
167	6	8	2800	5750					5.600	11.500	0.000	0.000	0.000	0.000	**17.100**
168	6	3	3600	5850					7.200	11.700	0.000	0.000	0.000	0.000	**18.900**
169	8	3	3100	3750	4600	4950			6.200	7.500	9.200	9.900	0.000	0.000	**32.800**
170	8	3	2900	4200	4900	5050			5.800	8.400	9.800	10.100	0.000	0.000	**34.100**
171	8	3	2500	5300	4800	4650			5.000	10.600	9.600	9.300	0.000	0.000	**34.500**
172	9	4	2400	5350	5800	5950	6100		4.800	10.700	11.600	11.900	12.200	0.000	**51.200**
173	9	4	2500	5500	6050	6200	6150		5.000	11.000	12.100	12.400	12.300	0.000	**52.800**
174	6	2	2950	4500					5.900	9.000	0.000	0.000	0.000	0.000	**14.900**

175	6	7	2750	5650					5.500	11.300	0.000	0.000	0.000	0.000	**16.800**
176	8	4	2800	6300	4050	4100			5.600	12.600	8.100	8.200	0.000	0.000	**34.500**
177	7	11	2950	6100	4800				5.900	12.200	9.600	0.000	0.000	0.000	**27.700**
178	7	2	3200	5600	5550				6.400	11.200	11.100	0.000	0.000	0.000	**28.700**
179	7	7	3350	4850	5050				6.700	9.700	10.100	0.000	0.000	0.000	**26.500**
180	6	8	2650	5300					5.300	10.600	0.000	0.000	0.000	0.000	**15.900**
181	7	11	3150	5700	5650				6.300	11.400	11.300	0.000	0.000	0.000	**29.000**
182	7	7	3200	5750	5600				6.400	11.500	11.200	0.000	0.000	0.000	**29.100**
183	7	7	3400	6100	5950				6.800	12.200	11.900	0.000	0.000	0.000	**30.900**
184	8	8	2350	4200	4400	4700			4.700	8.400	8.800	9.400	0.000	0.000	**31.300**
185	8	11	2900	4050	4800	4700			5.800	8.100	9.600	9.400	0.000	0.000	**32.900**
186	7	1	2750	4950	5050				5.500	9.900	10.100	0.000	0.000	0.000	**25.500**
187	7	7	2600	4600	4750				5.200	9.200	9.500	0.000	0.000	0.000	**23.900**
188	6	7	2700	5900					5.400	11.800	0.000	0.000	0.000	0.000	**17.200**
189	7	11	3550	5550	5350				7.100	11.100	10.700	0.000	0.000	0.000	**28.900**

190	4	13	1950	3100					3.900	6.200	0.000	0.000	0.000	0.000	**10.100**
191	4	13	2950	5500					5.900	11.000	0.000	0.000	0.000	0.000	**16.900**
192	7	8	3100	4650	4850				6.200	9.300	9.700	0.000	0.000	0.000	**25.200**
193	6	3	3600	5400					7.200	10.800	0.000	0.000	0.000	0.000	**18.000**
194	6	8	2650	5900					5.300	11.800	0.000	0.000	0.000	0.000	**17.100**
195	6	8	3050	5400					6.100	10.800	0.000	0.000	0.000	0.000	**16.900**
196	7	11	2750	4100	3850				5.500	8.200	7.700	0.000	0.000	0.000	**21.400**
197	7	6	3050	5800	5100				6.100	11.600	10.200	0.000	0.000	0.000	**27.900**
198	7	7	3100	5450	5500				6.200	10.900	11.000	0.000	0.000	0.000	**28.100**
199	6	11	2450	6050					4.900	12.100	0.000	0.000	0.000	0.000	**17.000**
200	6	4	2550	5700					5.100	11.400	0.000	0.000	0.000	0.000	**16.500**
201	7	11	3250	5250	5450				6.500	10.500	10.900	0.000	0.000	0.000	**27.900**
202	7	7	3250	5550	5400				6.500	11.100	10.800	0.000	0.000	0.000	**28.400**
203	7	1	2700	4200	4100				5.400	8.400	8.200	0.000	0.000	0.000	**22.000**
204	7	11	3250	4850	4650				6.500	9.700	9.300	0.000	0.000	0.000	**25.500**

