Strengthening Of Soft Subgrade Soil Using Industrial Waste Iron Powder And Recycled Plastic Mesh

Kruthika D M
PG Student, Department of Geo-Technical Engineering
Bheemanna Khandre Institute of Technology
Bhalki Bidar, Karnataka, India

M. D. Khaja Moinuddin
Professor, Department of Civil Engineering
Bheemanna Khandre Institute of Technology
Bhalki Bidar, Karnataka, India

Dr .Vageesh Mathad
Professor, Department of Geo-Technical Engineering
Bheemanna Khandre Institute of Technology
Bhalki Bidar, Karnataka, India

Sharan Kumar
Asst. Professor, Department of Geo-Technical Engineering
Bheemanna Khandre Institute of Technology
Bhalki Bidar, Karnataka, India

***Abstract*—Construction of pavement on expansive or soft subgrade soil demands great deal of attention. It is more important to concentrate on strength of soil layers underlying the surface course, because the strength, thickness and design life of pavement are mainly depends upon the subgrade strength. There are many alternative methods available in order to improve the strength of subgrade. Soil stabilization is an effective method of improving soil properties. Subgrade strengthening using geogrids, geotextiles and geomembranes as soil reinforcement are most widely used methods. Now a day Use of industrial wastes as admixtures for soil stabilization has become trendy method in order to reduce the environmental hazards.**

In the present study an attempt was made to strengthen the soft subgrade soil using industrial waste iron powder (IP) as an admixture and recycled plastic mesh as soil reinforcement. Black cotton Soil was collected from Kharanja Dam, Bidar district. First Soil was blended with different percentages of iron powder i.e. 4, 5, 6, 7, and 8% and for all those proportions Compaction tests, atterberg limits and laboratory CBR tests were conducted for unsoaked and soaked conditions. From the tests we got 6% as the optimum percentage of iron powder. Similar to geogrid, three types of recycled plastic meshes having different colour and aperture sizes i.e. black grid mesh (BG), light green mesh (LG), dark green mesh (DG) were used as soil reinforcement. Soil specimens reinforced by 3 layers of each type of plastic meshes were prepared and for all those specimens laboratory CBR tests were performed in both Soaked and Unsoaked conditions. Further work is carried out to know the combined effect of iron powder and plastic mesh on soft subgrade soil. Finally in order to know the interaction of black cotton soil-iron powder-plastic mesh, soil specimens were prepared by combining optimum percentage of iron powder i.e. 6% and plastic mesh with highest CBR value i.e. BG mesh. The combined proportions are as follows; BC soil+6% IP+ single layer of BG mesh positioned at the center, 1/3rd from the top and 1/3rd from the bottom of the specimen respectively. BC soil+6% IP+2 layer of BG mesh positioned at 1/3rd points from both top and bottom of the specimen. BC soil+6% IP+3 layers of BG mesh positioned at the center and 1/3rd points from both top and bottom of the specimen. The unsoaked CBR values show considerable increase in strength than soaked CBR values.

***Keywords*— Iron Powder, recycled plastic mesh, OMC, MDD, CBR**

I. Introduction

Strengthening of soft subgrade soil using traditional materials like Cement, Lime and Bitumen has become common method. But in order to minimise the environmental hazards which has taken place due to rapid urbanisation and industrialization, it is more important to concentrate on proper utilization of industrial waste materials. Soil stabilization using industrial waste materials has become trendy from the point of view of environment and economy.

Iron is the 4th most copious element in the earth's crust and it makes up about 6.2% of the earth crust by weight. The per capita consumption of iron is taken as an important indicator of the level of economic development and also living standards of the people in that country. Iron is an important metal which is widely being used in every field. As a result a large quantity of Iron powder or Iron dust generated from different fields.

We all know that due to urbanization and industrialization, a huge quantity of waste plastic is emanated from many fields. For the present study, similar to geogrids recycled plastic mesh is used as reinforcement for soft subgrade soil. Here an attempt was made to strengthen the soft subgrade using recycled plastic mesh as soil reinforcement. In the current work we have used three types of plastic meshes having different colour and aperture sizes.

