Effect of Waste Plastic on the Strength Characteristics of the Subgrade for the Flexible Pavement

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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 up to 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.
Keywords- Highway

I. 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.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 ithe soil mobilize tensile resistance in the fibers, which in turn imparts greater strength to the soil.

II. LITERATURE REVIEW

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, thestraw 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.

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.

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.

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 The percentage increase in CBR value is higher at lower percentage of fibre content in 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

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. Value of deviator stress at failure for different test conditions.typical stress–strain plots for 70% silty sand (SM) +30% fly ash at confining pressure of 50 kN/m² under different reinforcement conditions.

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%.

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.

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.

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 type's 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. 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.

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.

III. EXPERIMENTAL PROGRAMME

A. Materials

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

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.

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.

- Low Density Polyethylene (LDPE)

It is a thermoplastic made from monomer ethylene .it was a first grade of polyethylene LDPE is more branching than HDPE so its intermolecular forces are weaker its tensile strength is lower and its resilience is high. It can't withstand temperature of 80C continuously and 95C for short time.

Made in translucent or opaque variations it is quite flexible and tough but brakeble. The cost of LDPE waste plastic is 65 Rs per kg.

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.

Table 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*

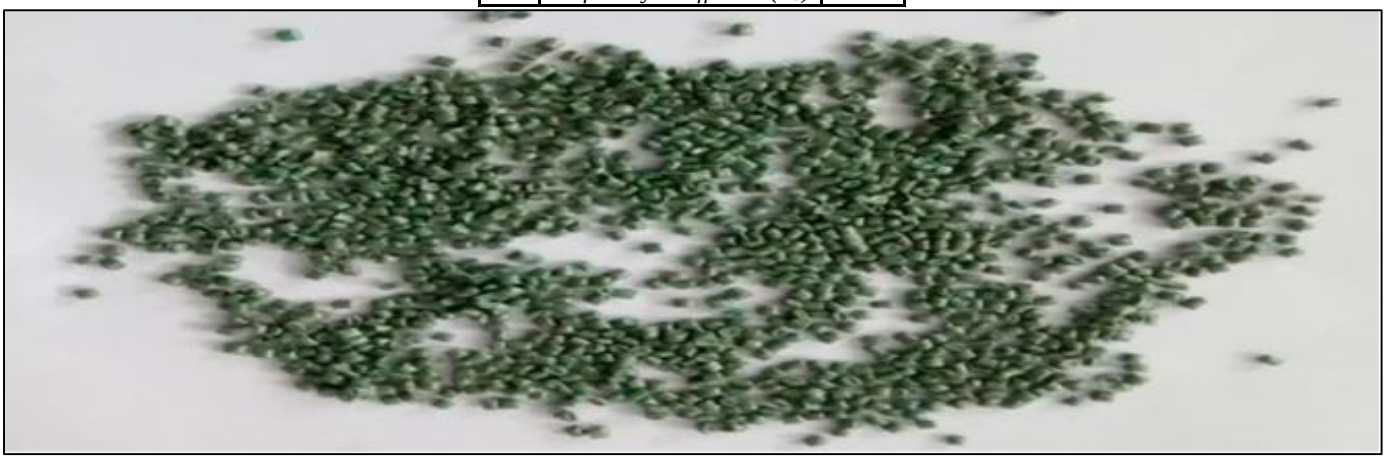


Fig. 1: High Density Polyethylene (HDPE)

Fig. 2: Low Density Polyethylene (LDPE)

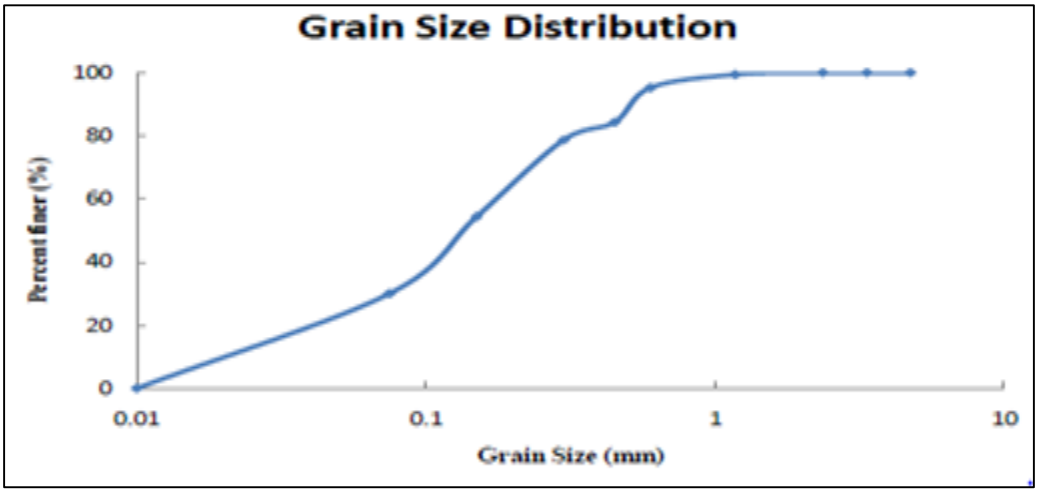


Fig. 3: Grain Size Distribution of Sand

B. 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.

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.

