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ENHANCING THE ENGINEERING PROPERTIES OF EXPENSIVE SOIL USING SOLID PLASTIC WASTES WITH BRICK POWDER

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Abstract: More than 20% of the land area of India is covered by expansive soil. It is found in Madhya Pradesh, Maharashtra, Andhra Pradesh, Gujarat, Tamil Nadu, Karnataka, and other parts of India. Soils with a lot of clay and a lot of space can change their volume in ways that aren't good. When the amount of water in the soil changes, the volume of the soil also changes.

Since many years ago, engineers have had trouble with the amount of water in expansive soil. For geotechnical engineers, this stress shows up as constant worry about the uplift of expansive soil caused by increased or decreased moisture content in foundation soil. For pavement engineers, it shows up as a lot of worry about longitudinal cracks on pavements if the subgrade soil is expansive and has a lot of moisture change throughout the year.

This study shows the results of an experiment on how to improve the geotechnical properties of loose soil by stabilizing it with solid plastic wastes and brick powder. Even materials that don't make the cut are expected to have basic qualities like strength, stiffness, and permeability. If these things aren't true, engineers are supposed to come up with ways to make the ground better. Due to the rising cost of traditional stabilizing agents like lime and cement and the need to use industrial and agricultural wastes in engineering in a cost-effective way, researchers are looking into whether Brick Powder can be used to stabilize highly expansive clay soil. Brick Powder is a byproduct of industry that can be used in building materials if it has the right physical, chemical, and mechanical properties. The goal of this research is to find out how well Brick Powder and solid plastic waste can hold clay soil together.

As part of the lab work, index properties were used to sort the soil samples. Most of the time, the soils in this class are not good enough to build on. Atterberg limits, grain size analysis, specific gravity, free swell test, compaction, and CBR tests will be used to evaluate the geotechnical properties of stabilized soil and compare them to standards.

Brick Powder was added at 5%, 10%, 25%, and 50% of the soil's dry weight to stabilize it. Adding 0.25 %, 0.5 %, 0.75 %, and 1 % plastic waste strips enhanced the soil.

Keywords: Brick Powder, plastic Strips, CBR, Proctor test, Liquid Limit, Soil Stablisation.

I. INTRODUCTION

Expansive Soil shrinks when there is less water in it and grows when there is more water in it. This is because of a mineral called montmorillonite, which is a type of clay. Structures that are light or small and have a low overburden pressure are more likely to get damaged. Uneven shrinking and growing makes the structure less useful and can cause hairline cracks or even large cracks that cause the structure to fall down. Extensive soil has been shown to cause property damage and economic loss. Before building in areas with Expansive Soil, the right steps should be taken to fix the problem. There are many ways to make Expansive Soil easier to work with and lessen the swelling and expanding it does. to reduce or avoid losses caused by the dangerous behavior of soil, you can do things like remove the Expansive Soil to a certain depth, keep the water table steady well below the level of the foundation, strengthen the soil, use an under-reamed foundation, or change the properties with some additives. The world makes a huge amount of slag every year, which makes it hard to deal with waste. At the moment, builders are legally required to have a Geo - technical Engineer (G.E.) make a soils report. This report will show the builder where the expansive soils are and give the builder advice on how to build a house that can stand up to them.

Richards et al. (1983) say that about 20% of the surface soils in Australia are moderately to highly expansive, and that about 50% of the surface soils in Victoria are also in this category. Most of these kinds of soils are in the west of Melbourne. [1]

There are different ways to fix the engineering properties of soils that are causing problems. These include adding chemicals to the soil, pre-wetting the soil, moisture control techniques, surcharge loading thermal methods, reinforcement, and replacing the soil with compaction control [2]. Additives like salt, polymers, cement, lime, fly ash, and, in some cases, a mix of these, are often used to improve the performance of expansive clays. Lime has been used more often to stop the soil from swelling and make it easier to work with. It is also cheap and widely available in many places around the world [3].

Objectives of Study

1. The main goal of this study is to improve the engineering properties of the soil, such as its shear strength and its ability to hold weight.
2. To offer an alternative way to get rid of plastic waste
3. Using cheaper materials to stabilize the soil and bring down its cost
4. Using waste and things that are bad for the environment to make useful things

Research area

The Rajasthan district of Jhalawar is between the districts of Kota and Baran, and it touches the state of Madhya Pradesh. It is in Agricultural Climate Zone V. (humid south eastern plain). On average, the weather is pretty dry and good for your health. There are four seasons in a year: the hot season, which lasts from March to the middle of June, the monsoon season, which lasts from mid-June to September, the post-monsoon season, which lasts from October to November, and the cold season, which lasts from December to February. Between 900 and 1000 mm of rain fall each year.

II. LITERATURE REVIEW

The term "Expansive soil" is used to describe any soil whose volume changes a lot when its moisture content changes. When expansive soil gets wet, it tends to get higher, and when it dries, it gets smaller. If the change in volume from season to season isn't carefully taken into account when the structure is built, it could cause the structure to fail. Many people have tried to figure out what happens to buildings when the soil moves.

In 1973, Jones and Holtz said that in the US alone, "each year, shrinking and swelling soil causes at least $2 billion in damage to houses, buildings, roads, and pipelines. That's more than twice as much damage as floods, hurricanes, tornadoes, and earthquakes!" [12]. They also came to the conclusion that 60% of the new houses built in the US will have minor damage during their useful life, and 10% will have damage so bad that it can't be fixed. In 1980, Krohn and Slosson estimated that damage to all kinds of structures built on soil that expands costs the US $7 billion each year [13].

In 1986, Snethen said, "Few people have ever heard of expansive soil, and even fewer know how much damage it causes. However, more than one-fifth of American families live on expansive soil, and no state is safe from the problems it causes." People have called expansive soil the "hidden disaster" because it doesn't kill people, but it is now one of the most expensive natural disasters in the US" [14]. Fredlund said in 1979 that there are two main reasons why unsaturated soil mechanics haven't changed much:

(1) there isn't enough science and theoretical background because the stress condition and mechanics of an unsaturated expansive soil aren't well understood; and

(2) there isn't enough money for engineers because the liability to the engineer is often higher compared to the money they get. This is especially true when it comes to earthquakes. Consultants might find that they can make more money in other areas of geotechnical engineering.