Many of the researchers worked on the strengthening of black cotton soil using Iron powder. Some researchers studied the problems due to soft subgrade and provided solutions namely geosynthetic and coarse fill for construction on these soils. Due to the cost of the project and scarcity of fill material they are effectively used locally available soft soils by adopting the soft soils strengthening techniques namely soil reinforcement.

In the current work weak subgrade soil is improved by using industrial waste iron dust as an admixture and plastic mesh as soil reinforcement. We have conducted the experimental work in order to know the performance of subgrade soil using recycled plastic mesh and Iron powder. Usually the pavement design is mainly depend upon California bearing ratio (CBR) value, CBR is one of the most significant engineering property of soil for design of subgrade.

II. EXPERIMENTAL DETAILS

A. Materials

1) Black cotton soil: Soil was collected from Karanja Dam, Bidar District from an open excavation, soil was collected at a depth of 1m to 1.5m below the natural ground surface..The soil is greyish black in color the physical properties of soil is tabulated in Table 1.

TABLE I. SHOWS THE PHYSICAL PROPERTIES OF CLAY SOIL

Sl No	Properties	B.C soil
1	Specific gravity	2.42
2	Liquid limit (%)	74
3	Plastic limit (%)	47.77
4	Shrinkage limit (%)	18.12
5	Plasticity index	26.23
6	I S Soil classification	CH
7	MDD (g/cc)	1.60
8	OMC (%)	23.5
9	CBR (%) Unsoaked Soaked	3.22 2.58

2) Industrial Waste Iron powder: Iron powder or Iron Dust used in the present work is taken from GOGGA MINERALS AND CHEMICALS, Hospet, Karnataka. Chemical properties of iron powder are tabulated as follows.

TABLE II. SHOWS THE CHEMICAL COMPOSITION OF IRON POWDER

Sl No	Properties	Percentage (%)
1	Ferric Oxide(Fe_2O_3)	98.06
2	Silica (SiO_2)	0.27
3	Alumina (Al_2O_3)	0.83
4	Sulphur (S)	0.008
5	Specific Gravity	5.10

3) Plastic mesh: Plastic meshes are collected from Raniganj, Hyderabad. Three different types of plastic meshes are used.

TABLE III. THREE TYPES OF PLASTIC MESHES

Type	Opening (cm)	Plate thickness (mm)
Black grid mesh (BG)	1.5	3
Dark green grid mesh (DG)	1.3	2
Light green grid mesh (LG)	3	2

B. Preparation of sample

Black cotton soil is replaced by different percentages of Iron powder i.e. 4%, 5%, 6%, 7% and 8%. For all these proportions MDD and OMC is calculated by conducting the standard proctor test. Atterberg limits named as Liquid limit, Plastic limit and Plasticity Indices were evaluated for all the proportions and in order to know the Load-settlement behaviour of soft subgrade soil California bearing ratio (CBR) tests were conducted. From all these experimental studies we have got an optimum percentage of Iron Powder.

In the current work three types of Recycled plastic meshes having different colour and aperture sizes as mentioned in the table 3 i.e. Black grid mesh, Dark green mesh and Light green mesh were used.

The soil is reinforced by three layers of black grid mesh, three layers of dark green mesh and three layers of light green mesh separately. CBR tests were conducted for all reinforced soil specimens in both soaked and un-soaked condition. Among these three types of mesh, the type of the mesh for which maximum CBR value obtained is taken as best reinforcement and is taken for further experimental work.

Further work is carried out to know the combined effect of iron powder and plastic mesh on soft subgrade. Finally the interaction of BC soil-iron powder-plastic mesh are determined by combining the optimum percentage of iron powder i.e. 6% and plastic mesh with highest CBR i.e. BG mesh. The combined proportions are as follows; BC soil+6% IP+ single layer of BG mesh positioned at the centre, 1/3rd from the top and 1/3rd from the bottom of the specimen respectively. BC soil+6% IP+2 layer of BG mesh positioned at 1/3rd points from both top and bottom of the specimen. BC soil+6% IP+3 layers of BG mesh positioned at the centre and 1/3rd points from both top and bottom of the specimen.