205	6	2	2700	3500					5.400	7.000	0.000	0.000	0.000	0.000	**12.400**
206	7	2	3200	4000	3800				6.400	8.000	7.600	0.000	0.000	0.000	**22.000**
207	7	11	2600	4900	4750				5.200	9.800	9.500	0.000	0.000	0.000	**24.500**
208	6	11	2950	6250					5.900	12.500	0.000	0.000	0.000	0.000	**18.400**
209	7	7	2800	5550	5450				5.600	11.100	10.900	0.000	0.000	0.000	**27.600**
210	7	4	3200	6050	6000				6.400	12.100	12.000	0.000	0.000	0.000	**30.500**
211	6	6	3100	6100					6.200	12.200	0.000	0.000	0.000	0.000	**18.400**
212	6	11	2700	5350					5.400	10.700	0.000	0.000	0.000	0.000	**16.100**
213	7	6	2900	6500	6050				5.800	13.000	12.100	0.000	0.000	0.000	**30.900**
214	7	6	3000	6050	5850				6.000	12.100	11.700	0.000	0.000	0.000	**29.800**
215	4	13	2550	3200					5.100	6.400	0.000	0.000	0.000	0.000	**11.500**
216	6	4	2850	4500					5.700	9.000	0.000	0.000	0.000	0.000	**14.700**
217	6	4	3050	4500					6.100	9.000	0.000	0.000	0.000	0.000	**15.100**
218	7	5	3400	7500	7350				6.800	15.000	14.700	0.000	0.000	0.000	**36.500**
219	7	11	2700	4500	4400				5.400	9.000	8.800	0.000	0.000	0.000	**23.200**

220	7	1	2850	4950	4800				5.700	9.900	9.600	0.000	0.000	0.000	**25.200**
221	6	7	3100	5200					6.200	10.400	0.000	0.000	0.000	0.000	**16.600**
222	7	2	2850	4800	4750				5.700	9.600	9.500	0.000	0.000	0.000	**24.800**
223	7	7	3000	5550	5350				6.000	11.100	10.700	0.000	0.000	0.000	**27.800**
224	6	11	2300	4550					4.600	9.100	0.000	0.000	0.000	0.000	**13.700**
225	7	7	3600	7100	7050				7.200	14.200	14.100	0.000	0.000	0.000	**35.500**
226	8	4	3200	6050	5200	5050			6.400	12.100	10.400	10.100	0.000	0.000	**39.000**
227	7	1	2700	4050	3900				5.400	8.100	7.800	0.000	0.000	0.000	**21.300**
228	7	11	3050	5200	5750				6.100	10.400	11.500	0.000	0.000	0.000	**28.000**
229	7	7	2950	5100	4800				5.900	10.200	9.600	0.000	0.000	0.000	**25.700**
230	8	11	2400	4050	4000	4050			4.800	8.100	8.000	8.100	0.000	0.000	**29.000**
231	8	4	2600	4400	4250	4250			5.200	8.800	8.500	8.500	0.000	0.000	**31.000**
232	7	11	2750	6050	5850				5.500	12.100	11.700	0.000	0.000	0.000	**29.300**
233	7	4	2850	5500	5300				5.700	11.000	10.600	0.000	0.000	0.000	**27.300**
234	7	3	3200	6200	6000				6.400	12.400	12.000	0.000	0.000	0.000	**30.800**