2) Apparatus

1) 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 - 1982.2)Balances - one of 10kg capacity, sensitive to 1g and the other of 200g capacity, sensitive to 0.01g
2) Oven - thermostatically controlled with an interior of non-corroding material to maintain temperature between 105 and 110℃.
3) 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)
4) IS Sieves of sizes - 4.75mm, 19 mm.

Fig. 4: Automatic Compactor

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℃ to 110℃ 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.

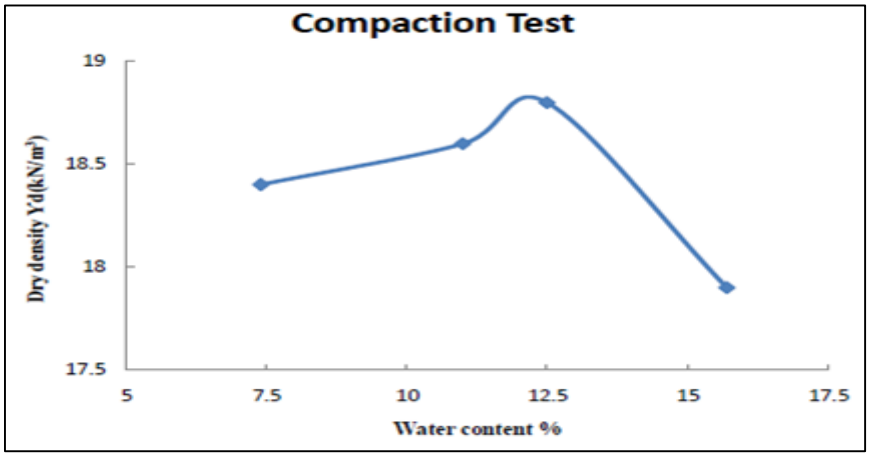


Fig. 5: compaction test on unreinforced soil

Optimum Moisture Content:12.5 %
Maximum Dry Density:18.8 kN/m3
Compaction Test were performed on Polypropylene waste plastic content 1%,2% and 4% as shown in Figure 6 to 8. It was found that there is no. change in Dry Density. There is small change in water content 1% to 2%.