C. Experimental work

Following tests were carried out specific gravity test, moisture content test, atterberge limits, standard proctor test, California bearing ratio test.

III. RESULT AND DISCUSSIONS

A. OMC and MDD results for Black cotton soil replaced by different percentage of iron powder

TABLE IV. DESCRIBING RESULT FOR OMC AND MDD FOR BC SOIL WITH DIFFERENT PERCENTAGE OF IRON POWDER

SL.NO	Description	MDD (g/cc)	OMC (%)
1	Black cotton soil	1.6	23.52

2	Replacement of 4% iron powder in soil	1.8	23.52
3	Replacement of 5% iron powder in soil	1.84	26.31
4	Replacement of 6% iron powder in soil	1.85	22.22
5	Replacement of 7% iron powder in soil	2.04	25
6	Replacement of 8% iron powder in soil	1.92	27.58

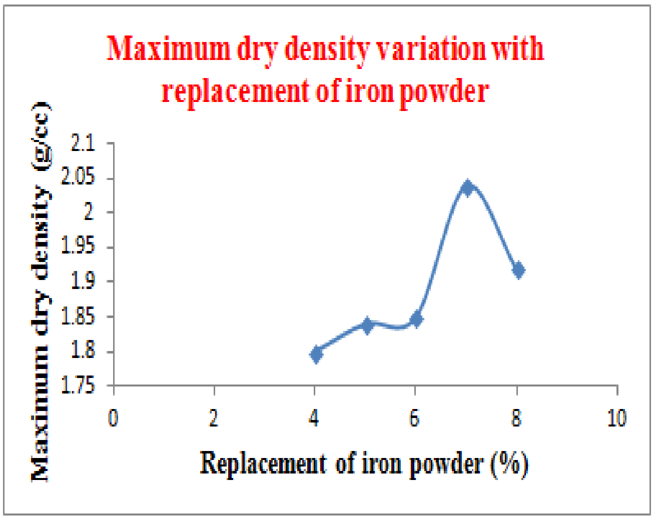

Fig. 1. Indicating the MDD variation for different proportions of BC soil and iron powder.

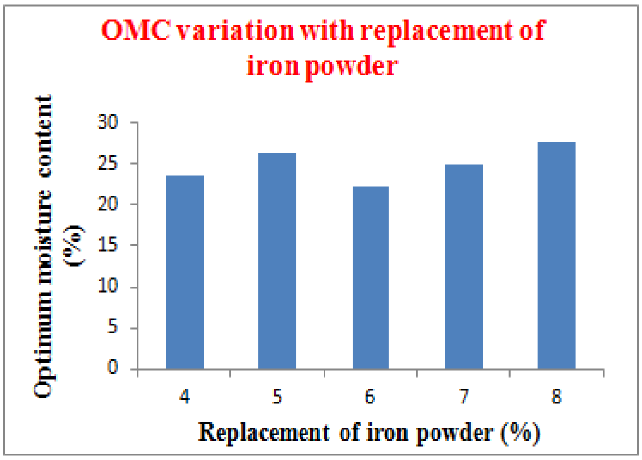

Fig. 2. Indicating the OMC variation for different proportions of BC soil and iron powder.

Figure 1 and 2 shows plot of MDD and OMC for BC soil replaced by 4,5,6,7 and 8% iron powder respectively. When BC soil and iron powder are blended, particles of iron powder intrude into the voids of soil leading to decrease in permeability of soil thereby density of soil is increased. Hence with increasing the percentage of iron powder MDD of soil get increased upto 7% of iron powder after that there is descending order in the MDD values. Figure 2 shows the variation of OMC for BC soil blended with different percentages of iron powder. From the table 4 it is observed that soil blended with 6% iron powder shows MDD at minimum OMC, therefore 6% iron powder is the optimum content for BC soil.

