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Utilization of Waste Fibers in Road Construction

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Abstract: In this project, we are using plastic as a fiber in road construction. We have used plastic milk bags as a fiber because global plastic production is growing with the population growth and many environmental issues can arise as a result of the significant increase in the use of plastics like polyethylene (PE) and polypropylene (PP). Therefore, it's critical to find strategies for getting rid of these waste products without endangering the environment. The disposal of plastic becomes complicated because they are not biodegradable. It is therefore better to recycle than to dispose of. One of the trends in plastic recycling is its use in road construction. Road transport is undoubtedly the lifeline of the nation and its development is a vital concern. Therefore, we decided to use the concept of using plastic as a fiber in road construction. This type of recycling can also help protect the environment from greenhouse gases that are released into the atmosphere during disposal. This will also exhibit high strength, better bindingproperties, stability and increased resistance to wear, and better durability and tear of pavements.
Keywords: Fiber-reinforced road construction, plastic bags, strength, durability, California Bearing Ratio(C.B.R), Standard Proctor Test(S.T.P), Soil.

I. INTRODUCTION

Roads are the key to economic development. A good road network is an essential infrastructure that accelerates the development process through connectivity and opening up underdeveloped regions to trade and investment. Roads play a key role in the development of intermodal transport and create connections with airports, railway stations, and ports. Since independence, there has been a huge increase in the volume of road traffic, both passenger and freight. However, the main road network consisting of national and state highways does not match this increase in traffic. Fiber reinforced road has a history of adding huge performance improvements at a reasonable cost. The future of pavements must be more durable, crack resistant, and cost-effective. Fiber-reinforced road construction provides high performance and safety. Various experiments are being carried out to improve the properties of the road. The use of waste plastic in road construction represents a recent development in this field of study. Due to their effectiveness, durability, and affordable construction, plastics are being used more and more in road construction.

Most nations around the world are starting to experience problems with waste disposal. Large-scale accumulation of these waste materials results in issues with the environment and the economy. The most widespread waste is plastic waste materials. Plastic is non-biodegradable and many researchers have found that plastics take about 4500 years to decompose. Several studies have shown that plastic disposal causes many health problems and reduces soil fertility. The production of plastics worldwide has exceeded 400 million tons and the recycling of plastics is only 10%.**[1]** These materials are the ones that we use the most frequently every day. Large amounts of plastic waste are created, including the polyethylene terephthalate (PET) used to make plastic bottles and the polypropylene (PP) used to make plastic bags and carpets. The recycling and reuse of these materials in construction applications as a solution to protect the environment from plastic waste material pollution have been the subject of numerous studies by researchers looking for efficient ways to reduce the pollution of these materials. When building roads, using these materials as soil stabilizers is an efficient use of them. The base layers of the road can be made better by stabilizing the soil with plastic waste.

II. LITERATURE SURVEY

The paper explains how adding thermoplastic modifiers to conventional bitumen can improve the bitumen's viscoelastic behavior and alter its rheological characteristics. High-density polyethylene (HDPE) and polypropylene (PP) were the two types of modifiers used; it was found that they had varying degrees of influence, increasing the softening point and decreasing the penetration value while increasing the overall dynamic and absolute viscosities of the binder.**[2]**

The optimal percentage of waste plastics is equal to 0.3% and 0.4% of the dry unit weight of soil, respectively, for gravel and fly ash materials, according to the paper's descriptions of direct shear tests and CBR tests. When laid on an expansive soil subgrade with gravel or flash sub bases reinforced with an ideal percentage of waste plastics, the load-carrying capacity of the flexible pavement has increased significantly. When compared to waste plastics reinforced fly ash sub base, gravel reinforced with waste plastics in the model flexible pavement performed better at all deformation levels.**[3]**