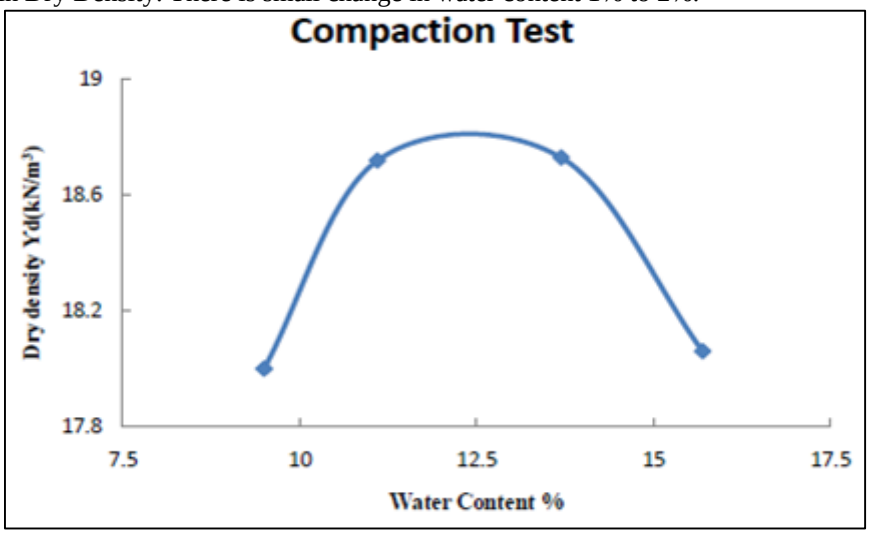


Fig. 6: compaction test on 1% polypropylene

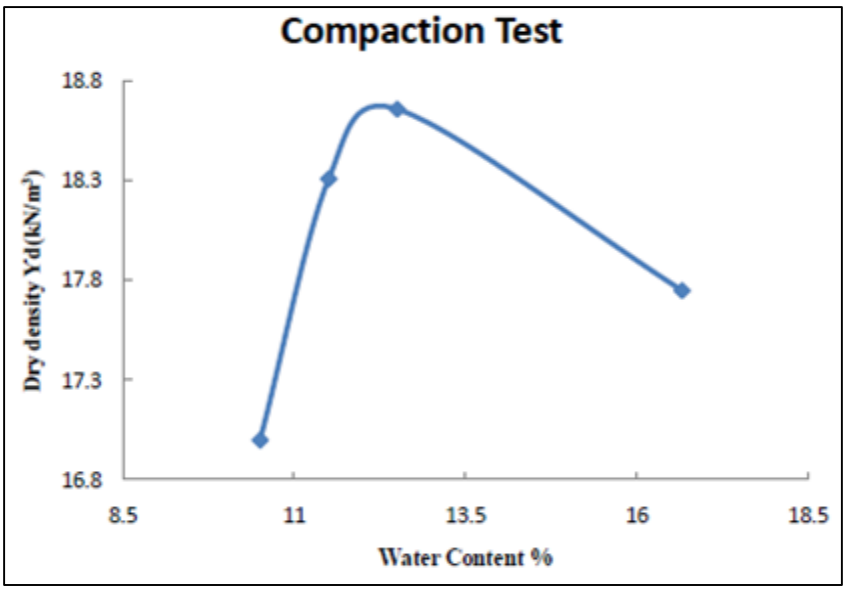


Fig. 7: compaction test on 2% polypropylene

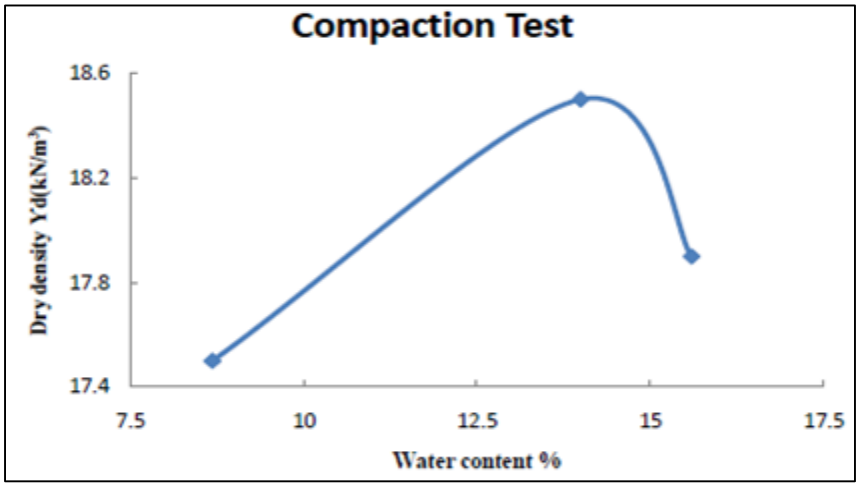


Fig. 8: compaction test on 4% polypropylene

C. 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.

$$\text{C.B.R.} = \frac{(\ )}{(\ )} \times 100$$

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

Table 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.

1) Equipment's 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.

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.

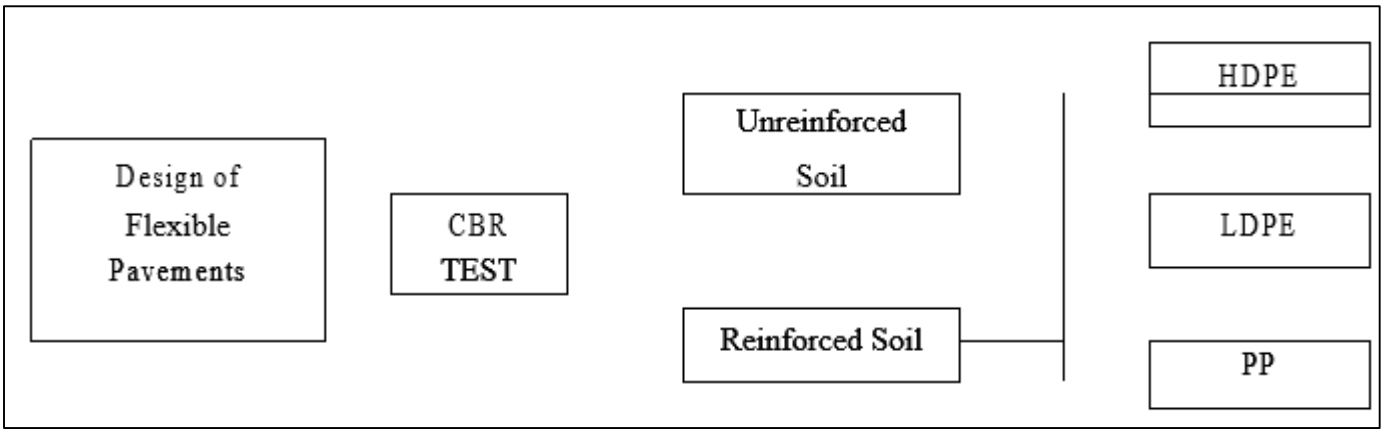
3) Compact the mix soil in the mould using either light compaction or heavy compaction. For light compaction, compact the soil in 3 equal layers, each layer being given 55 blows by the 2.6 kg rammer. For heavy compaction compact the soil in 5 layers, 56 blows to each layer by the 4.89 kg rammer.
4) Remove 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) 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/m3.Design of flexible pavement is done thereafter.

Fig. 9: California bearing ratio testing Machine



IV. RESULT AND DISCUSSION

A. California Bearing Ratio

Various load penetration curves obtained from the CBR test for unreinforced and randomly distributed reinforced sample with different waste plastic (HDPE, LDPE, PP) content but here only HDPE described.