If the volume change behavior of expansive soil can be accurately predicted [15,16], it will be possible to design buildings that are more stable and cost less.

Abdulla and Majeed (2021) looked at how adding 10, 20, or 30% WMD from three different sources could be used to stabilize expansive soil. It was decided that an increase in the amount of Brick Powder makes expansive soils less likely to swell [31].

Jain et al. (2020) looked at how waste brick powder could be used as a geomaterial to improve the properties of expansive soil and how particles interact with each other. The results showed that Brick Powder could keep the soil from swelling and make it more flexible. The mineralogy, chemistry, and elemental make-up of Brick Powder and the type of soil were the main things that affected how marble-added soils interacted with each other [32].

Deboucha et al. (2020) looked into how Brick Powder and ceramic waste affected the CBR, MR, and MDD of the sub-base layer of a road. The study came to the conclusion that combining MD and CW with a small amount of OPC could be a good way to stabilize the soil in the sub-base layer of roads [33].

Bansal and Sidhu (2016) looked at what happened to the soil when the amount of WMD was changed from 0 to 30 %. The limit for liquids went down from 31.70 to 25%, while the limit for plastics went up from 17.69 to 19.26%. Also, the optimal moisture content of the soil went down from 18 to 14.10 %, and the maximum dry density went up from 1.738 to 1.884 gm/cc. Also, CBR Value went up from 2.46 % to 6.07 %.[37]

Kumar and Tamilarasan (2015) found that the Optimum Moisture Content (OMC) of clay went up from 18 to 24%, and the maximum dry density (MDD) went up by up to 10% when WMD was added to the soil, but then went down when more WMD was added. WMD was added in different amounts, from 5% to 25%, with a 5% increase between each amount. By adding WMD, the liquid limit value kept going down from 70% to 55%. Around, the plastic limit value went up by about 25 %.[38]

Plastic waste

Many studies have been done to find ways to keep these materials from polluting the environment, such as recycling and reusing them in civil engineering. One good way to use these materials is to use them to stabilize the soil when building roads.

Choudhary K. (2016) said that the CBR value and secant modulus go up when recycled HDPE strips are added to local sand. The CBR and secant modulus improve the most when the strip content is 4% and the viewpoint proportion is 3. This is about three times as much as an unreinforced structure. Also, if HDPE strip-reinforced sand is used as sub-level material in asphalt design, the thickness of the base course can be cut down to almost nothing [49].

Sabat A. K. (2012) mixed 12-mm-long WASTE strands with very compressible clayey soil and saw a shift from 0% to 1%. They came to the conclusion that the dirt bearing limit and the safe bearing pressure (SBP) both go up as the fiber content goes up to 0.50 %. After that, it goes down as the number of strands goes up. Strands made of polyethylene (PE): Some research has been done on the idea that polyethylene (PE) strips or filaments could be used to strengthen soil. It has been thought that a small number of high-density polyethylene (HDPE) strands can make the soil more likely to crack. This is because when plastic materials are mixed with soil, they act like soil that has been reinforced with fibers [50].

Khattab et al. (2011) Using plastic waste to stabilize the soil can help make the base layers of a road better (So, this can solve the waste problem by reducing the amount of waste and recycling it to improve the quality of soils. One way to use plastic to stabilize soil is to use it as separate fibers [51].

III. METHODOLOGY

Methodology mainly consists of three parts.

Part 1

It includes identification of problems in of Expansive Soil, review of literatures, collection of soil and waste bottle and waste brick near to site.

Part 2

Conversion of plastic bottle into strip and waste brick into brick power will be carried out.

Part 3

Part 3 are laboratory works which are mainly focused on determination of index, engineering, chemical properties of soil and chemical properties of soil and plastic bottle strip and waste brick power.

Part 3

Mixing of Soil

Part 4

Test will be carried out.

Specimen Specification

Brick Powder was added at 5%, 10%, 25%, and 50% of the soil's dry weight to stabilize it. Adding 0.25 %, 0.5 %, 0.75 %, and 1 % plastic waste strips enhanced the soil.

NORMAL SOIL: 0%BRICK POWDER + 0%PLASTIC STRIP + SOIL.
MIX 1: 5%BRICK POWDER + 0.25%PLASTIC STRIPS + SOIL.
MIX 2: 10%BRICK POWDER + 0.5%PLASTIC STRIPS + SOIL.
MIX 3: 25%BRICK POWDER + 0.75%PLASTIC STRIPS + SOIL.
MIX 4: 50%BRICK POWDER + 1%PLASTIC STRIP + SOIL.

IV. RESULT AND DISSUSION

The engineering behaviour of a composite made of soil and PET plastic waste was investigated, with a particular emphasis placed on the influence of the %age of PET plastic trash that was included in the soil. This chapter offers the test findings, an analysis, and discussions based on the numerous experiments described in Chapter 3. Indicator tests, compaction testing, California Bearing Ratio (CBR) tests, and direct shear box tests are all provided in this Chapter. These experiments were carried out on soil and soil mixed with PET plastic trash. The vast majority of the tests were carried out on unreinforced and reinforced soil simultaneously. The unreinforced soil was used as a point of comparison in order to assess the impact that PET plastic trash had on the soil that was being researched.