The paper illustrates an experimental study that was conducted to show how three industrial wastes, including fly ash, stone dust, and waste recycled product (WRP) made from recycled blast furnace slag from a steel plant, could be used in pavements after being randomly reinforced with HDPE plastic waste strips. In this study, the feasibility of using plastic strips to reinforce industrial waste materials was examined by measuring CBR values, subgrade modulus (ks), CBRI, and PPLR at 12.5 mm penetration.**[4]**

The paper describes that waste plastic is utilized in bituminous mixes. Using a shredding machine, the plastic waste is reduced to fit through a 2.36mm sieve. After heating the aggregate mixture, the plastic was evenly spread over the aggregates. To create the mix formula, these plastic-coated aggregates were combined with hot bitumen. The shredded plastic waste is combined with hot aggregate to create the plastic-modified mix, which is then made with bitumen that contains 6%, 8%, 10%, 12%, and 14% plastic by weight. When 12% plastic waste is added to the mixture, it has been discovered that the Marshall stability value is at its highest. With the inclusion of plastic in the mixture, the flow value continuously rises. With the addition of plastic waste, the percentage of air voids in the mixture continuously decreases, and the VFB continuously rises.**[5]**

The paper explains how poor stabilization leads to road cracks. When compared to the properties of soil without stabilization, it can be said that the engineering properties of soil are enhanced after stabilization with waste plastic. Therefore, in the case of flexible pavements, plastic can be used as a reinforcement material to reduce fatalities in the soil subgrade. The ideal amount that can be used to stabilize the soil subgrade is 5% of waste plastic by weight of the soil sample.**[6]**

The paper tells that there are many types of waste materials available in many parts of India, such as fly ash, baggage, GGBS, plastic waste, and rice husk ash, and they are all easily available and have a low cost compared to conventional materials. We can reduce the soil's tendency to swell and improve its properties by adding waste materials to expansive soils like black cotton soil. Utilizing waste materials in the highway sector is necessary for both environmental protection and the country's sustainable development. Utilizing industrial wastes is cost-effective for the neighborhood and environmentally responsible. We can effectively improve the properties of soil by mixing fiber with waste. It is possible to compare the stabilization of soil samples with the use of cement and other materials to the use of lime and other materials.**[7]**

It is described in the paper that fly ash is mainly used for concrete and soil stabilization because its properties are the same as those of cement. During the process of generating electricity, it is a waste material produced by combustion. Adding 5% fly ash to expansive soil reduces swell pressure and swell potential from around 175 kph to 75 kph, respectively. Initially, it decreased by about 60% when fly ash was added, but later on, it gradually increased. When the fly ash was increased to 15% mixed with the same cement content, the soaked CBR value was found to be increased, and when the fly ash increased, it decreased. A significant improvement in strength and reduction of swelling is observed when 15% of fly ash is mixed with 5% of cement. Therefore, 15% of fly ash with 5% of cement can effectively stabilize soil at low costs by using 15% of fly ash with 5% of cement.**[8]**

According to the study, local soil gains more CBR value when HDPE, LDPE, and PP waste plastic are added. The CBR value of the plain soil was 7.9%, but it was increased to 26.9% by the addition of 5% each of waste HDPE, LDPE, and PP plastic. The CBR value increased the maximum when the amount of waste plastic in the mixture was 5%. The Bearing Ratio Index (BRI) value for HDPE waste plastic was discovered to be around 3.40, whereas LDPE and PP had BRI values of 2.57 and 2.93, respectively. With the addition of HDPE, LDPE, and PP to the subgrade soil, a significant reduction in pavement crust thickness has been observed. The total crust thickness was decreased from 635mm to 455mm with 5% HDPE waste plastic material, compared to 490mm and 470mm for LDPE and PP, respectively. Using 5% HDPE in the subgrade of the road can reduce the cost of road construction by 20%, while 5% LDPE and PP in a similar crust section can reduce costs by 5% and 15%, respectively. **[9]**