1) Load penetration curves for unreinforced sample

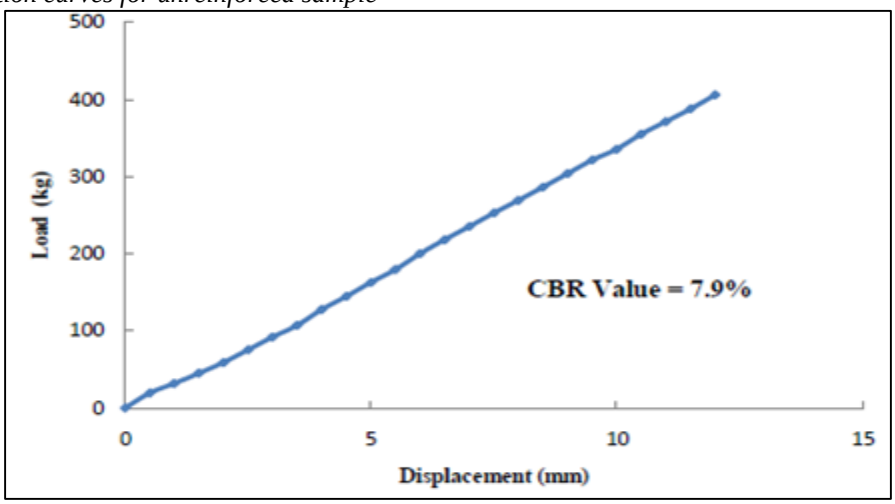


Fig. 10: Load penetration curves for unreinforced soil

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:

2) Load penetration curves for HDPE waste plastic

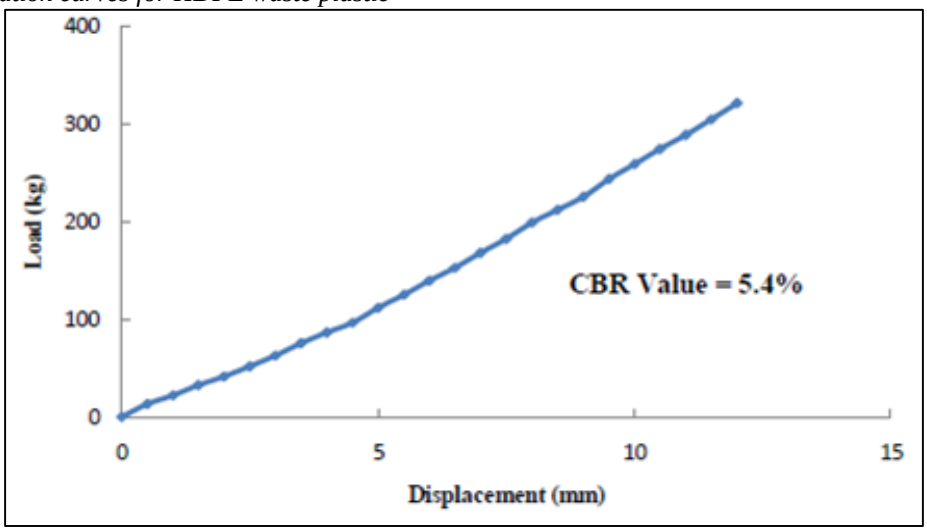


Fig. 11: Load penetration curves for soil having 1% HDPE waste plastic

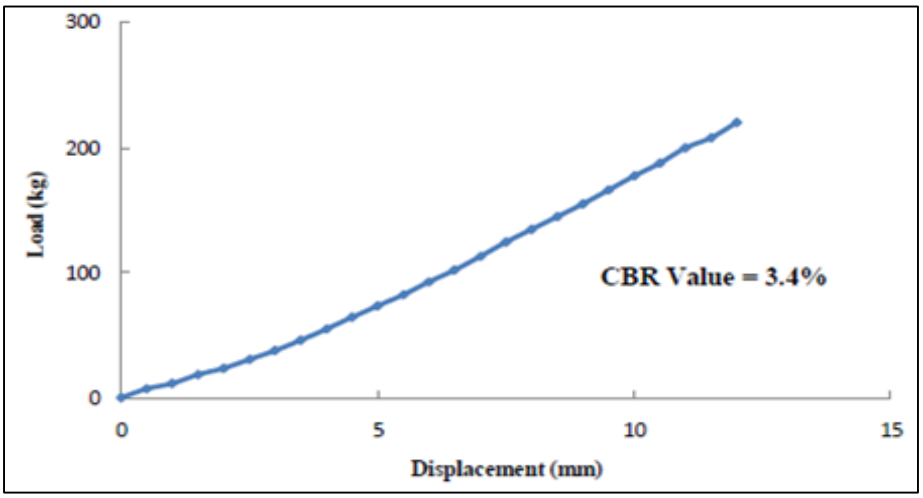


Fig. 12: Load penetration curves for soil having 2% HDPE waste plastic

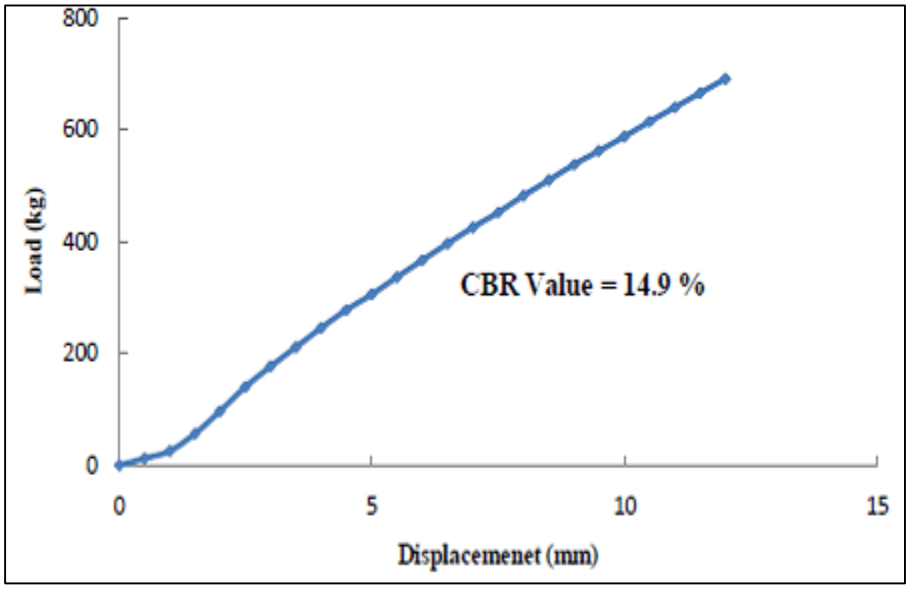


Fig. 13: Load penetration curves for soil having 3% HDPE waste plastic

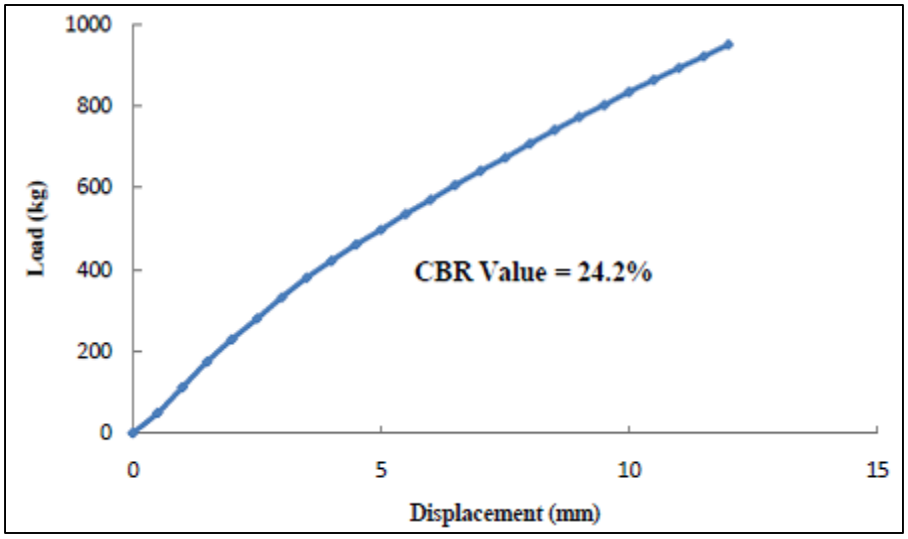


Fig. 14: Load penetration curves for soil having 4% HDPE waste plastic

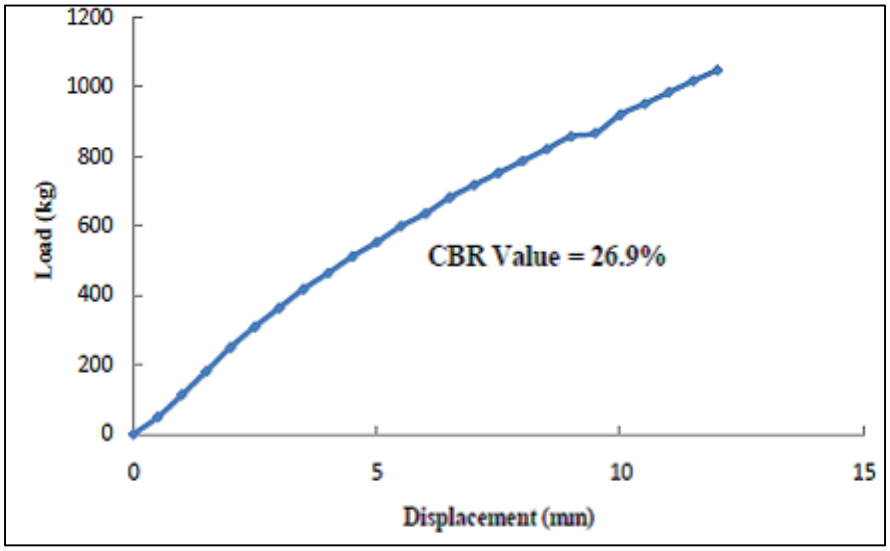


Fig. 15: Load penetration curves for soil having 5% HDPE waste plastic

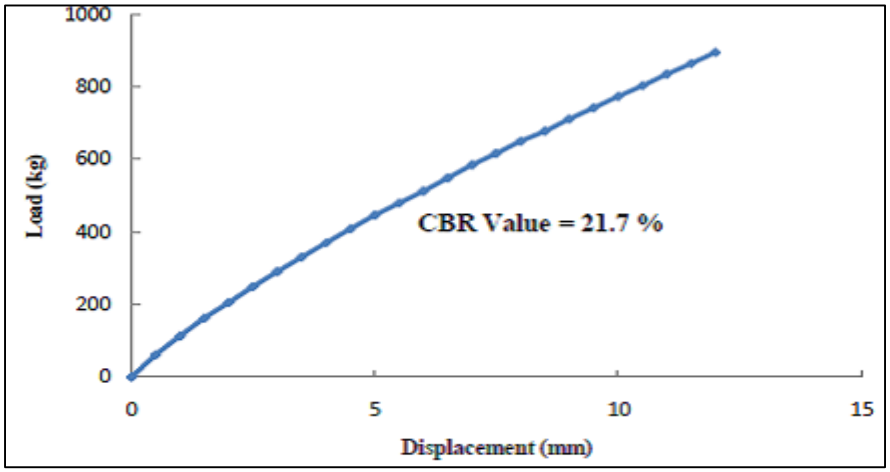


Fig. 16: Load penetration curves for soil having 6% HDPE waste plastic

