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RECYCLED CRUSHED PLASTIC WASTE STRIPS (PWS) FOR IMPROVING EXPANSIVE CLAY

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ABSTRACT: Many geotechnical problems may arise when dealing with soils of high swelling pressure. The present study recommends the application of plastic waste strip (PWS) materials to mitigate these challenges through the improvement of expansive soil. In order to prepare the expansive soil, natural earth obtained from Nahrawan was mixed with 70% Bentonite by weight. A detailed experimental program was carried out to assess the influence of incorporating four varying percentages of PWS (2%, 4%, 6%, and 8%) by weight on the properties of expansive soil. The results of these additions were analyzed in comparison to those of untreated soils. After mixing dirt with a strip, several physical tests are conducted to examine the qualities of the soil. Specific gravity, consistency limits, compaction characteristics, free swelling, and swelling pressure were studied. When the prepared soil was treated with plastic waste strips (PWS), the results demonstrate how adding PWS decreased the specific gravity value, increased the plastic limit (PL), decreased the plasticity index (PI), and increased the liquid limit (LL). These results suggest that adding PWS could improve the current physical properties of soil. The maximum water content (O.M.C.) and the Standard Proctor Compaction Test (SPCT) marginally reduced the ideal percentage of plastic waste strips, which was found to be 8%, which in turn reduced the free swell and swell pressure in considerable percentages. The outcome demonstrated that adding plastic waste strips to expansive soils improved their geotechnical qualities, and these findings will help engineers and decision-makers who use this additive. So waste plastic strips is considered an eco-friendly and cost-effective material for stabilization.

Keywords: Free Swell, Swelling pressure, Plastic waste strips, Expansive soil, Bentonite

1. INTRODUCTION

Expansive soils may be found in tropical regions. the presence of these soils presents challenges not just for geotechnical engineers but also for civil engineers in general; they are able to cause harm to buildings that are erected atop them as a result of their tendency to react to changes in the moisture that they contain, respectively. The construction of retaining walls, pavements, airports, walkways, canal beds, and linings are all examples of civil engineering projects that might impact volumetric variances. A great number of creative approaches have been developed in order to protect buildings and reduce the effect of volume change [1]. Several different approaches may be taken in order to achieve soil stabilization for reactive soils. By mixing the problematic soil with another, it is feasible to get the requisite workability, strength and plasticity in the soil. Other mechanical methods may be used, such as incorporating suitable soil, regulating moisture levels, and pre-wetting soil in order to allow for expansion prior to construction; nevertheless, the utilization of these techniques may increase the cost of the project [2]. The physical qualities of soil have been improved by researchers over the course of many years via the development of large number of novel additives such as lime, cement kiln, and fly ash [3]. While using mixtures can stabilize expansive soils by limiting their ability to undergo volumetric changes, numerous studies have been undertaken in this area. In the laboratory, Al Soudany [4] created soil by combining natural soil with varying proportions of bentonite, namely thirty, fifty, and seventy percent by moisture content of the soil. Following the investigation of the role of bentonite in modifying natural soil characteristics, the next step was to investigate the impact of silica fume (SF) on prepared soil. This was accomplished by incorporating several percentages of silica fume (three percent, five percent, and seven percent by weight) into the soils that had been prepared. The findings indicate that the addition of silica fume resulted in a drop in both the liquid limit and the plasticity index. In contrast, the addition of silica fume increased the plastic limit. Increasing the percentage of silica fume that is added has resulted in a drop in the maximum dry unit weight as well as an increase in the optimal water contents. This information was collected by increasing the percentage of silica fume that was added. Bentonite clay with expansive properties was employed by Madhat et al [5], Different proportions of pulverized waste glass (PWG) were incorporated into the mixture, specifically at (0%, 5%, 10%, and 15%). The PWG was available in two forms: fine glass, which passes through sieve No. 200, and coarse glass. (passing sieve No. 2 mm). Both kinds of PWG were created. According to the findings, the Atterberg limits are significantly lowered when 15% by Bentonite weight of 2 mm of PWG is added to the mixture. In addition to this, the free swell and swelling pressure of the Bentonite samples were shown to have significant decreases.

When it comes to stabilizing and improving expansive soils, the use of conventional procedures such as mechanical compaction, additive application, grout injection, and so on is becoming costlier than it has ever been [6].