1. ATTERBERG LIMITS TEST

Sample No	1	2	3	4
Penetration	16	19	23	25
M1	30.71	35.73	39.35	40.92
M2	26.937	30.627	33.967	34.29
M1-M2	3.773	5.103	5.383	6.63
M3	13.44	14.09	18.58	16.44
M2-M3	13.497	16.537	15.387	17.85
w	27.95	30.86	34.98	37.14
AVERAGE	32.73			

Table 1: Liquid limit result for Normal Soil

Sample No	1	2	3	4
Penetration	17	20	22	23
M1	33.5775	36.5575	37.8175	41.2775
M2	29.47	31.65	32.36	35.28
M1-M2	4.1075	4.9075	5.4575	5.9975
M3	13.05	14.4	14.6	16.54
M2-M3	16.42	17.25	17.76	18.74
w	25.02	28.45	30.73	32
AVERAGE	29.05			

Table 2: Liquid limit result for MIX 1

Sample No	1	2	3	4
Penetration	16	18	22	25
M1	31.21	34.77	38.85	41.38
M2	27.89	30.93	34.22	35.24
M1-M2	3.32	3.84	4.63	6.14
M3	14.1	16.2	18.69	16.54
M2-M3	13.79	14.73	15.53	18.7
w	24.08	26.07	29.81	32.83
AVERAGE	28.2			

Table 3: Liquid limit result for MIX 2

Sample No	1	2	3	4
Penetration	15	17	20	25
M1	32.28	35.87	36.81	42.03
M2	28.81	31.79	33.05	36.51
M1-M2	3.47	4.08	3.76	5.52
M3	14.05	15.06	18.4	16.54
M2-M3	14.76	16.73	14.65	19.97
w	23.51	24.39	25.67	27.64
AVERAGE	25.3			

Table 4: Liquid limit result for MIX 3

Sample No	1	2	3	4
Penetartion	14	18	21	24
M1	26.792	29.772	33.032	34.492
M2	23.91	26.33	29.71	30.25
M1-M2	2.882	3.442	3.322	4.242
M3	11.05	12	16.5	14.12
M2-M3	12.86	14.33	13.21	16.13
w	22.41	24.02	25.15	26.3
AVERAGE	24.47			

Table 5: Liquid limit result for MIX 4

2. **GRAIN SIZE ANALYSIS:** The purpose of grain size analysis is to determine what proportion of soils are able to pass through various sieve holes of varying diameters. . A wet sieve test was performed in accordance with the standard (ASTM D6913M-17, 2017) in order to reduce the size of sticky soil particles to their original dimensions.

Sieve size	Retained (g)	Cumulative Retained	Wt.Retained (%)	Passing (%)
19	0	0	0	100
4.75	0	0	0	100
2	2	2	0.4	99.6
0.425	1	3	0.6	99.4
0.075	356	359	71.8	28.2
Pan				
Total	359			
Gravel (%)		Sand (%)	Silt and Clay (%)	
0%		71.8	28.2	

Table 6: Grain size analysis result for Normal soil

Sieve size	Retained (g)	Cumulative Retained	Wt.Retained (%)	Passing (%)
19	0	0	0	100
4.75	0	0	0	100
2	2	2	0.4	99.6
0.425	4	6	1.2	98.8
0.075	392	398	79.6	20.4
Pan				
Total	398			
Gravel (%)		Sand (%)	Silt and Clay (%)	
0%		79.6	20.4	

Table 7: Grain size analysis for MIX 1

Sieve size	Retained (g)	Cumulative Retained	Wt.Retained (%)	Passing (%)
19	0	0	0	100
4.75	0	0	0	100
2	2	2	0.4	99.6
0.425	9	11	2.2	97.8
0.075	411	422	84.4	15.6
Pan				
Total	422			
Gravel (%)		Sand (%)	Silt and Clay (%)	
0%		84.4	15.6	

Table 8: Grain size analysis for MIX 2

Sieve size	Retained (g)	Cumulative Retained	Wt.Retained (%)	Passing (%)
19	0	0	0	100
4.75	0	0	0	100
2	1	1	0.2	99.8
0.425	5	6	1.2	98.8
0.075	435	441	88.2	11.8
Pan				
Total	441			
Gravel (%)		Sand (%)	Silt and Clay (%)	
0%		88.2	11.8	

Table 9: Grain size analysis for MIX 3

Sieve size	Retained (g)	Cumulative Retained	Wt.Retained (%)	Passing (%)
19	0	0	0	100
4.75	1	1	0.1	99.9
2	2	3	0.6	99.4
0.425	4	7	1.4	98.6
0.075	455	462	92.4	7.6
Pan				
Total	462			
Gravel (%)		Sand (%)	Silt and Clay (%)	
0%		92.4	7.6	

