Experimental Study on Strength Behavior of Plastic Reinforced Red Earth

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***Abstract*-In this present study, an attempt has been made to use waste plastic bottle strips as a reinforcing element to improve the strength characteristic of Red earth. To fulfill these objectives, experiments are conducted in two stages viz., Direct shear tests with varying plastic content on the Red earth samples and Static load tests with varying plastic content.**

***Keywords:* soil, strength characteristics, waste plastic bottle strips, reinforcement.**

I. INTRODUCTION

Soil Reinforcement is the technique wherein soil is reinforced by means of materials like fibres, strips, geo grids etc for the purpose of improving its properties like shear strength, load carrying capacity etc.

Despite the ban in some Indian states, the use of plastic products, such as polythene bags, bottles, containers, and packaging strips, is increasing by leaps and bounds. As a result, open waste dumps are continuously filling up with this valuable resource. In many areas waste plastic is collected for recycling and reuse; however, the success of any recycling program will depend on the secondary market for waste plastic. At present, only a fraction of all waste plastic is used for recycling purposes. The recycled plastics are commercially available now a days in various forms and states, which actually can be very effectively used up for various purposes.

One of the best ways to handle the increasing pressure of waste plastic on open dumps will be to utilize it for ground improvement after shredding. In this present study, an attempt has been made to use waste plastic bottle strips as a reinforcing element to improve the strength characteristic of Red earth.

II. LITERATURE REVIEW

The bottled water is the fastest growing beverage industry in the world. According to the international bottled water association (IBWA), sales of bottled water have increased by 500 percent over the last decade and 1.5 million tons of plastic are used to bottle water every year.

The general survey shows that 1500 bottles are dumped as garbage every second and it is reported a world's annual consumption of water bottles is approximately 10 million tons and this number grows about up to 15% every year. On the other hand, the number of recycled or returned bottles is very low. On an average, an Indian uses one kilogram (kg) of plastics per year and the world annual average is an alarming 18 kg, approximately, 4000- 5000 tonnes per day postconsumer plastics waste are generated. And it becomes very serious problems in metropolitan cities.

In order to overcome these problems, there needs to be concerted efforts in the reuse of plastic waste from water bottles and this study is in this direction. In this chapter an attempt is made to study ground improvement techniques, brief description about reinforced soil structures and the review the various literatures that use of waste water bottles in the field of geotechnical engineering.

A laboratory investigation was carried out by **Dr. Sujit Kumar Pal (2008)** to evaluate the effect of waste plastic fibre on compaction and consolidation behavior of reinforced soil.In this experimental study, raw plastic bottle fibres has been used in three different aspect ratios (AR), i.e. 2 (size=10mm X 5 mm), 4 (size=10mm X 2.5mm) and 8 (size=10 mm X 1.25 mm). These different sizes of plastic strips have been mixed with local sandy-silt soil with clay (Fine Sand = 40.15%, Silt = 30.90%, and Clay = 28.95%) in four different percentages 0.00, 0.25, 0.50 and 1.00% by dry weight of the soil. Various consolidation tests were conducted on soil alone and soil mixed with waste plastic fibres. From the Figures 2.5, 2.6, 2.7 it is concluded that, with the increase of plastic fibres in soil, compression index (Cc) and coefficient of volume change (mv) of soil decreases up to 0.50% fibre content. But the values increases with further inclusion of plastic fibre of 1.00% in soil. The values of coefficient of consolidation increases with the increase of plastic fibres in soil for aspect ratios 2, 4 and 8.

Studies carried out by **A K choudhary et al (2010)** on the performance of paved and unpaved roads. The experimental study involved performing a series of laboratory CBR tests on unreinforced and randomly oriented HDPE strip reinforced sand specimen. HDPE having a width of 12mm and a thickness of 0.40 mm. These were cut into lengths of 12mm [Aspect Ratio (AR) =1, 24mm (AR=2) and 36mm (AR=3)]. They maintain the mould diameter remains at least 4 times the maximum strip length, which will ensure that there is sufficient room for the strips to deform freely and independent of mould confinement. The tests were conducted at various strip contents of 0.0%, 0.25%, 0.50%, 1.0%, 2.0% and 4.0%.