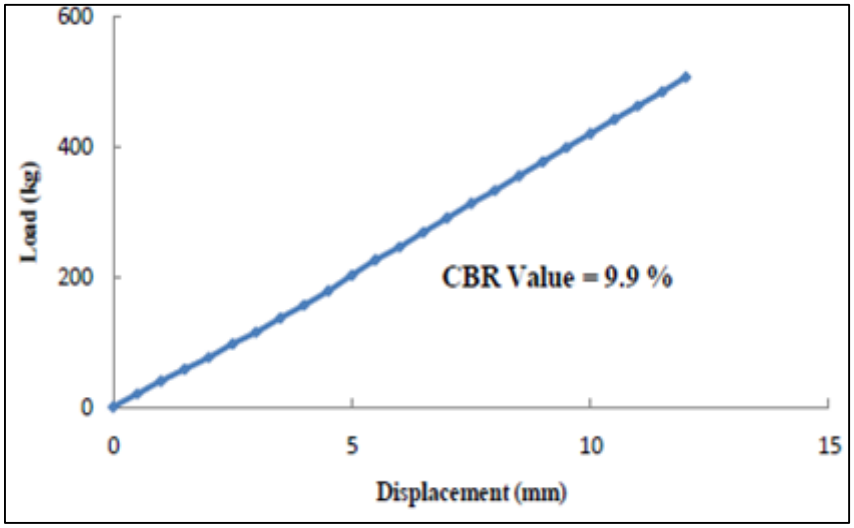


Fig. 17: Load penetration curves for soil having 7% HDPE waste plastic

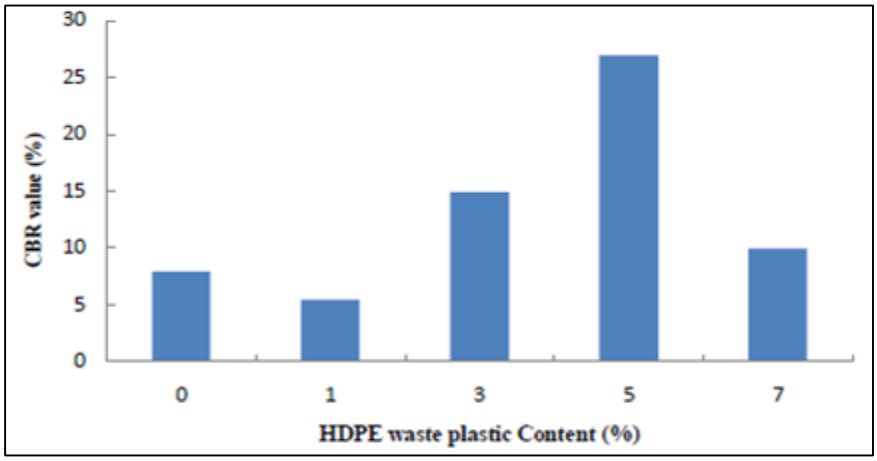


Fig. 18: CBR value with different HDPE content

Table 3: 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 3 and figure 18 it shows that CBR value increases in HDPE content and it is maximum at 5%. After that it decreases with increase in content. Maximum value of CBR is 26.9%.

3) Comparison of CBR Value for Different Waste Plastic Content

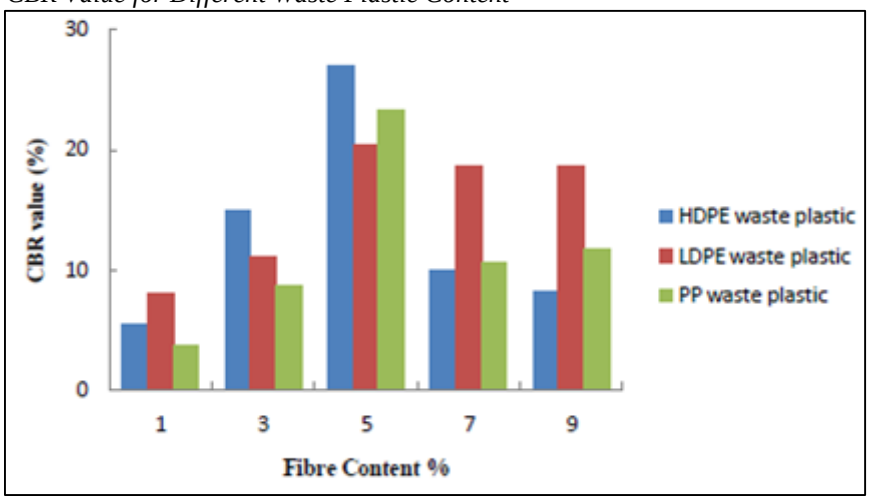


Fig. 19: Comparison of CBR Value for Different Waste Plastic Content

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 CBR value of reinforced soil (CBR_r) to the CBR value of unreinforced soil (CBR_u).