Table 10: Grain size analysis for MIX 4

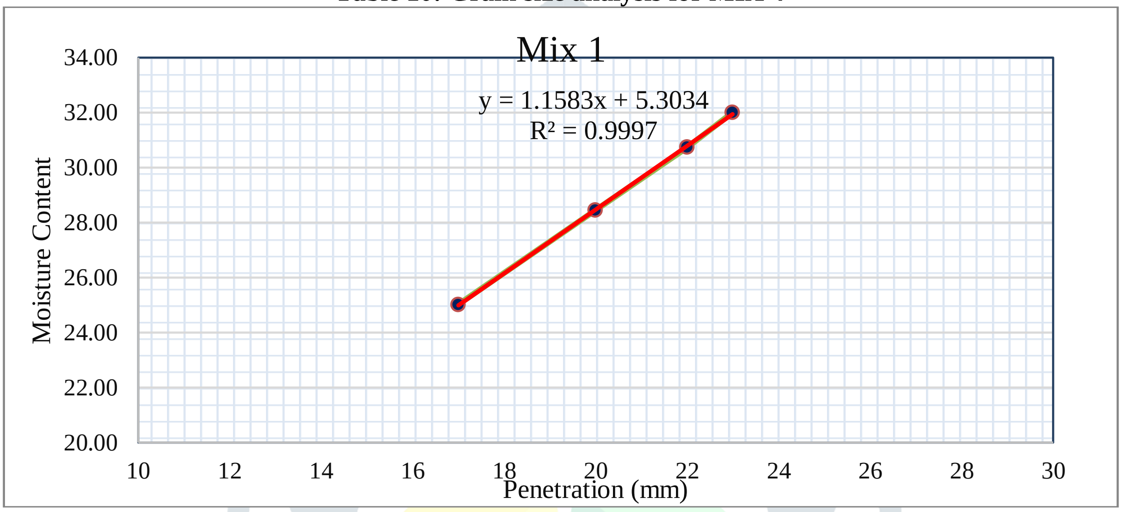

Figure 1: Liquid Limit result for MIX 1

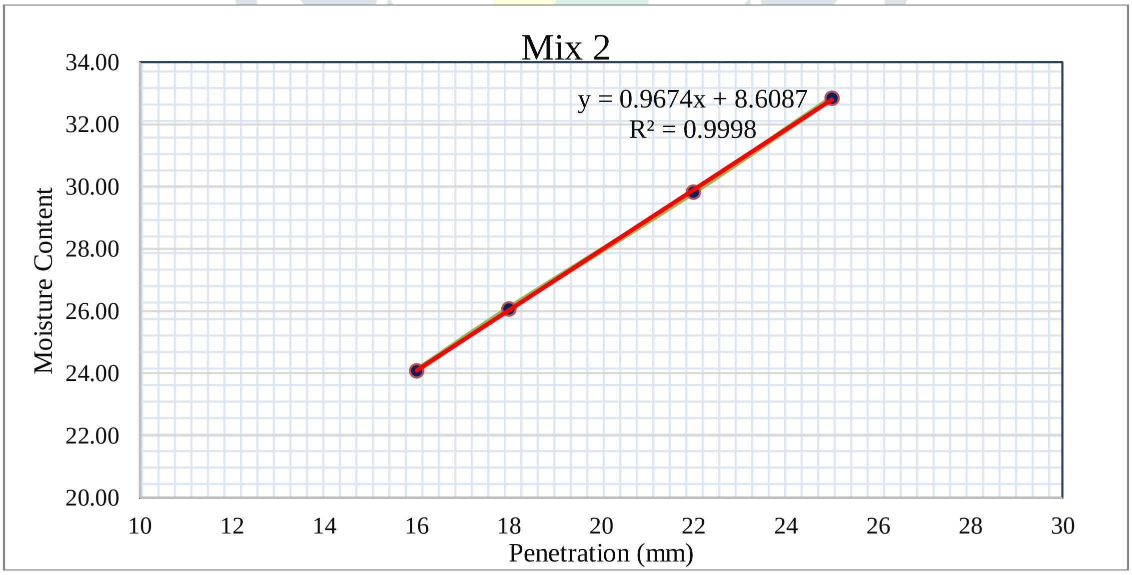

Figure 2: Liquid limit graph for MIX 2

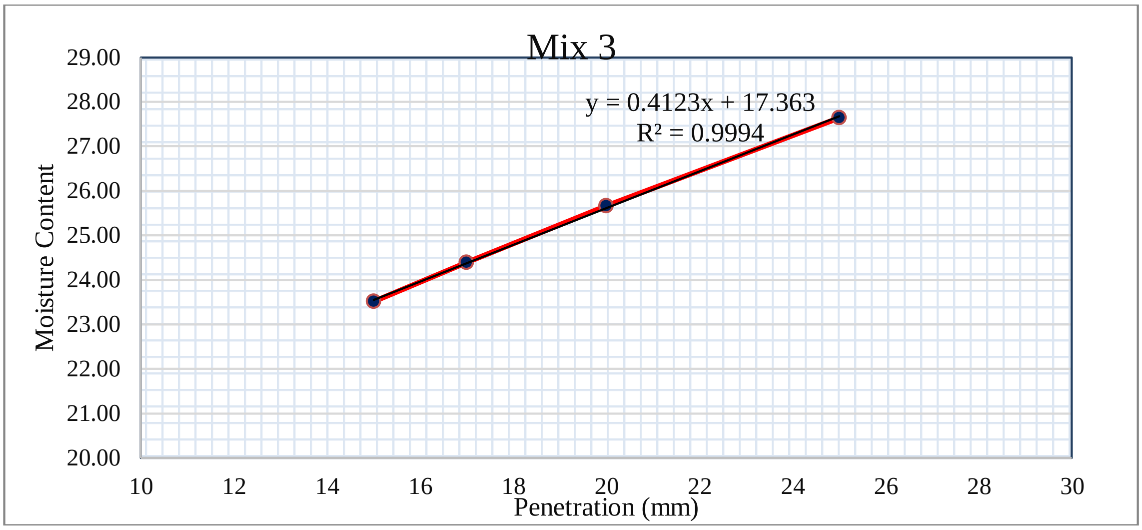

Figure 3: Liquid limit graph for MIX 3

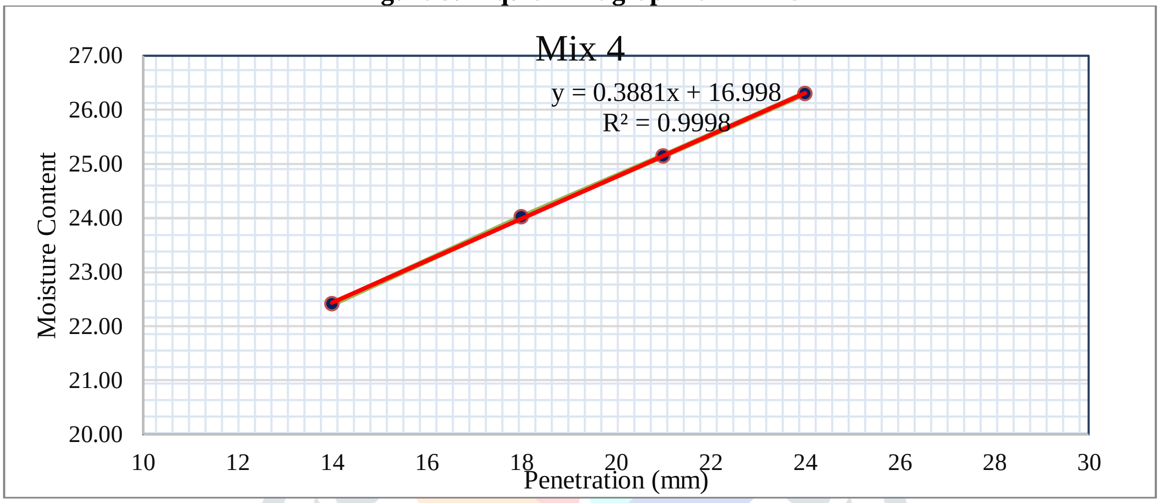

Figure 4: Liquid limit graph for MIX 4

From figure 1,2,3and 4 it is observed that the compression index, which is used in settlement analysis, can be estimated from the liquid limit test and it is changed with plastic and brick content.