B. Atterberg's limits

TABLE V. ATTERBERG LIMITS FOR BC SOIL REPLACED WITH VARIOUS PERCENTAGE OF IRON POWDER

SL. NO	Replacement of iron powder in soil (%)	Liquid limit	Plastic limit	Plasticity index
1	4%	71	20	51
2	5%	59.5	20	39.5
3	6%	58	20	38
4	7%	55	20	35
5	8%	51	20	31

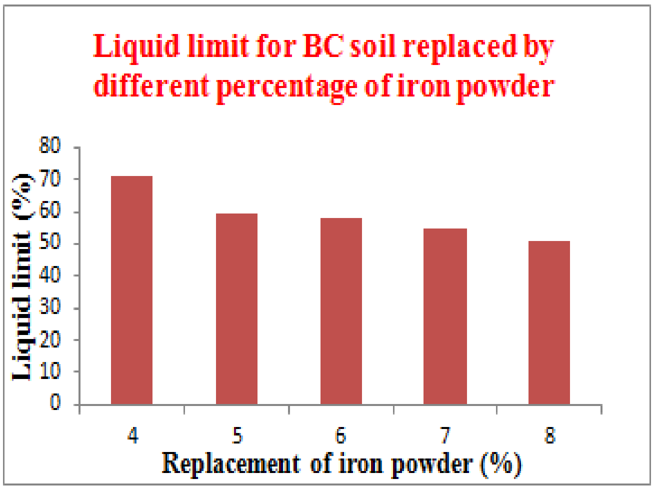

Fig. 3. Indicating the results of Liquid limit for BC soil replaced by various percentage of iron powder.

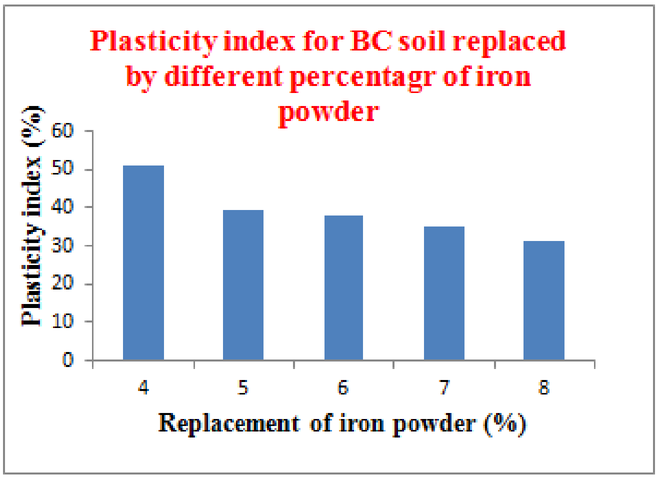

Fig. 4. Indicating the results of plasticity index for BC soil treated various percentage of iron powder.

Table 5 shows Atterberg limits for BC soil and iron powder mixed in different proportions. From the figure 3 and 4 it is figured that the liquid limit and plasticity index of soil shows descending order with increasing replacement of iron powder whereas Plastic limit of soil remains same. With the decrease in liquid limit of soil, expansive and contractive nature of BC soil also reduced.

C. CBR test results for BC soil blended with iron powder

TABLE VI. CBR RESULTS FOR REPLACEMENT OF VARIOUS PERCENTAGE OF IRON POWDER IN BC SOIL

SL.NO	Replacement of iron powder in soil (%)	CBR (%)	
		Unsoaked	Soaked for 4 days
1	0	3.22	2.58
2	4	4.51	2.58
3	5	5.8	2.58
4	6	6.45	3.22
5	7	7.09	3.22
6	8	9.67	3.22