The CBR value of the unreinforced sand corresponding to 2.5mm and 5.0mm penetration were found to be 14.01 % and 18.88 %, which were increased to 24.23% and 29.20% respectively when sand was reinforced with 0.25% waste plastic strips having aspect ratio equal to 1. Further increase in strip content from 0.25% to 1% without changing the aspect ratio again enhanced the CBR value to 29.78% and 32.89% respectively corresponding to 2.5mm and 5.0 mm penetration. The trend remained unchanged even when the percentage of waste plastic strip content is further increased from 1% to 2% or 4% in the soil. The maximum value of CBR at 5 mm penetration is 41.65% when 4% waste plastic strip content having aspect ratio equal to 1 was mixed with the soil. Similar results have been observed for other values of aspect ratios. The variation of CBR for strip reinforced sand with different strip lengths at various strip contents is shown in Figure 2.3. On the other hand, Figure 2.4 shows the variation of CBR with different strip contents at various aspect ratios.

Based on the results, the following conclusions can be drawn:

The addition of reclaimed HDPE strips, a waste material, to local sand increases the CBR value. The reinforcement benefit increases with an increase in waste plastic strip content and length. The maximum CBR value of a reinforced system is approximately 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. This suggests that the strips of appropriate size cut from reclaimed HDPE may prove beneficial as soil reinforcement in highway sub-base if mixed with locally available granular soils in appropriate quantity.

Chandra Shekar Arya et al.,(2013) carried out an experimental study to investigate the dry density and CBR behavior of waste plastic (PET) content on stabilized red mud, fly ash and red mud fly ash mix. PET bottle of size less than 20mm and bigger than 4.75mm was taken and mixed in different proportions of 0.5,1, 2, 3, and 4% by dry weight of red mud, fly ash, and red mud fly ash mix. From the test results it was found that with inclusion of plastic,

1. The dry density of red mud, fly ash, red mud fly ash mix increases at 2% plastic content. And there after with the inclusion of plastic there is no increase in dry density.

2. The dry density of red mud, fly ash, red mud fly ash mix at 2% plastic content was found to increase from 1.53gm/cc, 1.21gm/cc, 1.38gm/cc to 1.62gm/cc, 1.27gm/cc, 1.44gm/cc.

3. The unsoaked and soaked CBR values increased with the varying plastic content and found to be optimum at 2% plastic content.

4. The unsoaked CBR values of unreinforced red mud, fly ash and red mud fly ash mix is found to be 2.92, 8.03 and 7.6%. The unsoaked CBR values of reinforced red mud, fly ash and red mud fly ash is found to be 9.72, 11.84 and 10.66 at 2% plastic content.

Dr.Haider mohammed mekkiya (2013) carried out experimental study on new soil improvement method with a minimum cost by using polymer fiber materials having a length of 3cm in both directions and 2.5mm in thickness, distributed in uniform medium dense sandy soil at different depths (b, 1.5b and 2b) below the footings. Three square footings has been used (5,7.5 and 10 cm) to carry the above investigation by using lever arm loading system design for such purposes. These fibers were distributed from depth of (0.1b) below the footing base down to the investigated depth. It was found that the initial vertical settlement of footing was highly affected in the early stage of loading due to complex soil-fiber mixture (SFM) below the footing. The failure load value for proposed model in any case of loading increased compared with the un-reinforced soil by increasing the depth of improving below the footing. The bearing capacity ratio (BCR) for soil-fiber mixture has been increased by ratio of (1.4 to 2.5), (1.7 to 4.9), and (1.8 to 8) for footings (5, 7.5, and 10 cm) respectively. The yield load-settlement for soil-fiber mixture system started at settlement of about 1.1% b while the yield load in un-reinforced soil started at smaller percentage which reflects the benefits of using such fiber material for improving soil behavior.