3. COMPACTION TEST

Moisture	1.94	7.99	9.16	10.8	**12.69**	14.58	16.57
Dry Density	1.57	1.651	1.669	1.697	**1.715**	1.704	1.623

Table 11: Moisture content and dry density for Normal Soil

Moisture Content	6.76	8.69	9.8	11.39	**13.81**	16.07
Dry Density	1.664	1.691	1.705	1.723	**1.727**	1.683

Table 12: Moisture content and dry density for MIX 1

Moisture Content	5.34	6.54	8.66	10.2	**13.11**	15.06
Dry Density	1.688	1.701	1.72	1.735	**1.748**	1.697

Table 13: Moisture content and dry density for MIX 2

Moisture Content	4.79	7.39	9.39	10.91	**13.34**	15.31
Dry Density	1.684	1.713	1.74	1.76	**1.765**	1.708

Table 14: Moisture content and dry density for MIX 3

Moisture Content	5.25	6.59	8.74	**10.13**	13.21	15.11
Dry Density	1.736	1.748	1.774	**1.788**	1.752	1.705

Table 15: Moisture content and dry density for MIX 4

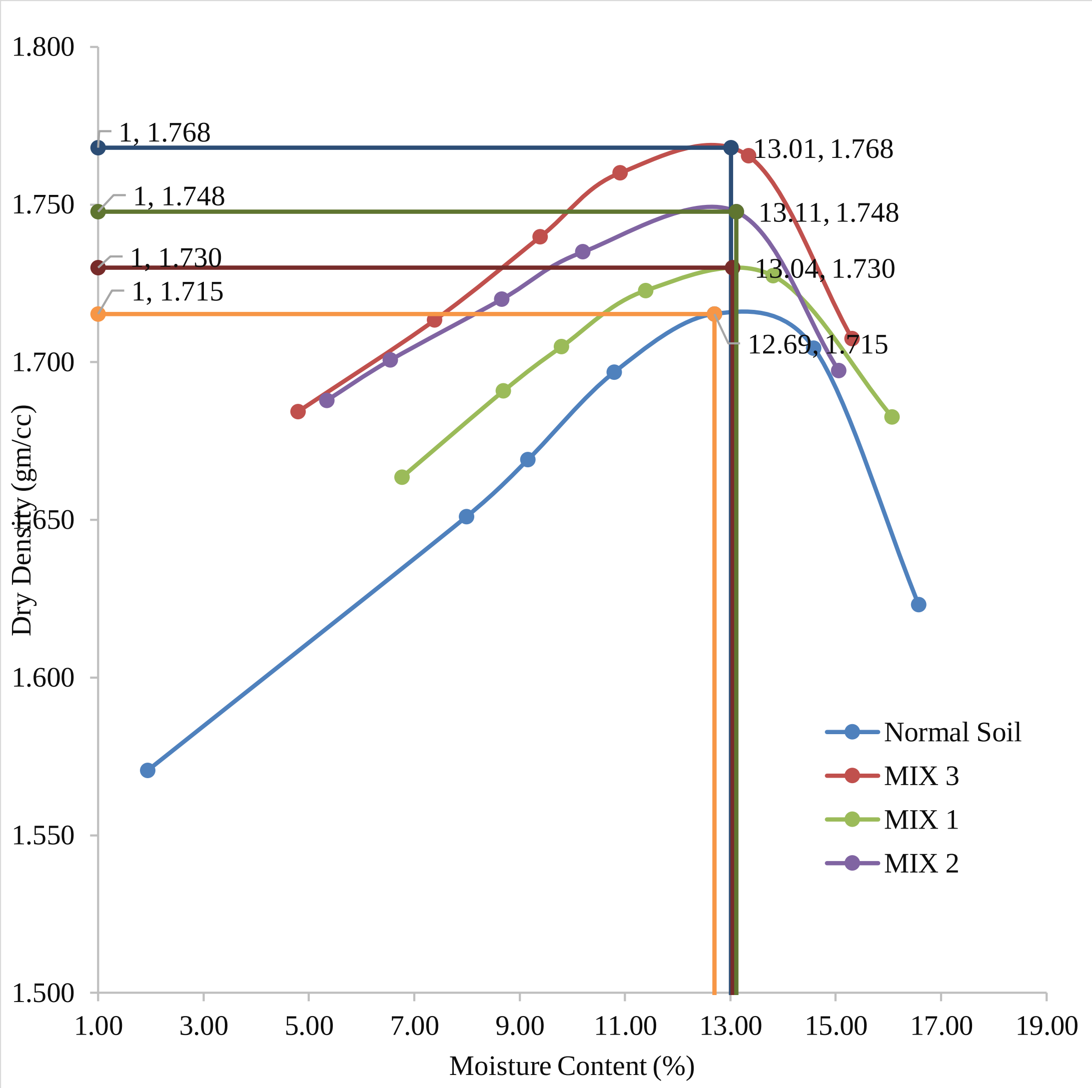

Figure 5: Proctor test result for all MIX

The moisture content will illustrate the correlation that permits the MDD and optimal moisture for every type of soil to be determined. The saturation curve helps overlay dry unit weights upon that soil compaction curve from figure 5 it is notes that the maximum dry density was recorded for Mix 3, because of higher brick powder with plastic strips.