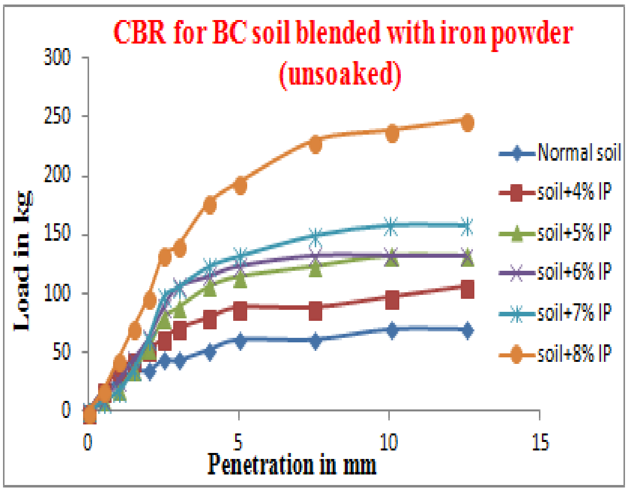

Fig. 5. Load-Penetration curve for BC soil blended with different percentage of iron powder in unsoaked condition.

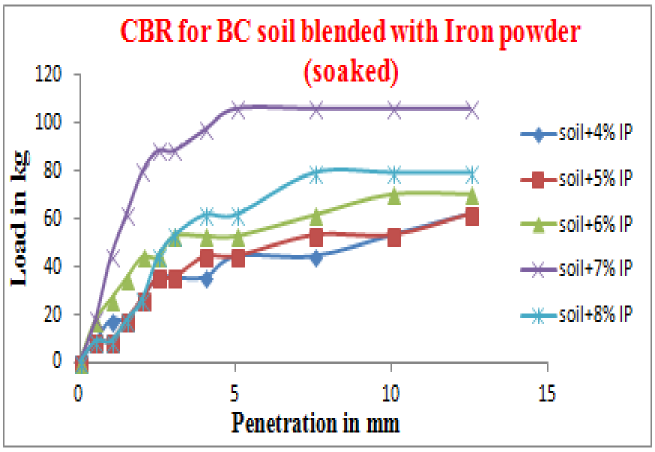

Fig. 6. Load-Penetration curve for BC soil blended with different percentage of iron powder (soaked).

From the figure 5 we can notice that the unsoaked California bearing ratio of BC soil is gradually increased with increasing replacement of iron powder in BC soil and thereby increasing the penetration resistance of subgrade i.e. the bearing capacity of soil.

Figure 6 shows soaked California bearing ratio values for soil blended with different percentage of iron powder. Soil with 4% and 5% iron powder shows same CBR values for soaked condition as that of normal soil whereas soil with 6%, 7% and 8% iron powder gives increase in penetration resistance of soil subgrade.

D. CBR results for soil with three layers recycled plastic meshes

TABLE VII. CBR RESULTS FOR SOIL WITH 3 LAYERS OF RECYCLED PLASTIC MESHES

SL.NO	Description	CBR (%)	
		Unsoaked	Soaked for 4 days
1	BC Soil + (DG+DG+DG)	5.80	3.87
2	BC Soil + (LG+LG+LG)	9.67	3.87
3	BC Soil + (BG+BG+BG)	13.55	4.19
4	BC Soil + (BG+LG+BG)	7.74	2.90
5	BC Soil + (BG+DG+BG)	3.87	2.58

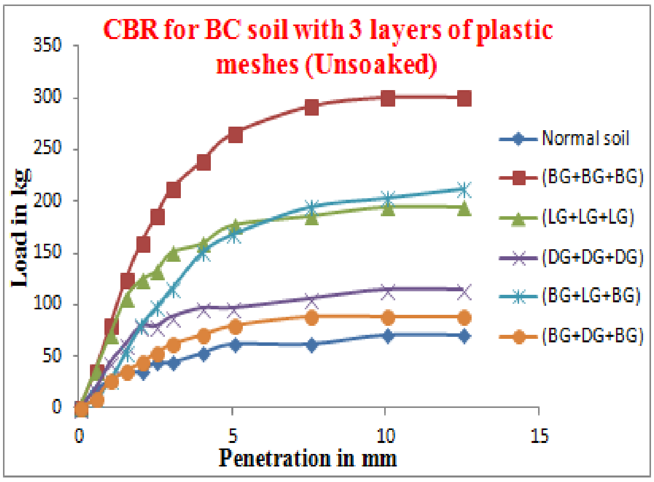

Fig. 7. Load-Penetration curve for BC soil blended with different percentage of iron powder (soaked).