It is concluded that, the bearing capacity ratio increased from unreinforced to reinforced condition which reflect the benefit of using such polymer fiber material underneath footing as minimum cost solution for increasing the bearing capacity and reduces soil settlement

III. MATERIALS

The materials used for the present study is Red earth and plastic strips obtained by shredding of waste water bottles.

A. Red earth

Table 1 presents the properties of the red earth used. The red earth is classified as Silt of Low compressibility/plasticity according to Indian standard classification system (ISCS).

PROPERTIES	TEST RESULT
specific gravity	2.78
Liquid Limit (%)	45
Plastic Limit (%)	25
Shrinkage Limit (%)	14
Dry unit weight (kN/m3)	18.2
Optimum Moisture Content (%)	18
Silt + Clay (%)	58 + 18 = 76
Soil classification (IS)	ML

Table 1: Properties of Red Earth

B. Plastic

Used water bottles manufactured by a particular company are collected from restaurants and old scrap dealers. After splitting it open rectangular sheets are obtained. These sheets are cut in to required dimensions manually using small hand instruments like razors and cutters.

Preliminary experiments are conducted with shredded plastic with red earth. Further to improve the performance of such shredded plastic – a modification is made for the shredded plastic. 5mm diameter holes are punched in each of the shredded plastic strips at prefixed spacing. Providing such perforation in the shredded plastic is expected to provide confinement to the soil particles at the microlevel and thereby may contribute to the improvement in the performance of plastic reinforced red earth.

C. Other accessories

The dimensions of footing and steel tank are,

1. Mild steel footing Size/Diameter of circular footing = 60mm Thickness = 4mm

2. Mild steel tank Diameter = 300mm and Height= 450mm.

IV. EXPERIMENTAL WORK

Shredded plastic strips with perforation are mixed with red earth to improve the shear strength parameters and Direct shear test is conducted on such mixtures. One dimensional large scale load – penetration tests was also conducted on 60mm circular footing. Tests were conducted on

i) Unreinforced earth

ii) reinforced red earth (with plain and perforated plastic strips)

A. Direct shear test setup

The unreinforced/reinforced red earth specimens are prepared by static compaction method in the square specimen cutter of dimension 6 x 6 x 3cm itself, after compacting it, the soil sample was placed on a 6 x 6 cm protuder having 0.5cm square protrusion and then required size of soil sample of dimension 6 x 6 x 2.5cm was obtained. It is then transferred to the shear box by pressing down the grid plate with the thumbs, with the base resisting plate, porous plate, grid plate and loading plates required in place in the shear box. The test is conducted at various normal stresses (σ) = 50,100 and 200kpa.

B. Static load test set up

The static load equipment consists of,

1. Loading frame
2. Proving ring
3. Mild steel square tank
4. Mild steel loading plates
5. Dial gauges

C. Loading frame and Proving ring

The loading frame designed to apply a maximum compressive load of 500KN as shown in Fig.2 It is a strain controlled equipment capable of applying six constant rates of strain.

A circular base plate of 32mm thickness and 250mm diameter is attached to a vertical stem. The stem has threads and connected to a worm wheel arrangement. The tank containing the soil is placed over the base plate and is made to butt against the upper rigid arm of the loading frame through proving ring. A vertical movement of the base plate thus induces a compressive load on the soil and the load is read by the proving ring reading.

The proving ring has a maximum capacity of 50KN and capable of measuring least compressive load of 0.063kN.

D. Mild steel circular tank & Mild steel footing with load connector

The distance between the two vertical arms of loading frame is 540mm available in the laboratory. Hence a 300mm diameter of circular tank is selected. The height of the tank is 450mm.The tank is made up of mild steel plate of 4mm wall thickness and base thickness of 6mm adequate enough to prevent buckling of tank during loading. On outer surface of tank, 3 numbers of 5mm diameter mild steel rods are welded to facilitate in fixing dial gauges in position, which are required to record the settlements. Two mild steel handles are welded on the outer face of tank wall for facilitating easy lifting of tank. The inner surfaces of the tank wall are made as smooth as possible coating with lubrication gel to reduce the side friction. Mild steel circular footing of diameter 60mm and thickness 4mm with a circular load connecter is used as model footing.