According to the study, when lime content rose from 1% to 5% during the modified Proctor test, the ideal moisture content gradually dropped from 21.5% to 13.84%. For lime contents ranging from 1% to 4%, the maximum dry density values increased from 17.59 kN/m3 to 18.527 kN/m3. However, the maximum dry density value decreases when 5% lime is added. The maximum dry density is 18.527 KN/m3, and the optimal values are thus obtained for soil blended with 4% lime, with the optimal moisture content being 14.1463%. Black cotton soil has a CBR value of 2.005%. The CBR values for 1% to 4% lime increased from 3.3416% to 3.8428% after adding lime content to the soil. But the CBR values start to fall after 5% lime content. In a different study, the inclusion of plastic fiber content increased CBR values from 3.9416% to 6.1819% gradually, and the values decreased with further addition of PF percentage. The soil added with 4% lime and 0.75% plastic fibers has the highest CBR value. The Free Swell Index is calculated as 50% for black soil and drops to 35.7% for soil mixed with 4% lime. In soil mixed with 4% lime, the Specific Gravity for black cotton soil dropped to 2.33 from 2.6. Since 4% lime has been added to the black soil, the liquid limit has dropped from 64% to 50.4%. When 4% lime was added to the black soil, the plastic limit was lowered from 15.38% to 11%. Indicators of plasticity decreased from 48.62% to 39.40% when black soil and 4% lime have been combined.**[10]**

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The paper explains that regardless of the amount of ceramic dust added, the liquid limit, plastic limit, and plasticity index continue to decline. The soil is changed from the CH group to the CL group by the addition of 30% ceramic dust. With an increase in the percentage of ceramic dust addition, MDD continues to rise while OMC continues to fall. The UCS keeps rising with an increase in the percentage of ceramic dust addition. With an increase in the percentage of ceramic dust addition, the soaked CBR keeps rising. When 30% ceramic dust was added, the soaked CBR value increased by 150% in comparison to untreated soil. With an increase in the percentage of ceramic dust addition, the cohesion value keeps falling and the angle of internal friction keeps rising. According to the results of the compaction test, maximum dry density decreases as coir content increases while ideal moisture content rises.**[11]**

III. EXPERIMENTAL STUDY

A description of the material and the methods used for the test are given in the below paragraph:

A. Soil

The soil used for the test is collected from the construction site which was obtained during the excavation. The soil obtained was brown and it was coarse-grained soil.

Fig. 1 Soil

B. LDPE (Low-Density Polythene)

The waste milk pouch is used as fiber for testing. The milk pouch is gathered at home and collected for the test. The milk pouch is then cut into the shape of a grid which contains a square of dimensions 2 cm x 2cm, 3cm x 3cm, and 4cm x 4cm respectively. The waste milk pouch grid is to be added to the soil.

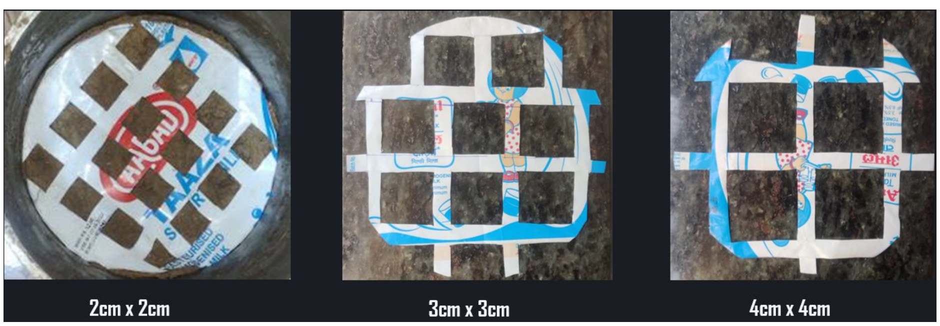

Fig. 2 Low-Density Polyethylene

C. Method

The experimental study included a variety of laboratory test which is as follow:

1) Standard Proctor Test

The soil must be compacted to increase its strength before road construction. A labor-intensive field test to perform soil compaction is called the Standard Proctor Test. To determine the ideal moisture content and maximum dry density of the soil sample, the Standard Proctor Test was used. The soil used for the test was 3 kg and the soil was passed to the 4 mm sieve. The soil sample was dived into three-layer and for each layer, 25 blows were applied and gradually the water was added to the soil.