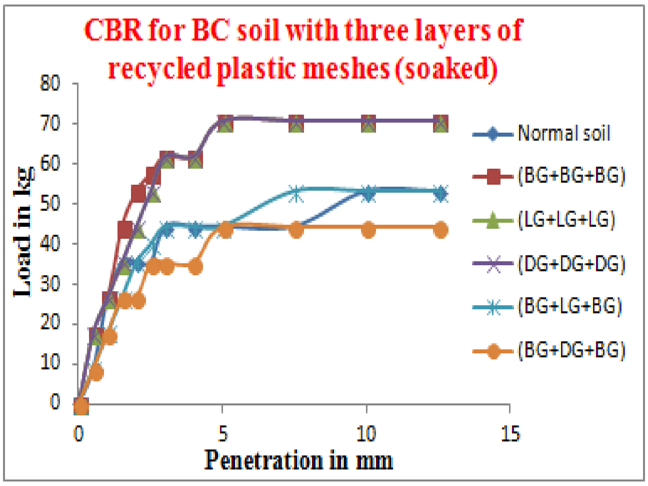

Fig. 8. Load-Penetration curve for soil with three layers of plastic meshes (soaked).

Figure 7 shows comparison of unsoaked CBR for BC soil provided with three layers of plastic meshes. Maximum strength achieved for soil with three layers of black grid mesh. Use of three layers of light green grid gives second highest strength for soil and insertion of light green mesh in between two layers of black grid mesh also gives good results.

From the figure 8 we can observe that there is no much difference in CBR for soaked condition for soil with plastic meshes when compared to that of normal soil.

E. CBR results for BC soil + iron powder + plastic meshes

TABLE VIII. CBR FOR BC SOIL +6% IRON POWDER + BG MESH

SL.NO	Description	CBR (%)	
		Unsoaked	Soaked for 4 days
1	BC soil+6% IP+ 1 layer of BG mesh at the centre of the specimen	5.80	2.58
2	BC soil+6% IP+ 1 layer of BG mesh at 1/3rd height from bottom of the specimen	7.09	2.58
3	BC soil+6% IP+ 1 layer of BG mesh at 1/3rd height from top of the specimen	7.42	2.58
4	BC soil+6% IP+ 2 layers of BG mesh placed at 1/3rd points from both top and bottom of the specimen	8.38	2.90
5	BC soil+6% IP+ 3 layer of BG mesh placed at centre and 1/3rd points from both top and bottom of the specimen	4.51	2.58

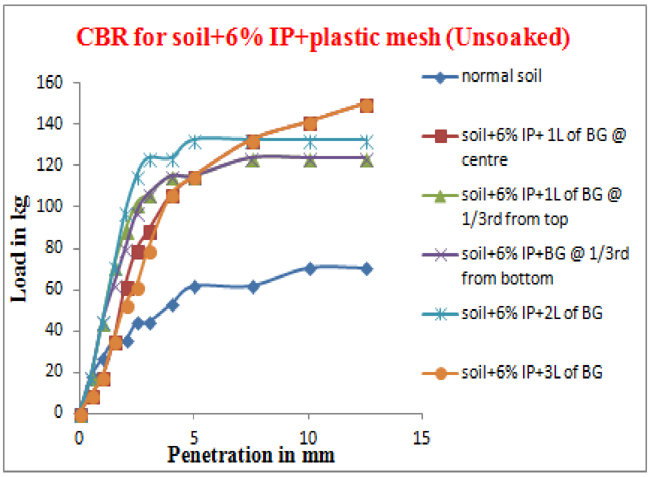

Fig. 9. Load-Penetration curve for BC soil+6% iron powder +plastic mesh (unsoaked).