E. Dial gauge

For Present study dial gauge was used to measure the settlement of model footing. The least count of dial gauge is 0.01mm.

F. Preparation Of Reinforced Red Earth

For the present study, red earth is used as a foundation soil. The tank is divided into five equal layers each of 80mm depth. In order to avoid spilling of soil particles while compacting last layer at the top, a clearance of about 30mm-50mm is given. Test are conducted on red earth compacted at MDD of 1.8gm/cc at an OMC of 18%. From the MDD value, and by knowing volume of tank, the mass of red earth required can be calculated. This mass was divided into five equal parts of uniform moisture content throughout. Using the depth markings on the sides of the tank as a guide, the red earth is compacted in five equal layers. Then footing with connecting rod is placed at the top layer of the soil. (according to the ratio of depth of footing to width of the footing.ie. D/B=0).

V. TESTING PROGRAMME

Normal stress (kPa)	Perforated plastic (%)
50	0
	0.5
	1.0
	1.5
100	0
	0.5
	1.0
	1.5
150	0
	0.5
	1.0
	1.5

Table 2: Experimental Programme of Direct Shear Test

Static load test	
Embedded depth (D/B)	Perforated plastic (%)
0	0
	1
	2
	3

Table 3: Experimental Programme of static load test

VI. RESULTS

A. Direct Shear Test Results

To bring out the effect of inclusion of perforated plastic strips direct shear tests are conducted on red earth soil sample with 0.5%, 1.0% and 1.5% perforated plastic strips. The direct shear tests are conducted on sample of size 6cmx6cmx2.5cm. The plastic strip had an aspect ratio of 1 with a hole of diameter 5mm at the centre of the strip. Due to the sample size other aspect ratio for the perforated plastic strips could not be tried. However the experiments are conducted with different aspect ratios and varying number of perforations in large scale triaxial test. This discussion in this section is limited to the results of direct shear test.

Fig 1 to Fig 4 presents the shear strength envelope for soil alone and 0.5%, 1.0% and 1.5% perforated plastic strips reinforced red earth soil sample respectively. The cohesion and angle of internal friction for the untreated red earth soil sample is 48kPa and 33^{o} at the test condition. These values are in the range of expected results. Upon treatment with 0.5% perforated plastic strips the cohesion increased considerably to 76kPa and the angle of internal friction increased marginally to 36^{o}. These experimental results are confirmed by conducting reproducibility test on all the samples. This increase in the cohesion and angle of internal friction of the red earth soil sample may be attributed to the development of pseudo confinement due to the perforation made in the plastic strips. It is to be mentioned at this stage that experiments conducted with plastic strips without perforations did not yield any improvement in the shear strength parameter. In fact the soil sample showed a negative kind in case of plain plastic strips and hence it can be inferred that the perforation made at the centre of the strips is responsible for the improvement exhibited due to the development of confinement.

Similar trend of results is observed in case of 1.0% perforated plastic strip reinforced red earth sample also. Fig 6 indicates that c and Φ values are increased further compared to 0.5% perforated plastic reinforced red earth (c = 87kPa against 76kPa and Φ = 44^{o} against 33^{o}). However 1.5% perforated plastic strip reinforced red earth sample showed a decreasing trend in c and Φ values compared to 1.0% perforated plastic reinforced red earth sample (fig 7, c = 58kPa against 87kPa and Φ = 38^{o} against 44^{o}). However compared to the unreinforced red earth sample, still an improvement in c and Φ values (Fig 5 and Fig 8, c = 58kPa against 48kPa, Φ = 38^{o} against 33^{o}) is observed. The decrease in the shear strength parameter at higher dosage of perforated plastic strip may be attributed to the possible slippage between the soil particles and the smooth plastic surfaces.

The discussion presented above clearly establishes that the provision of perforated plastic strips is effective in improving the shear strength properties of red earth soil sample and the optimum plastic content appears to be 1.0% to 1.5% by weight of the soil sample.