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Fig. 3 SPT Mould

2) CBR (California Bearing Ratio)

A penetration test used to assess the subgrade strength of roads and pavements is called the California Bearing Ratio test. The test results are used to determine the penetration thickness (2.5mm – 5mm) and it is also used as an index of the strength and bearing capacity of the soil. In this test, we have compacted soil in three layers, and in between each layer, a plastic grid of 2cm by 2cm is placed of radius 15cm. The soil was compacted using light dynamic compaction. The hammer which was used for compaction was allowed to fall freely from a height of 31cm. Only flexible pavements are suitable for use with this technique. The road pavement needs to be designed and built with less thickness the stronger the subgrade is (the higher the CBR reading), which results in significant cost savings. In contrast, if CBR testing reveals that the subgrade is weak (a low CBR reading), we must build a suitable thicker road pavement to distribute the wheel load over a larger area of the weak Subgrade to prevent the weak subgrade material from deforming and leading to the failure of the road pavement.

Fig. 4 CBR Test

IV. RESULT AND DISCUSSION

A. Standard Proctor Test

The Proctor contraction test, also known as the standard Proctor test, determines how the soil's unit weight and degree of contraction change with moisture content. It also aids in determining the ideal moisture level for the highest practicable viscosity. When we average the Standard Proctor test results, we see that the unit weight or density initially increases with rising humidity, reaches a maximum, and then rapidly decreases. The optimum moisture content obtain was 21%.

Sr.no	Water Content (%)	Wt.of moist+Compacted Soil (g)	Wt.Compacted Soil (g)	Bulk Density (g/cm3)	Dry Density (g/cm3)
1	14	5300	1129	1.129	0.9903
2	17	5400	1229	1.229	1.0504
3	20	5495	1324	1.324	1.1033
4	23	5472	1301	1.301	1.0577
5	26	5410	1239	1.239	0.9833

Fig. 5 Standard Proctor Test readings

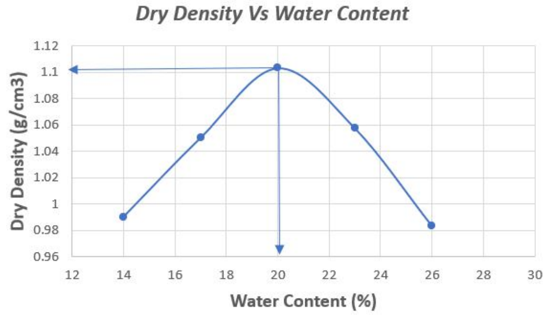

Fig. 6 Standard Proctor Test graph

B. California Bearing Ratio

1) Test Without Fiber

The C.B.R. values are typically computed for penetrations of 2.5 mm and 5 mm. The C.B.R. value at 2.5 mm will typically be higher than at 5 mm, so in this situation, the former value should be used as the C.B.R. for design purposes. If the C.B.R. for 5 mm is greater than that for 2.5 mm, the test should be repeated. The C.B.R. corresponding to 5 mm penetration should be used for design if identical results occur. The soils used for the CBR test had particles that were 12.5 mm in size. The initial curve was concave upward and the reading obtained at 2.5mm penetration was 1.931% and for 5mm penetration was 1.578%.