4. CBR TEST

CBR measures the strength of a road's subgrade and construction materials. The ratio is measured using a California Division penetration test for roadway engineering. The CBR value goes up if the surface is hard

S. No	Penetration (mm)	Proving ring Reading (A)	Load (Kg) Calibration Factor x A	Corrected load (Kg)
1	0.5	8	0	22.74
2	1	12	0	34.12
3	1.5	21	0	59.7
4	2	28	0	79.6
5	2.5	32	0	90.98
6	3	38	0	108.03
7	4	45	0	127.94
8	5	54	0	153.52
9	7.5	56	0	159.21
Penetration	Load	CBR%	CBR% Reported	
2.5	90.98	6.64	7.47	
5	153.52	7.47		

Table 16: CBR test result for Normal Soil

S. No	Penetration (mm)	Proving ring Reading (A)	Load (Kg) Calibration Factor x A	Corrected load (Kg)
1	0.5	4	0	11.37
2	1	11	0	31.27
3	1.5	22	0	62.55
4	2	29	0	82.45
5	2.5	32	0	90.98
6	3	45	0	127.94
7	4	49	0	139.31
8	5	56	0	159.21
9	7.5	59	0	167.74
Penetration	Load	CBR%	CBR% Reported	
2.5mm	90.98	6.64	7.75	
5.0mm	159.21	7.75		

Table 17: CBR test results for MIX 1

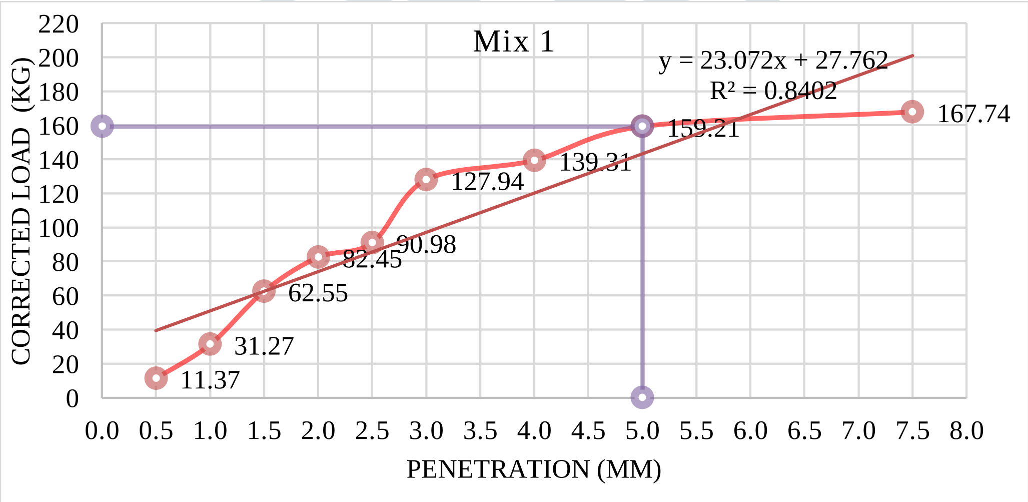

Figure 6: CBR Test result for MIX 1

S. No	Penetration (mm)		Proving ring Reading (A)	Load (Kg) Calibration Factor x A	Corrected load (Kg)
1	0.5		5	0	14.22
2	1		11	0	31.27
3	1.5		22	0	62.55
4	2		28	0	79.6
5	2.5		34	0	96.66
6	3		50	0	142.15
7	4		57	0	162.05
8	5		61	0	173.42
9	7.5		72	0	204.7
Penetratio	Load	CBR%	CBR% Reported		
2.5mm	96.66	7.06	8.44		
5.0mm	173.42	8.44			

Table 18: CBR test result for MIX 2

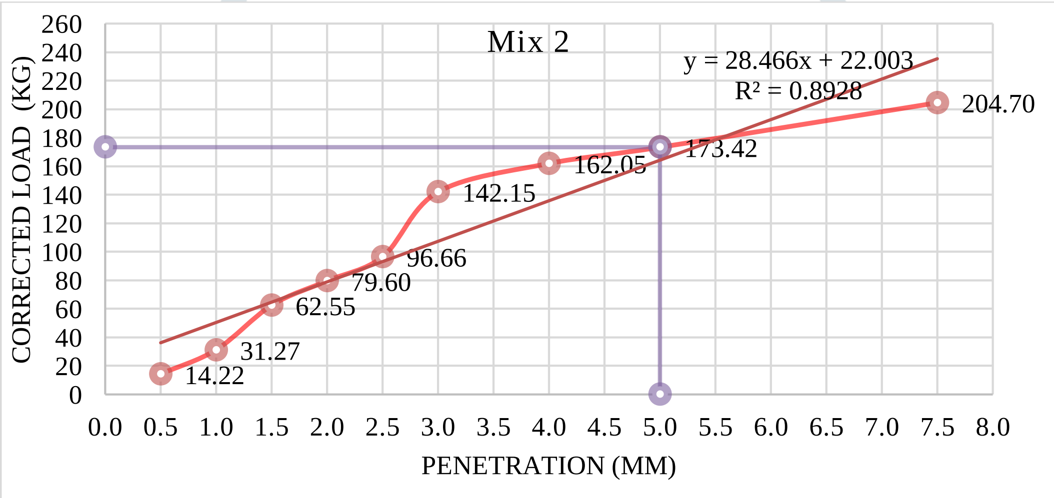

Figure 7: CBR Test result for MIX 2

S. No	Penetration (mm)		Proving ring Reading (A)	Load (Kg) Calibration Factor x A	Corrected load (Kg)
1	0.5		6	0	17.06
2	1		11	0	31.27
3	1.5		22	0	62.55
4	2		32	0	90.98
5	2.5		40	0	113.72
6	3		50	0	142.15
7	4		66	0	187.64
8	5		67	0	190.48
9	7.5		73	0	207.54
	Load	CBR%	CBR% Reported		
2.5 mm	113.72	8.3	9.27		
5.0mm	190.48	9.27			