B. Effect of inclusion of perforated plastic on shear strength parameter

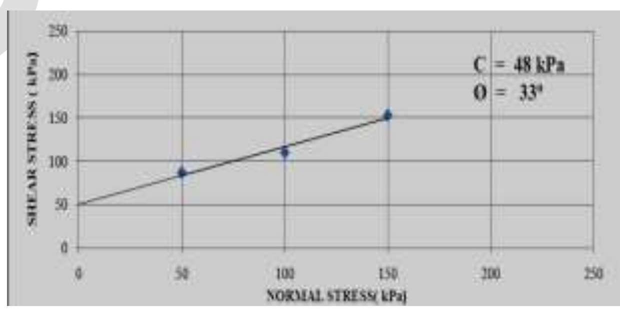

Fig 1: Strength envelope for Red earth alone subjected to Direct shear test

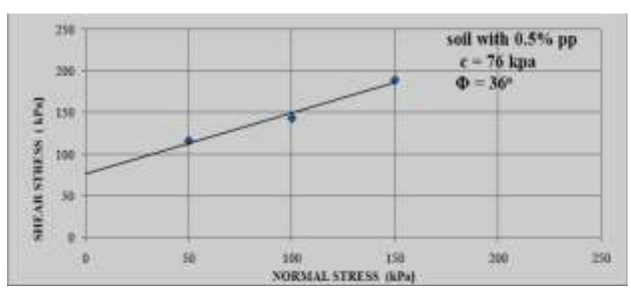

Fig 2: Strength envelope for Red earth treated with 0.5% perforated plastic strips subjected to Direct shear test

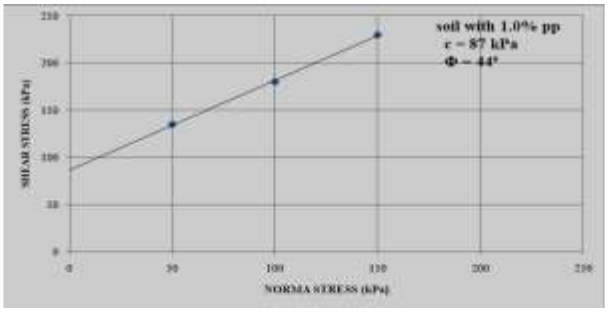

Fig 2: Strength envelope for Red earth treated with 1.0% perforated plastic strips subjected to Direct shear test

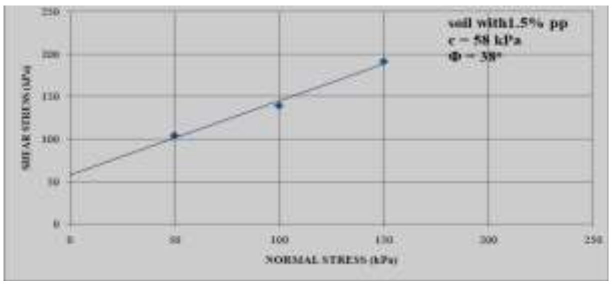

Fig 4: Strength envelope for Red earth treated with 1.5% perforated plastic strips subjected to Direct shear test

C. Effect of perforated plastic reinforcement on load-bearing & settlement behaviour

In this section efforts are made to bring out the effect of load settlement behaviour of untreated Red earth and reinforced Red earth. The load carrying capacity of untreated and treated Red earth is recorded at different dosage of perforated plastic content. The perforated plastic is added to the Red earth insteps of 1% up to 3% by weight of the soil sample. The corresponding settlement of unreinforced and reinforced Red earth is recorded at various perforated plastic strip content. The dry density and moisture content are same as maintained in the Direct shear test, conventional Triaxial test and large scale Triaxial test.

(a) Effect of perforated plastic strips on load behaviour in Static load test

Fig. 5 and Fig 6 presents the load-settlements curves for footing with embedded depth D/B=0(surface). The same data has been tabulated in Table 4 for the similar testing conditions.

From the Figures it can be observed that, as plastic (%) content increases in Red earth bed the load carrying capacity of the footing increases. This is because of plastic strips having holes offer more interfacial frictional resistance and thereby increases the load carrying capacity.