Penetration Dial Reading (mm)	Proving Ring Reading Load (KN)	Proving Ring Reading Load (KN)	Corrected Load
0	0	0	0
0.5	2.8	14	16.464
1	3.4	17	19.992
1.5	3.8	19	22.344
2	4.2	21	24.696
2.5	4.5	22.5	26.46
3	4.8	24	28.224
3.5	5	25	29.4
4	5.2	26	30.576
4.5	5.4	27	31.752
5	5.5	27.5	32.34
5.5	5.8	29	34.104
6	6	30	35.28
6.5	6.1	30.5	35.868
7	6.2	31	36.456
7.5	6.4	32	37.632
8	6.5	32.5	38.22
8.5	6.5	32.5	38.22
9	6.6	33	38.808
9.5	6.8	34	39.984
10	6.8	34	39.984
10.5	6.9	34.5	40.572
11	6.9	34.5	40.572
11.5	6.9	34.5	40.572
12	7.1	35.5	41.748

Fig. 7 California Bearing Ratio reading (without fiber)

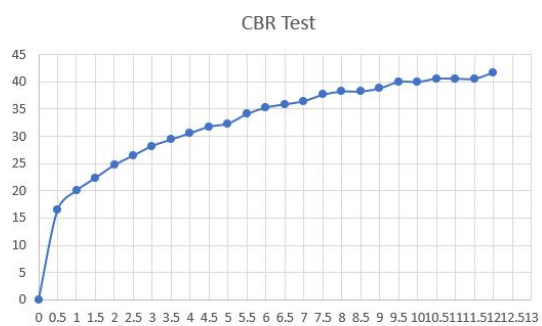

Fig. 8 California Bearing Ratio graph (without fiber)

2) Test With Fiber

The C.B.R. values are generally calculated using plastic fiber for 2.5 mm and 5 mm penetration. The plastic grid was placed between the two layers during the C.B.R test to increase the strength and the bearing capacity of the soil. The C.B.R test was carried out in three phases:

- Phase 1: With a plastic grid of dimension 2cm x 2cm.
- Phase 2: With a plastic grid of dimension 3cm x 3cm.
- Phase 3: With a plastic grid of dimension 4cm x 4cm.

The following results were obtained:-

Penetration Dial Reading (mm)	Proving Ring Reading Load (KN	Proving Ring Reading Load (KG)	Corrected Load
0	0	0	0
0.5	1.4	7	8.232
1	2.2	11	12.936
1.5	3.3	16.5	19.404
2	5.4	27	31.752
2.5	8.4	42	49.392
3	8.6	43	50.568
3.5	8.6	43	50.568
4	8.7	43.5	51.156
4.5	8.7	43.5	51.156
5	8.7	43.5	51.156
5.5	8.8	44	51.744
6	8.8	44	51.744
6.5	8.8	44	51.744
7	8.8	44	51.744
7.5	8.9	44.5	52.332
8	8.9	44.5	52.332
8.5	9	45	52.92
9	9.5	47.5	55.86
9.5	9.6	48	56.448
10	9.6	48	56.448
10.5	9.6	48	56.448
11	9.6	48	56.448
11.5	9.6	48	56.448
12	9.7	48.5	57.036

Fig. 9 California Bearing Ratio reading with fiber (2cm x 2cm)

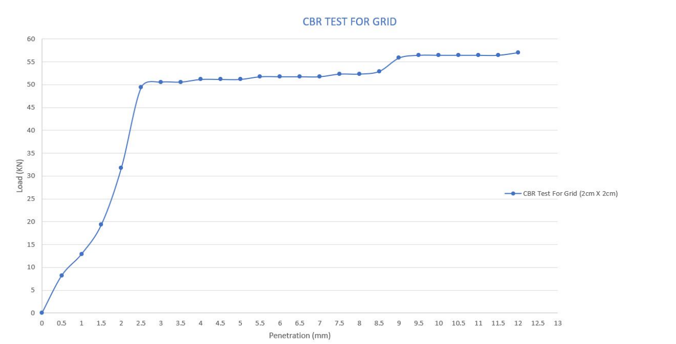

Fig. 10 California Bearing Ratio graph with fiber (2cm x 2cm)