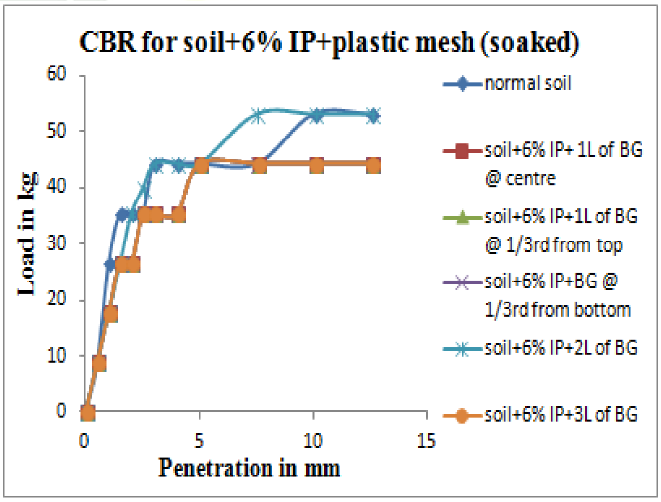

Fig. 10. Load-Penetration curve for BC soil+6% iron powder +plastic mesh (soaked).

From the table 8 and figure 9 we can observe that for BC soil-6% iron powder-single layer of BG mesh, the optimum position of BG mesh is at 1/3rd height from top of the specimen. Highest unsoaked CBR observed for BC soil-6% iron powder-2 layer of BG mesh. For BC soil-6% iron powder-

3 layer of BG mesh unsoaked CBR value get decreased. There is no much variations observed for soaked CBR when compared to normal soaked CBR.

CONCLUSION

Many researchers have made work on improvement of weak subgrade soil using geosynthetic materials like geotextile, geomembrane and geogrid as soil reinforcement and also improvement in properties of weak soils have made by using industrial wastes as admixtures. In the current work recycled plastic meshes are used as soil reinforcement and iron powder as an admixture. In the present work we have made an attempt to know the combined effect of recycled plastic mesh and iron powder on strength properties of soft subgrade soil.

Following conclusions are made from the current work.

- When iron powder was mixed with BC soil, it intrudes into voids of soil thereby permeability of soil reduces leading to decrease in swelling and shrinkage of BC soil, thus increase in density of soil i.e. strength of soil.
- With the increase percentage of iron powder, liquid limit and plasticity index of soil decreases thereby swelling and shrinkage properties of soil reduced leading to increase in efficiency of soil.
- For 6% of iron powder maximum dry density is achieved at minimum optimum moisture content. Therefore 6% is the optimum percentage of iron powder for the current research work.
- CBR values of BC soil shows incremental order with increasing the percentage of iron powder thereby the strength of soil get increased.
- With the introduction of plastic mesh in soil sample, the CBR value has increased 3.2 times to the normal soil.
- When optimum percentage of iron powder and two layers of plastic mesh combined, CBR of soil has increased 2.6 times to the normal soil.
- The aperture size, thickness and number of layers of plastic meshes and their location within the specimen also influences the CBR of soil.
- Insertion of plastic mesh in the soft subgrade stabilisation results in better distribution of applied loads. Thus improves the service life of pavement with reduction in thickness of pavement.

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FUTURE SCOPE

The current work was conducted on the black cotton soil in order to increase its strength enough to pavement construction. Nature and properties of soil varies from place to place, which may be laterite, BC soil, marine soil, alluvial soil etc. The experimental work conducted in the present study may also be carried out for following changes.

- The present work is mainly concentrated on strengthening of BC soil, it may also be conducted for different subgrade soil conditions having weak strength.
- Along with plastic meshes, instead of iron powder other alternative industrial wastes may be used as admixtures.
- Along with iron powder, instead of plastic meshes, fibres may be used as reinforcement material for soil.
- In the present work initially CBR was conducted for soil with iron powder and plastic meshes separately. Later CBR was conducted for soil by combining the optimum percentage of iron powder and plastic mesh with high strength. In the future work CBR may be conducted for the combination of higher proportions of iron powder and plastic meshes.

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