235	8	4	2700	4800	4300	4450			5.400	9.600	8.600	8.900	0.000	0.000	**32.500**
236	7	6	3500	7200	5750				7.000	14.400	11.500	0.000	0.000	0.000	**32.900**
237	7	7	3300	5800	5750				6.600	11.600	11.500	0.000	0.000	0.000	**29.700**
238	5	7	2700	4050					5.400	8.100	0.000	0.000	0.000	0.000	**13.500**
239	6	11	2800	4500					5.600	9.000	0.000	0.000	0.000	0.000	**14.600**
240	7	7	3150	6100	5850				6.300	12.200	11.700	0.000	0.000	0.000	**30.200**
241	7	8	2950	5250	5100				5.900	10.500	10.200	0.000	0.000	0.000	**26.600**
242	7	8	2750	5300	5150				5.500	10.600	10.300	0.000	0.000	0.000	**26.400**
243	7	6	3400	6250	6050				6.800	12.500	12.100	0.000	0.000	0.000	**31.400**
244	7	7	2950	5450	5550				5.900	10.900	11.100	0.000	0.000	0.000	**27.900**
245	7	4	3100	6550	5300				6.200	13.100	10.600	0.000	0.000	0.000	**29.900**
246	6	6	3200	6100					6.400	12.200	0.000	0.000	0.000	0.000	**18.600**
247	7	11	2750	4900	4850				5.500	9.800	9.700	0.000	0.000	0.000	**25.000**
248	7	4	2900	5200	5450				5.800	10.400	10.900	0.000	0.000	0.000	**27.100**
249	6	11	2450	4550					4.900	9.100	0.000	0.000	0.000	0.000	**14.000**

250	6	8	3050	5850					6.100	11.700	0.000	0.000	0.000	0.000	**17.800**
251	7	7	2900	6800	6650				5.800	13.600	13.300	0.000	0.000	0.000	**32.700**
252	7	6	2950	7200	7050				5.900	14.400	14.100	0.000	0.000	0.000	**34.400**
253	7	7	3100	5800	5750				6.200	11.600	11.500	0.000	0.000	0.000	**29.300**
254	7	2	2900	6550	6500				5.800	13.100	13.000	0.000	0.000	0.000	**31.900**
255	7	11	3600	7500	7550				7.200	15.000	15.100	0.000	0.000	0.000	**37.300**
256	7	7	3300	6500	6250				6.600	13.000	12.500	0.000	0.000	0.000	**32.100**
257	7	7	2850	5500	5400				5.700	11.000	10.800	0.000	0.000	0.000	**27.500**
258	7	3	3100	5800	5650				6.200	11.600	11.300	0.000	0.000	0.000	**29.100**
259	6	6	3400	6200					6.800	12.400	0.000	0.000	0.000	0.000	**19.200**
260	7	9	3600	7200	6950				7.200	14.400	13.900	0.000	0.000	0.000	**35.500**
261	7	11	2850	5050	5100				5.700	10.100	10.200	0.000	0.000	0.000	**26.000**
262	7	8	2950	4800	4950				5.900	9.600	9.900	0.000	0.000	0.000	**25.400**
263	7	7	2850	6050	6300				5.700	12.100	12.600	0.000	0.000	0.000	**30.400**
264	7	7	2700	5400	5250				5.400	10.800	10.500	0.000	0.000	0.000	**26.700**

265	7	11	2800	4300	4450				5.600	8.600	8.900	0.000	0.000	0.000	**23.100**
266	7	7	2950	6250	6050				5.900	12.500	12.100	0.000	0.000	0.000	**30.500**
267	7	7	2950	5550	5300				5.900	11.100	10.600	0.000	0.000	0.000	**27.600**
268	6	6	3100	4500					6.200	9.000	0.000	0.000	0.000	0.000	**15.200**
269	6	11	2850	4550					5.700	9.100	0.000	0.000	0.000	0.000	**14.800**
270	7	7	3050	4700	4800				6.100	9.400	9.600	0.000	0.000	0.000	**25.100**
271	7	7	2750	5100	4950				5.500	10.200	9.900	0.000	0.000	0.000	**25.600**
272	8	8	2900	5800	4600	4700			5.800	11.600	9.200	9.400	0.000	0.000	**36.000**
273	7	11	3400	6500	6350				6.800	13.000	12.700	0.000	0.000	0.000	**32.500**
274	8	4	3100	5200	4500	4700			6.200	10.400	9.000	9.400	0.000	0.000	**35.000**
275	7	7	2800	4400	4650				5.600	8.800	9.300	0.000	0.000	0.000	**23.700**
276	7	11	3050	4900	5050				6.100	9.800	10.100	0.000	0.000	0.000	**26.000**
277	6	7	2050	4500					4.100	9.000	0.000	0.000	0.000	0.000	**13.100**
278	5	11	1850	2900					3.700	5.800	0.000	0.000	0.000	0.000	**9.500**
279	7	7	2850	4700	4750				5.700	9.400	9.500	0.000	0.000	0.000	**24.600**