Table 19: CBR Test result for MIX 3

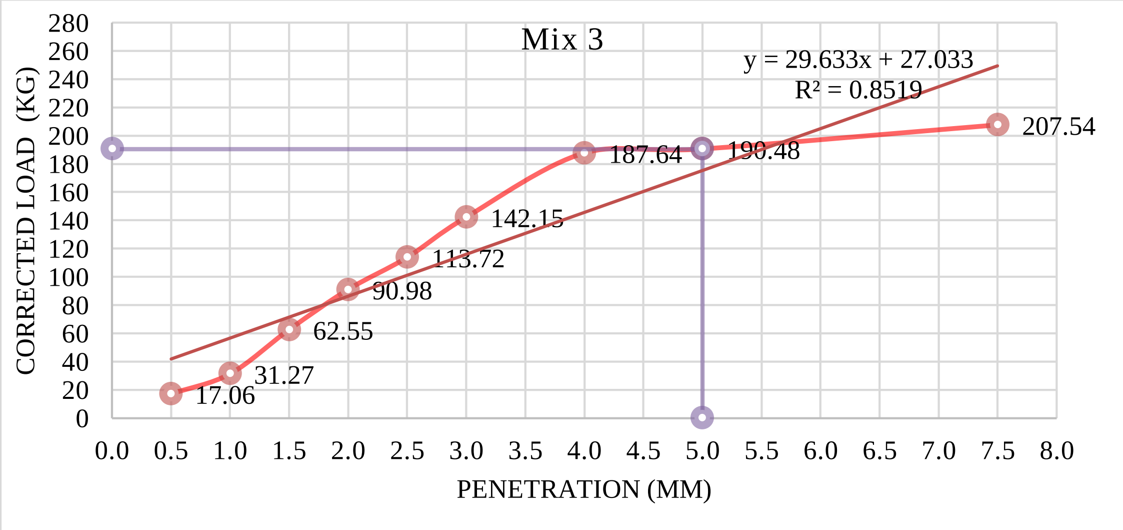

Figure 8: CBR Test result for MIX 3

S. No	Penetration (mm)		Proving ring Reading (A)	Load (Kg) Calibration Factor x A	Corrected load (Kg)
1	0.5		9	0	25.59
2	1		13	0	36.96
3	1.5		21	0	59.7
4	2		34	0	96.66
5	2.5		43	0	122.25
6	3		53	0	150.68
7	4		67	0	190.48
8	5		71	0	201.85
9	7.5		75	0	213.23
	Load	CBR%	CBR% Reported		
2.5 mm	122.25	8.92	9.82		
5.0mm	201.85	9.82			

Table 20: CBR Test result for MIX 4

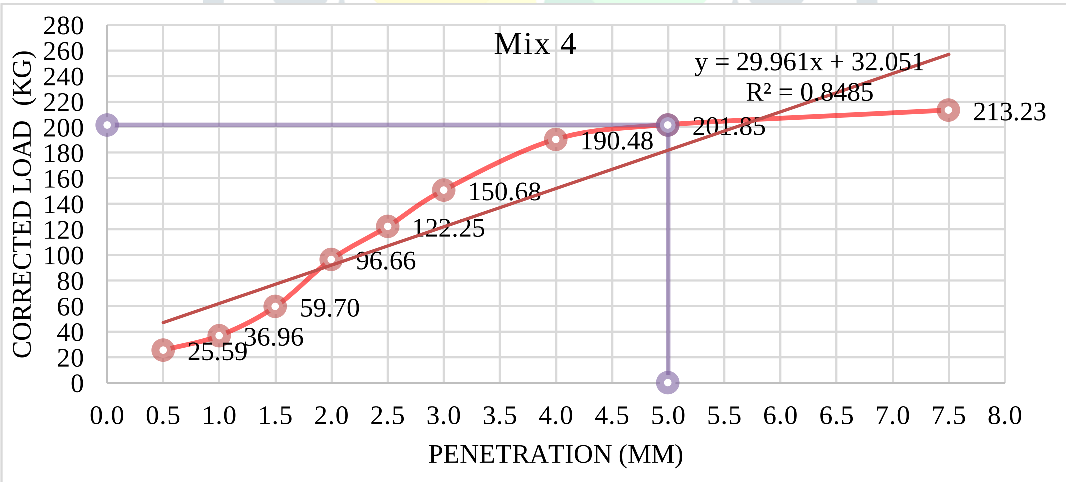

Figure 9: CBR Test result for MIX 4

CBR measures the strength of a road's subgrade and construction materials. The ratio is measured using a California Division penetration test for roadway engineering. The CBR value goes up if the surface is hard. A CBR value of 2% is usually clay, while a CBR value of 10% could be sand. A good sub-base will be worth between 80% and 100%. (maximum). The CBR test is done on soils with particles no bigger than 20mm.

5. DST TEST

Normal Stress(kg/cm)	Proving ring reading	Shear Load (N)	Shear Load (kg)	Shear Stress (kg/cm2)
0.5	36	137.52	14.03	0.39
1	44	168.08	17.15	0.48
1.5	56	213.92	21.83	0.61

Table 21: DST value for MIX 2

Normal Stress(kg/cm)	Proving ring reading	Shear Load (N)	Shear Load (kg)	Shear Stress (kg/cm2)
0.5	32	122.24	12.47	0.35
1	49	187.18	19.1	0.53
1.5	63	240.66	24.56	0.68

Table 22: DST value for MIX 3

Normal Stress(kg/cm)	Proving ring reading	Shear Load (N)	Shear Load (kg)	Shear Stress (kg/cm2)
0.5	31	118.42	12.08	0.34
1	46	175.72	17.93	0.5
1.5	58	221.56	22.61	0.63