Penetration Dial Reading (mm)	Proving Ring Reading Load (KN)	Proving Ring Reading Load (KG)	Corrected Load
0	0	0	0
0.5	1.1	5.5	6.468
1	2.5	12.5	14.7
1.5	4.8	24	28.224
2	8	40	47.04
2.5	10.8	54	63.504
3	11.5	57.5	67.62
3.5	11.6	58	68.208
4	11.7	58.5	68.796
4.5	11.7	58.5	68.796
5	11.8	59	69.384
5.5	11.8	59	69.384
6	11.8	59	69.384
6.5	11.9	59.5	69.972
7	11.9	59.5	69.972
7.5	12.1	60.5	71.148
8	12.3	61.5	72.324
8.5	12.3	61.5	72.324
9	12.5	62.5	73.5
9.5	12.5	62.5	73.5
10	12.5	62.5	73.5
10.5	12.5	62.5	73.5
11	12.6	63	74.088
11.5	12.6	63	74.088
12	12.6	63	74.088

Fig. 11 California Bearing Ratio reading with fiber (3cm x 3cm)

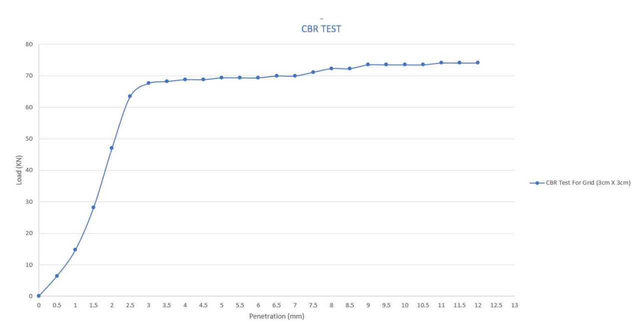

Fig. 12 California Bearing Ratio graph with fiber (3cm x 3cm)

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Penetration Dial Reading (mm)	Proving Ring Reading Load (KN)	Proving Ring Reading Load (KG)	Corrected Load
0	0	0	0
0.5	1.3	6.5	7.644
1	2.8	14	16.464
1.5	4.9	24.5	28.812
2	8.4	42	49.392
2.5	11.4	57	67.032
3	12.6	63	74.088
3.5	13	65	76.44
4	13.2	66	77.616
4.5	13.3	66.5	78.204
5	13.3	66.5	78.204
5.5	13.4	67	78.792
6	13.5	67.5	79.38
6.5	13.7	68.5	80.556
7	13.9	69.5	81.732
7.5	14.1	70.5	82.908
8	14.1	70.5	82.908
8.5	14.4	72	84.672
9	14.5	72.5	85.26
9.5	14.6	73	85.848
10	14.6	73	85.848
10.5	14.9	74.5	87.612
11	14.9	74.5	87.612
11.5	14.9	74.5	87.612
12	14.9	74.5	87.612

Fig. 13 California Bearing Ratio reading with fiber (4cm x 4cm)

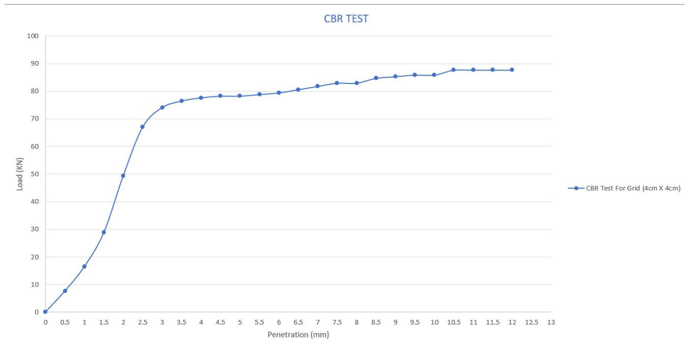

Fig. 14 California Bearing Ratio graph with fiber (4cm x 4cm)