280	7	11	2600	3800	3650				5.200	7.600	7.300	0.000	0.000	0.000	**20.100**
281	9	4	2700	5550	4850	4700	4600		5.400	11.100	9.700	9.400	9.200	0.000	**44.800**
282	8	4	2950	5400	4350	4200			5.900	10.800	8.700	8.400	0.000	0.000	**33.800**
283	4	13	2050	2550					4.100	5.100	0.000	0.000	0.000	0.000	**9.200**
284	5	11	1750	3000					3.500	6.000	0.000	0.000	0.000	0.000	**9.500**
285	7	2	3200	4500	4450				6.400	9.000	8.900	0.000	0.000	0.000	**24.300**
286	6	11	2850	4500					5.700	9.000	0.000	0.000	0.000	0.000	**14.700**
287	8	4	3150	4900	4400	4500			6.300	9.800	8.800	9.000	0.000	0.000	**33.900**
288	7	1	2800	5050	4800				5.600	10.100	9.600	0.000	0.000	0.000	**25.300**
289	7	2	3400	6050	5200				6.800	12.100	10.400	0.000	0.000	0.000	**29.300**
290	8	8	2350	3600	4200	4050			4.700	7.200	8.400	8.100	0.000	0.000	**28.400**
291	9	4	2500	5500	5850	6050	6200		5.000	11.000	11.700	12.100	12.400	0.000	**52.200**
292	6	3	2800	5900					5.600	11.800	0.000	0.000	0.000	0.000	**17.400**
293	6	3	2900	6050					5.800	12.100	0.000	0.000	0.000	0.000	**17.900**
294	5	11	1550	3100					3.100	6.200	0.000	0.000	0.000	0.000	**9.300**

295	7	7	3200	5400	5350				6.400	10.800	10.700	0.000	0.000	0.000	**27.900**
296	7	3	2900	5100	5050				5.800	10.200	10.100	0.000	0.000	0.000	**26.100**
297	7	7	2900	5300	5050				5.800	10.600	10.100	0.000	0.000	0.000	**26.500**
298	6	5	3250	5400					6.500	10.800	0.000	0.000	0.000	0.000	**17.300**
299	6	6	3100	5800					6.200	11.600	0.000	0.000	0.000	0.000	**17.800**
300	7	4	2550	2700	2850				5.100	5.400	5.700	0.000	0.000	0.000	**16.200**
301	7	1	3050	5200	5100				6.100	10.400	10.200	0.000	0.000	0.000	**26.700**
302	7	4	3200	6050	6050				6.400	12.100	12.100	0.000	0.000	0.000	**30.600**
303	8	8	3050	3650	5050	4800			6.100	7.300	10.100	9.600	0.000	0.000	**33.100**
304	7	11	2850	5600	5850				5.700	11.200	11.700	0.000	0.000	0.000	**28.600**
305	7	5	3050	6400	6600				6.100	12.800	13.200	0.000	0.000	0.000	**32.100**
306	7	8	2250	3050	3200				4.500	6.100	6.400	0.000	0.000	0.000	**17.000**
307	6	7	2600	4550					5.200	9.100	0.000	0.000	0.000	0.000	**14.300**
308	7	2	3050	6150	5400				6.100	12.300	10.800	0.000	0.000	0.000	**29.200**
309	6	8	4000	4500					8.000	9.000	0.000	0.000	0.000	0.000	**17.000**