Table 23: DST value for MIX $

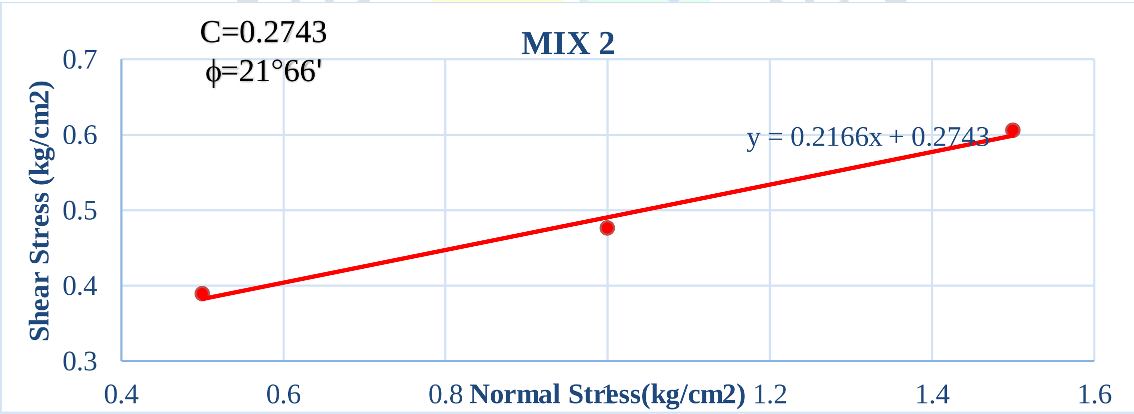

Figure 10: DST result for MIX 2

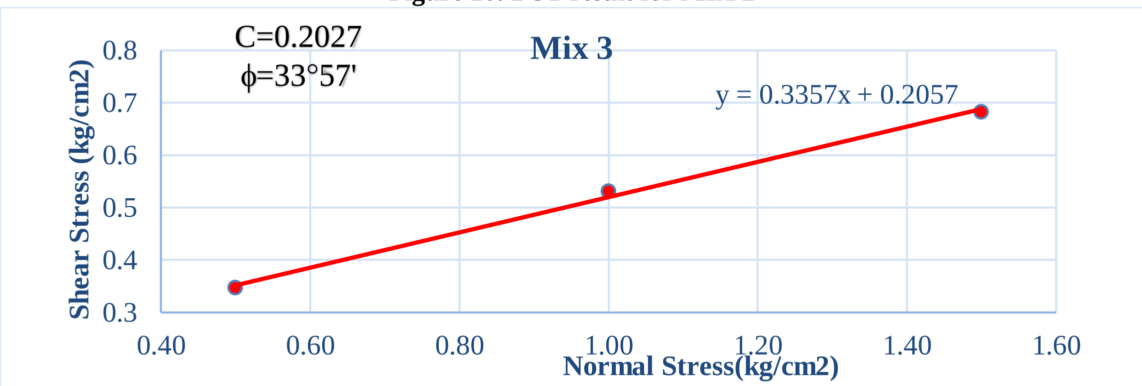

Figure 11: DST result for MIX 3

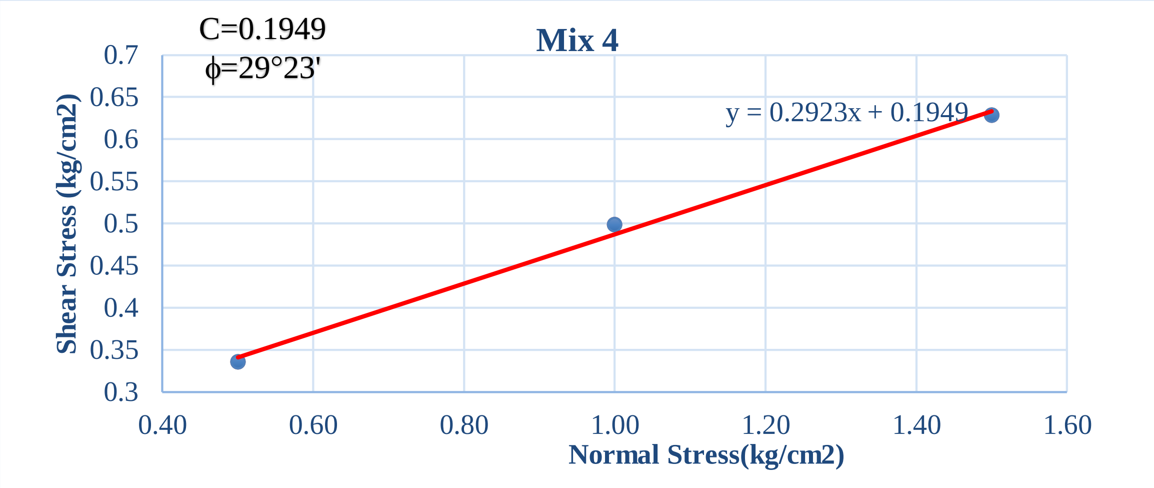

Figure 12: DST result for MIX 4

The Direct Shear Test is an experiment used in geotechnical engineering and research to find out how strong a material is when it is pulled apart. Shear strength is the maximum amount of force that a material can stand up to when it is sheared. From above figure it is concluded that the maximum frictional angle was observed at Mix 3 nearly to 33° 57' and after that it will decreased at 29° 23'.it shows the weak correlation at higher dose of Brick powder.

V. CONCLUSION

The goal of this study is to make the weak soils stronger and cut down on pollution by using old plastic strips as the subgrade layer of road pavements. The study can be used for two things. One is to find a good way to get rid of plastic waste, and the other is to make the subgrade layer of road pavements better. The following conclusions are drawn from the analysis and interpretations. Both MDD and OMC went down when different sizes and %ages of plastic strips were added to the soil. In some engineering projects, like building light embankments, a decrease in the density of the materials in the pavement layers is a good thing. As the number of strips goes up, the soil's ability to expand significantly goes down. This could be because an equal amount of soil was taken out and replaced with a strip of plastic.

All of the geotechnical properties of black cotton soil that has been treated with brick dust have been shown to improve.

- It is concluded that the maximum frictional angle was observed at Mix 3 nearly to 33° 57' and after that it will decreased at 29° 23'.it shows the weak correlation at higher dose of Brick powder.
- It is evaluated that the maximum corrected load was increased from 153Kg to 201.85Kg for the replacement of soil with brick powder and plastic strips.
- It is observed that the compression index, which is used in settlement analysis, can be estimated from the liquid limit test and it is changed with plastic and brick content.
- The saturation curve helps overlay dry unit weights upon that soil compaction curve. From figure 5, it is notes that the maximum dry density was recorded for Mix 3 , because of higher brick powder with plastic strips.
- This was due to the increment in the sand particles due to the brick elements in soil that increases the load bearing capacity.

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