For example from Figure 8, it is observed that as the plastic increases the load carrying capacity of the footing increases from 290kg for unreinforced Red earth to 360kg for 1.0% plastic of reinforced Red earth. Similar trend is observed for 2% and 3% plastic reinforced Red earth. The increase in load is 410kg at 2% plastic reinforced red earth and 480kg at 3% plastic reinforced red earth.

As the plastic strips having holes, more number of soil particles comes in contact with the plastic reinforcement and that may leads to increase the frictional interaction between soil and plastic. This interlocking of the soil through holes of the strips mobilizes the high tensile strength of the plastic strips as loads are applied and an efficient anchoring effect achieved and therefore the plastic reinforcement becomes stiff and that results in taking up in the higher load bearing capacity.

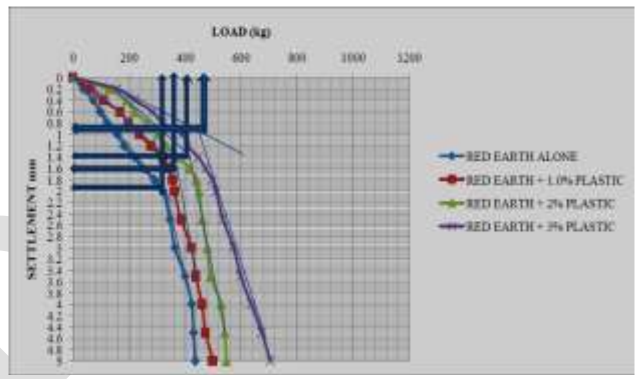

Fig 5: Effect of perforated plastic strips on load settlement behaviour in Static load test

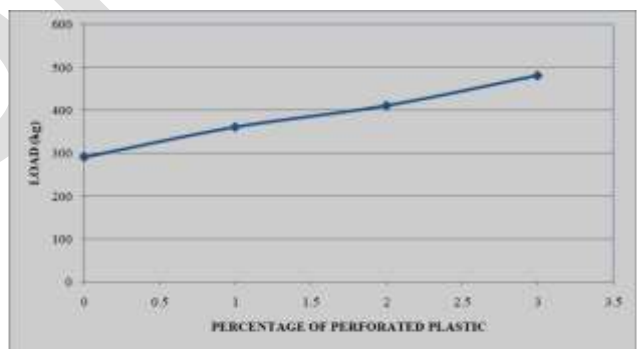

Fig 6: Effect of perforated plastic strips on load behaviour in Static load test

PERCENTAGE OF PLASTIC	LOAD (kg)
RED EARTH ALONE(RE)	290
RE + 1.0% PLASTIC	360
RE + 2% PLASTIC	410
RE + 3% PLASTIC	480

TABLE 4: Load behaviour in Static load test

D. Effect of perforated plastic strips on settlement behaviour in Static load test

Fig 7 and Table 5 presents the data of settlement behaviour of Red earth treated with perforated plastic for 1%, 2% and 3%. The test is conducted with varying plastic content and the corresponding settlement is recorded. It is observed from the data that with the inclusion of perforated plastic strips settlement reduces. For example the settlement of unreinforced Red earth is 2mm. whereas with the inclusion of plastic the settlement reduced to 1.6mm at 1% perforated plastic content. Similar trend of decrease in settlement is observed at 2% and 3% plastic content. The settlement decreased from 1.4mm at 2% perforated plastic content to 3% perforated plastic content.

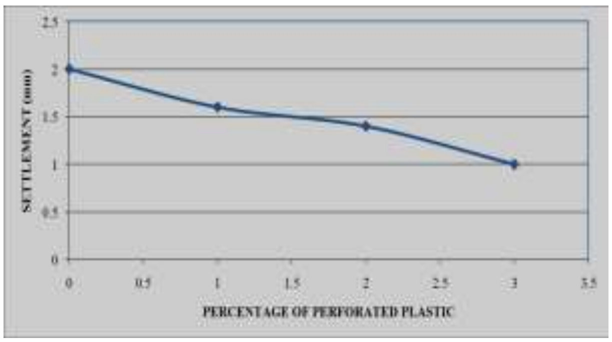

Fig 7: Effect of perforated plastic strips on settlement behaviour in Static load test