Penetration Dial Reading (mm)	Corrected Load (Without Plastic)	Corrected Load (With Plastic) 2X2 cm	Corrected Load (With Plastic) 3X3 cm	Corrected Load (With Plastic) 4X4 cm
0	0	0	0	0
0.5	16.464	8.232	6.468	7.644
1	19.992	12.936	14.7	16.464
1.5	22.344	19.404	28.224	28.812
2	24.696	31.752	47.04	49.392
2.5	26.46	49.392	63.504	67.032
3	28.224	50.568	67.62	74.088
3.5	29.4	50.568	68.208	76.44
4	30.576	51.156	68.796	77.616
4.5	31.752	51.156	68.796	78.204
5	32.34	51.156	69.384	78.204
5.5	34.104	51.744	69.384	78.792
6	35.28	51.744	69.384	79.38
6.5	35.868	51.744	69.972	80.556
7	36.456	51.744	69.972	81.732
7.5	37.632	52.332	71.148	82.908
8	38.22	52.332	72.324	82.908
8.5	38.22	52.92	72.324	84.672
9	38.808	55.86	73.5	85.26
9.5	39.984	56.448	73.5	85.848
10	39.984	56.448	73.5	85.848
10.5	40.572	56.448	73.5	87.612
11	40.572	56.448	74.088	87.612
11.5	40.572	56.448	74.088	87.612
12	41.748	57.036	74.088	87.612

Fig. 15 California Bearing Ratio reading (with and without fiber)

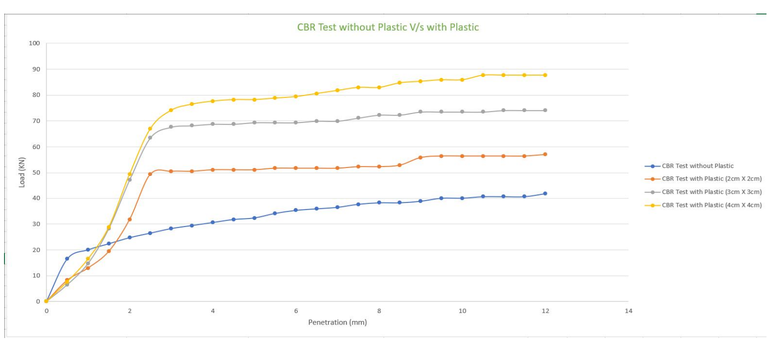

Fig. 16 California Bearing Ratio graph (with and without fiber)

From the above readings and graphs, we observed that initially, the California Bearing ratio(C.B.R) of the soil was less, and after introducing plastic fiber in the soil the California Bearing ratio(C.B.R) value was observed to be increased. So it clearly states that by adding plastic as a fiber in the soil the bearing capacity of the soil increases.

TABLE 1

. Comparison of soil penetration without and with plastic fiber

Sr. No.	Penetration (mm)	Without plastic (%)	With plastic (%) (2cm x 2cm)	With plastic (%) (3cm x 3cm)	With plastic (%) (4cm x 4cm)
1.	2.5	1.931	3.605	4.635	4.893
2.	5	1.578	2.515	3.384	3.814

V. CONCLUSION

The following conclusions were drawn from the above experimental study:

1) A fiber-modified mixture not only significantly lowers overall pavement maintenance and construction costs, but also reduces reflective and fatigue cracking.
2) It provides support to the bituminous layer, which decreases the chances of pothole formation.
3) Due to this the maintenance cost of the road decreases.
4) Soil properties can be effectively improved by adding fiber.
5) The flexible pavement's load-carrying capacity has successfully been significantly increased.
6) It also reduces the accumulation of plastic by using it effectively to increase the durability of the subgrade.