BRI= CBR r / CBR u

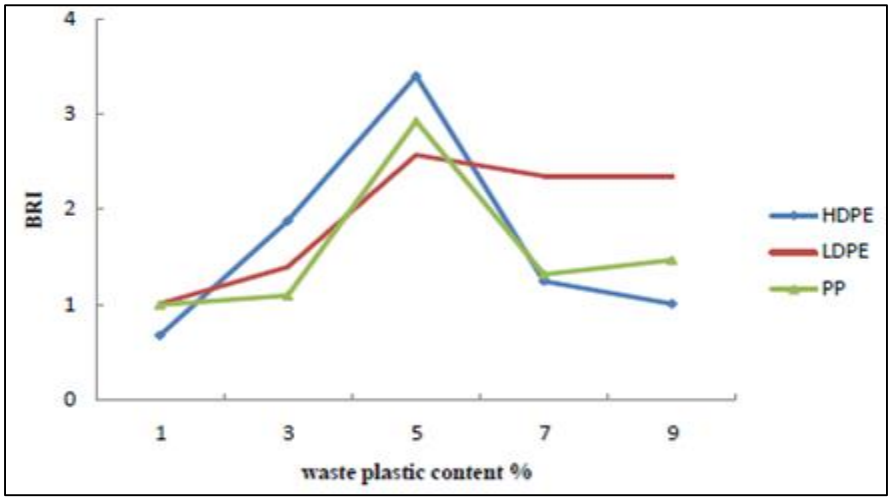


Fig. 20: Bearing Ratio Index with Different Waste Plastic Content

Fig 20 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.

V. 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 to26.9% 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 3.40for HDPE waste plastic whereas for LDPE and PP, BRI was 2.57 and2.93.

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.