310	7	9	3250	7400	7200				6.500	14.800	14.400	0.000	0.000	0.000	**35.700**
311	6	5	2900	4550					5.800	9.100	0.000	0.000	0.000	0.000	**14.900**
312	7	2	2950	5250	5600				5.900	10.500	11.200	0.000	0.000	0.000	**27.600**
313	7	5	2750	6900	6850				5.500	13.800	13.700	0.000	0.000	0.000	**33.000**
314	7	1	2950	4800	5000				5.900	9.600	10.000	0.000	0.000	0.000	**25.500**
315	8	8	2200	4400	4650	4550			4.400	8.800	9.300	9.100	0.000	0.000	**31.600**
316	6	8	2700	5950					5.400	11.900	0.000	0.000	0.000	0.000	**17.300**
317	5	11	1600	3500					3.200	7.000	0.000	0.000	0.000	0.000	**10.200**
318	7	1	2700	4900	5200				5.400	9.800	10.400	0.000	0.000	0.000	**25.600**
319	4	13	2250	2850					4.500	5.700	0.000	0.000	0.000	0.000	**10.200**
320	6	3	2700	5800					5.400	11.600	0.000	0.000	0.000	0.000	**17.000**
321	6	4	2600	5400					5.200	10.800	0.000	0.000	0.000	0.000	**16.000**
322	9	2	2750	6600	6200	6050	6200		5.500	13.200	12.400	12.100	12.400	0.000	**55.600**
323	7	8	2100	2750	2900				4.200	5.500	5.800	0.000	0.000	0.000	**15.500**
324	6	8	3900	6050					7.800	12.100	0.000	0.000	0.000	0.000	**19.900**

325	7	4	2700	5350	5300				5.400	10.700	10.600	0.000	0.000	0.000	**26.700**
326	7	6	2950	4650	4800				5.900	9.300	9.600	0.000	0.000	0.000	**24.800**
327	7	11	3050	4500	4400				6.100	9.000	8.800	0.000	0.000	0.000	**23.900**
328	6	5	3050	5800					6.100	11.600	0.000	0.000	0.000	0.000	**17.700**
329	7	4	2950	6400	5800				5.900	12.800	11.600	0.000	0.000	0.000	**30.300**
`330	7	11	3050	3850	4250				6.100	7.700	8.500	0.000	0.000	0.000	**22.300**
331	6	8	3600	6050					7.200	12.100	0.000	0.000	0.000	0.000	**19.300**
332	7	8	2050	2750	2850				4.100	5.500	5.700	0.000	0.000	0.000	**15.300**
333	7	6	3150	4900	5400				6.300	9.800	10.800	0.000	0.000	0.000	**26.900**
334	8	8	2350	4350	4600	4650			4.700	8.700	9.200	9.300	0.000	0.000	**31.900**
335	6	6	2850	5900					5.700	11.800	0.000	0.000	0.000	0.000	**17.500**
336	8	4	2750	5050	4800	4600			5.500	10.100	9.600	9.200	0.000	0.000	**34.400**
337	7	9	3600	6600	6850				7.200	13.200	13.700	0.000	0.000	0.000	**34.100**
338	7	1	2750	4300	4250				5.500	8.600	8.500	0.000	0.000	0.000	**22.600**
339	6	4	2750	4500					5.500	9.000	0.000	0.000	0.000	0.000	**14.500**