PERCENTAGE OF PLASTIC	SETTLEMENT (mm)
RED EARTH ALONE(RE)	2.0
RE + 1.0% PLASTIC	1.6
RE + 2% PLASTIC	1.4
RE + 3% PLASTIC	1.0

TABLE 5: Settlement behaviour in Static load test

E. Percentage change in load and settlement at different dosage of plastic strip

Fig 8 presents the percentage change in load at various perforated plastic content. The percentage change in load at 1%, 2% and 3% perforated plastic is presented in the Table 6. The percentage change in load at 1% perforated plastic. Similar trend is observed at 2% and 3% perforated plastic content. At 2% and 3% perforated plastic the percentage change in load is 30% and 65%.

Fig 9 and Table 7 presents the percentage change in settlement at 1%, 2% and 3% perforated plastic content. The percentage change in settlement at 1%, 2% and 3% perforated plastic content is 24%, 30% and 65%.

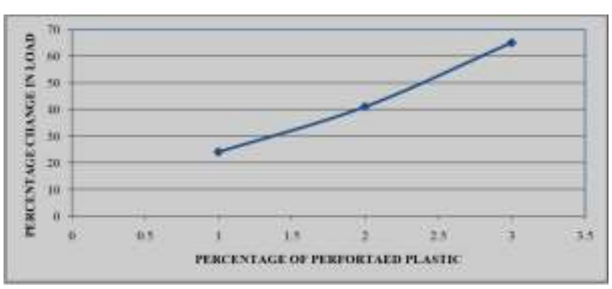

Fig 8: Effect of perforated plastic strip on percentage change in load Static load test

PERCENTAGE OF PLASTIC	PERCENTAGE CHANGE IN LOAD
RE + 1.0% PLASTIC	24
RE + 2% PLASTIC	30
RE + 3% PLASTIC	65

TABLE 6: Percentage change in load on inclusion of perforated plastic

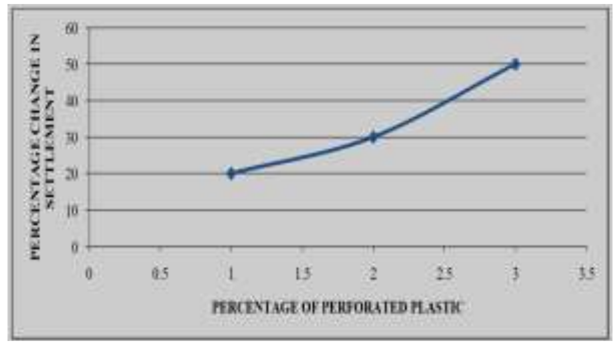

Fig 9: Effect of perforated plastic strip on percentage change in settlement Static load test

PERCENTAGE OF PLASTIC	PERCENTAGE CHANGE IN SETTLEMENT
RE + 1.0% PLASTIC	20
RE + 2% PLASTIC	30
RE + 3% PLASTIC	50

TABLE 7: Percentage change in settlement on inclusion of perforated plastic

VII. CONCLUSIONS

Based on the results of experiments presented and discussed the following conclusions are drawn

i) The provision of perforated plastic strips (obtained by the used plastic bottles) is effective in improving the shear strength of the Red earth. Though the angle of internal friction value is slightly improved, a significant development of cohesion is observed. The development of cohesion can be attributed to the confinement provided by the provision of perforation.

ii) The dosage of perforated plastic strip has a considerable influence on shear strength of perforated plastic Red earth mixture. The optimal dosage is about 1.0% for maximum development of cohesion.

iii) Beyond this percentage of perforated plastic the shear strength parameter decreases. Due to slippage between the soil particles and the plastic

iv) The stress-strain behaviour of reinforced Red earth improved considerably due to increase in perforated plastic content.

v) The static load test also indicated on improvement in the performance of perforated plastic Red earth mixture. This is clearly indicated by the higher load carrying capacity upon plastic mixing.

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