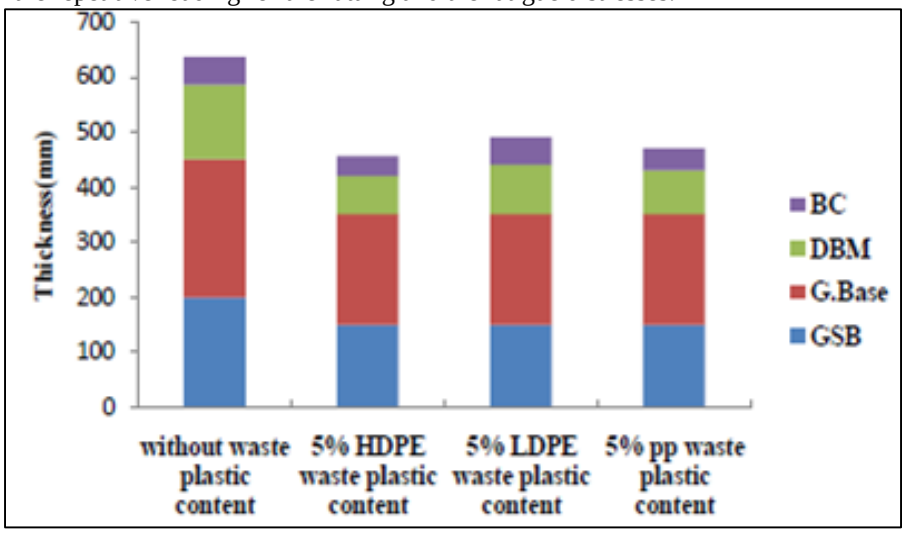


Fig. 21: pavement thickness with various waste plastic content

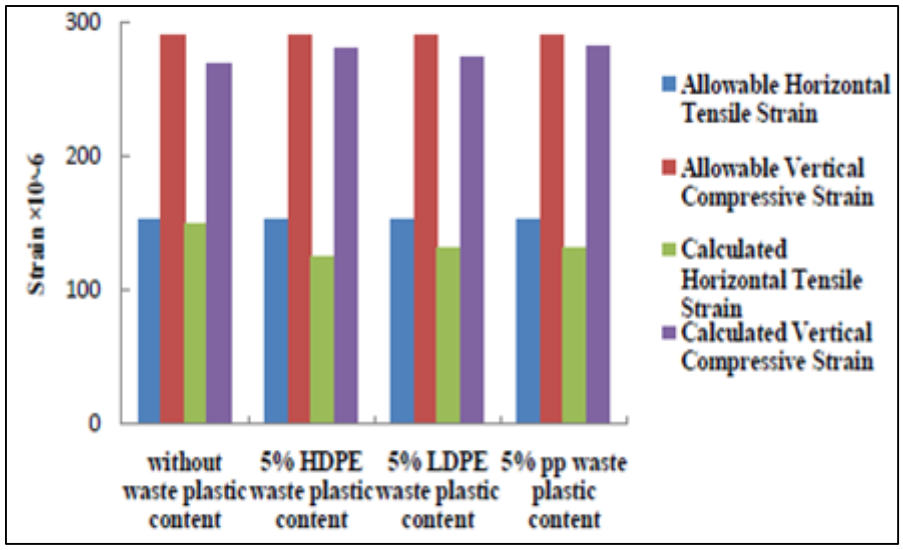


Fig. 22: comparison of calculated strain with allowable strain

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REFERENCES

[1] Aggarwal P, Sharma B. September, (2010). "Application of jute fibre in the improvement of subgrade characteristics. In: Proc of int conference on advancement in civil engg, Trabzon, Turkey; 27–30.
[2] Arvind K. , Baljit S. , Jatinder M., (2006) "Compressive strength of fibres reinforced highly compressible clay" Construction and Building Materials ;20:1063–1068
[3] Bouhicha M, Aouissi F, Kenai S.,(2005), "Performance of composite soil reinforced with Barley straw", Cement Concrete Compos; 27:617–21.
[4] Choudhary K, Jha J, Gill S. (2010), "A study on CBR behaviour of waste plastic strip reinforced soil". Emirates Journal of Engineering & Research; 15:51–57.
[5] Consoli C, Casagrande T, Prietto M, Thome A. (2003), " Plate load test on fibre reinforced soil". Journal of Geotech Geoenvironment Engg ASCE; 129:951–955.
[6] Consoli C, Montardo P, Donato M, Prietto M. (2004), "Effect of material properties on the behaviour of sand–cement–fibre composites". Ground Improvement; 8:77–90.
[7] Gosavi M, Patil A, Mittal S, Saran S. (2000), "Improvement of properties of black cotton soil subgrade through synthetic reinforcement". Journal Inst. Engg. (India); 84:257–62.
[8] Ghavami K, Filho R, Barbosa P., (1999), "Behaviour of composite soil reinforced with Natural fibres". Cement Concrete Composite; 21: 39–48.
[9] H C Mehndiratta, S Chandranarayana, S P Singh, (2005) "Effect of Randomly
[10] Distributed Fibres on Flyash Embankments". IE (I) Journal-CV Vol: 86.
[11] IS: 2720-Part iv (2006) Grain size analysis, Bureau of Indian Standard, New Delhi, India.
[12] IS: 2720-Part v (1985) Determination of Liquid limit & Plastic limit, Bureau of Indian Standard, New Delhi, India.
[13] IS: 2720-Part viii (1995) Determination of Water content, Bureau of Indian Standard, New Delhi, India.
[14] IS: 2720-Part xvi (2002) Determination of CBR, Bureau of Indian Standard, New Delhi, India.
[15] IRC: 37-2012 " Guidelines for design of flexible pavement"
[16] Khedari J, Watsanasathaporn P, Hirunlabh J., (2005), "Development of fibre-based soil-Cement block with low thermal conductivity". Cement Concrete Composite; 27:111–116.
[17] Kumar A, Walia B, Mohan J. 2006, "Compressive strength of fibre reinforced highly compressible clay". Constructing Building Material; 20:1063–1068.
[18] MORTH "Specifications for road and bridge works"
[19] Maheshwari V. (2011), "Performance of fibre reinforced clayey soil". EJGE; 16:1067-87
[20] Mahipal Singh C., Satyendra M., Bijayananda M., (2008) "Performance evaluation of silty sand subgrade reinforced with fly ash and fibre" Geotextile and Geomembranes; 26:429–435.
[21] Stabilized Subgrade Pavement Materials" , International journal of advanced engineering sciences and technologies Vol. No. 2, Issue No. 1:025 – 035
[22] Prabakara J, Sridhar R.,(2002), " Effect of random inclusion of sisal fibre on strength Behaviour of soil", Construct Building Material; 16:123–31.
[23] Park S. (2009) "Effect of fibre reinforcement and distribution on unconfined compressive strength of fibre-reinforced cemented sand". Geotextile Geomembranes; 27:162–166.
[24] Praveen A., Bajinder S.,(2011),"Application of Jute Fibre in the Improvement of Subgrade Characteristics", Journal on Transportation and Urban Development, Vol. 01, Issue No. 01.
[25] Pardeep S., K. Gill, (2012) "CBR Improvement of Clayey Soil with Geo-grid Reinforcement" International Journal of Emerging Technology and Advanced Engineering ISSN 2250-2459, Vol. 2, Issue no. 6.
[26] Ravishankar U, Raghavan S., (2004), "Coir stabilised lateritic soil for pavements". In: Indian geotech conference, Ahmedabad, India.
[27] Segetin M, Jayaraman K, Xu X. Harakeke,(2007) " Reinforcement of soil– cement "Building materials: manufacturability and properties. Building Environment; 42:3066–79.
[28] Srinivas R., B. and Jayalekshmi S.,(2010) "Fibre Reinforcement of Soil Sub Grade Beneath Flexible Pavements", Indian Geotechnical Conference, Geotrendz December: 16-18.
[29] Tang C, Shi B, Zhao L. (2010), "Interfacial shear strength of fibre reinforced soil". Geotextile Geomembranes; 28:5