VI. ACKNOWLEDGMENT

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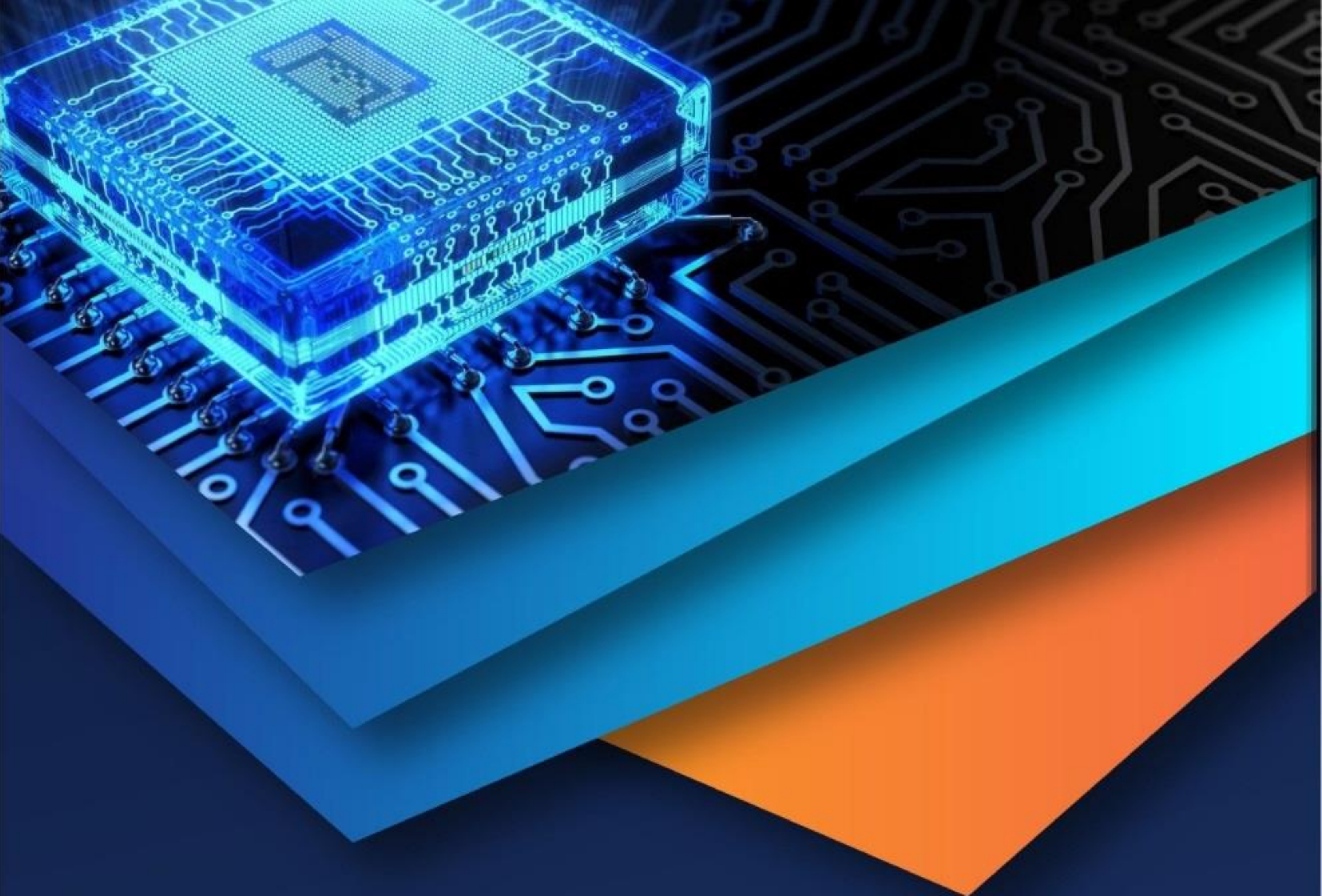

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