340	7	2	2800	4200	4600				5.600	8.400	9.200	0.000	0.000	0.000	**23.200**
341	7	5	2850	7300	7450				5.700	14.600	14.900	0.000	0.000	0.000	**35.200**
342	6	11	1900	4550					3.800	9.100	0.000	0.000	0.000	0.000	**12.900**
343	8	11	2950	3200	5200	4800			5.900	6.400	10.400	9.600	0.000	0.000	**32.300**
344	7	6	3250	7550	7150				6.500	15.100	14.300	0.000	0.000	0.000	**35.900**
345	6	3	2850	5900					5.700	11.800	0.000	0.000	0.000	0.000	**17.500**
346	7	8	3650	4450	4500				7.300	8.900	9.000	0.000	0.000	0.000	**25.200**
347	4	13	1900	2700					3.800	5.400	0.000	0.000	0.000	0.000	**9.200**
348	6	7	2700	5800					5.400	11.600	0.000	0.000	0.000	0.000	**17.000**
349	7	8	2200	2800	3000				4.400	5.600	6.000	0.000	0.000	0.000	**16.000**
350	8	8	2700	3800	4050	4500			5.400	7.600	8.100	9.000	0.000	0.000	**30.100**
351	7	8	3400	4500	4400				6.800	9.000	8.800	0.000	0.000	0.000	**24.600**
352	7	2	3200	5600	5550				6.400	11.200	11.100	0.000	0.000	0.000	**28.700**
353	7	8	2300	3100	3050				4.600	6.200	6.100	0.000	0.000	0.000	**16.900**
354	6	11	2500	5800					5.000	11.600	0.000	0.000	0.000	0.000	**16.600**

355	5	11	1600	3400					3.200	6.800	0.000	0.000	0.000	0.000	**10.000**
356	9	4	2600	5800	6300	6200	6050		5.200	11.600	12.600	12.400	12.100	0.000	**53.900**
357	6	5	2900	5950					5.800	11.900	0.000	0.000	0.000	0.000	**17.700**

Axle load survey coding schedule

Vehicle Code	Vehicle Type	Commodity Code	Commodity Carried
1	Car / Jeep	1	Liquid Cargo
2	Taxi	2	Chemicals / Fertilizers / Medicals
3	S.T.	3	Engineering Goods
4	Private Buses	4	Automobiles Goods
5	LCV / Vans - Tempo	5	Electronics
6	Truck 2 Axle	6	Buildings Materials
7	Truck 3 Axle	7	Foods & Agriculture Produts
8	MAV Container 4 Axle	8	Container Cargo
9	MAV Container 5 Axle	9	Clothes & Textiles
10	MAV Container 6 Axle	10	Coal
		11	Misc. & Others
		12	Empty
		13	Passenger

ANNEXURE-2

Year	Traffic					Traffic Growth Rate (%)	Lane Distribution	Vehicle Damage Factor					Traffic (CVD)	(365 * ((1+r)^n-1))/r	Million Standard Axle	
	Bus	LCV + Mini Bus	2 - Axle	3 - Axle	MAV			Bus	LCV + Mini Bus	2 - Axle	3 - Axle	MAV			MSA	Cummulative (MSA)
Present Year - 2010	123	336	791	1365	183								2798			
Base Year - 2013	153	417	983	1696	227	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	3476	1179.18	13.23	13.23
Year - 2014	164	448	1057	1823	244	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	3736	365.00	4.40	17.64
Year - 2015	176	482	1136	1960	262	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	4016	365.00	4.73	22.37
Year - 2016	189	518	1221	2107	282	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	4317	365.00	5.09	27.46
Year - 2017	203	557	1313	2265	303	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	4641	365.00	5.47	32.93
Year - 2018	218	599	1411	2435	326	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	4989	365.00	5.88	**38.81**
Year - 2019	234	644	1517	2618	350	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	5363	365.00	6.32	45.13
Year - 2020	252	692	1631	2814	376	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	5765	365.00	6.79	51.92
Year - 2021	271	744	1753	3025	404	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	6197	365.00	7.30	59.23
Year - 2022	291	800	1884	3252	434	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	6661	365.00	7.85	67.07
Year - 2023	313	860	2025	3496	467	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	7161	365.00	8.44	**75.51**
Year - 2024	336	925	2177	3758	502	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	7698	365.00	9.07	84.59

Year - 2025	361	994	2340	4040	540	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	8275	365.00	9.75	94.34
Year - 2026	388	1069	2516	4343	581	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	8897	365.00	10.49	104.82
Year - 2027	417	1149	2705	4669	625	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	9565	365.00	11.27	116.10
Year - 2028	448	1235	2908	5019	672	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	10282	365.00	12.12	**128.22**
Year - 2029	482	1328	3126	5395	722	7.50%	0.75	1.00	1.00	4.38	4.56	10.37	11053	365.00	13.03	141.25