Within the last several years, researchers have developed an additional method of soil stabilization that makes use of waste materials. Plastics are one of the most prominent examples of waste materials that have been discovered to be appropriate for this function. As a means of resolving this issue, they significantly cut down on the expenses associated with stabilization**.**

A review of the experimental program that was carried out for the purpose of stabilizing black cotton soil in Amravati, which is the capital of the newly established state of Andhra Pradesh, is presented in Madavi and Patel's [7] publication. They carried out a series of CBR tests in order to determine the correct quantity of plastic content that should be used in order to get the highest possible CBR rating. Therefore, it is possible to conclude that the CBR percentage continues to rise up to a level of 4% plastic content in the soil, after which it begins to fall as the amount of plastic in the soil increases. As a result, we are able to assert that the ideal amount of plastic garbage in the soil is four percent of the total plastic content**.** As a result of Kumar and Suryaketan's [8] research on the reinforcing effect of mixed plastic strips in soil, a series of standard Proctor tests along with unsoaked California Bearing Ratio (CBR) tests were performed. Based on the results of these tests, it was discovered that the maximum dry density of plastic mix soil decreases as the percentage of plastic strips increases, while the CBR increases as the percentage of plastic strips increases within a certain limit. The value of the MDD falls as the quantity of plastic contents grows, but the value of the OMC increases as the number of plastic contents increases**.** Patil and Neeralagi [9] The results of soil stabilization with plastic bottle and plastic bag strips were shown. The CBR value of a soil increases, and the maximum CBR is attained when 0.75% of plastic bottle strips are added to the soil; however, as more strips are added, the CBR value decreases. In the case of plastic bag strips, it has been observed that 2% of the total weight of the soil is the optimal proportion of the strips; nevertheless, the findings of this study reveal that strips cut from plastic bottles are a better alternative than strips from soil bags for increasing the CBR value of the soil. In this study, Kamblel et al., [10] used discarded plastic bottle strips that were 2 centimeters by 1 centimeter. Depending on the weight of the strips, they are incorporated into the soil in varying proportions. A range of different percentages of strips are used, including 0%, 0.2%, 0.4%, and 0.6% of the soil's dry weight. Atterberg limits, specific gravity, and free swelling index were some of the laboratory tests that were carried out. The improvements in soil strength that may be achieved via the use of plastic waste fiber for soil stabilization have been shown. This approach will result in a building that is better, more durable, and has a higher loading capacity. It will also assist in fulfilling a variety of societal challenges, such as lowering the amount of garbage and manufacturing usable material from waste materials that are not useful

According to Amena and Kabetal [11] research, the engineering features of expansive soils were investigated in relation to the use of plastic waste and marble waste dust. Extensive soil samples were subjected to a series of laboratory experiments, whereby marble was added at concentrations of 10, 15, and 20%, and plastic strips of 5 × 8 mm^2 were added at concentrations of 0.25, 0.5, and 0.75%. Due to the incorporation of marble dust and plastic strips, the results of laboratory tests demonstrated that there are significant improvements in terms of the metrics pertaining to strength. The values of the California Bearing Ratio (CBR) increase if there is an increase in the percentages of marble dust and plastic strips. The unconfined compressive strength (UCS) values rise linearly with the addition of marble dust, but the addition of plastic strips only results in an increase of up to 0.5% in the UCS values. There is a considerable reduction in both the free swell and the CBR swell of the soil as the proportions of marble dust and plastic strips rise. The fact that marble dust and plastic strips may be used to fortify the weak subgrade soil and reduce its swelling qualities is shown by the fact that environmental pollution trash can be used. As part of their research. Kumar et al. [12] conducted laboratory experiments using composite black cotton soil samples that varied in terms of both their size and the percentage of plastic strips they contained. The results were analyzed in order to study the influence that plastic strips with different aspect ratios had on a variety of variables, such as the shear strength of the expanded soil (CBR) and the features of the soil's compaction. The research demonstrates that a realistic strategy to improving the engineering properties of expanding soil is to use the strips from old plastic bags as reinforcing material. The findings of the study support this. Lime and waste plastic were used as subgrade paving components that were both cost-effective and ecologically beneficial. In order to improve the flexibility and strength of expansive soils**.**

In conclusion, the addition of 5% lime and 0.75 percent plastic waste strips results in a considerable improvement in compressive strength, unconfined compressive strength, and free swell. One of the findings of this research was that the plasticity and strength properties of the soil were significantly altered as a result of the use of plastic waste strips and lime in the process of stabilizing expansive soil. Plastic pollution and the cost of subgrade soil stabilizers are both affected by this technique, which helps to alleviate both of these issues.

2. RESEARCH SIGNIFICANCE

This research sheds light on the effect of adding recycled crushed plastic strips in varied percentages (2%,4%,6% and 8%) by weight of soil mixed with 70% bentonite by modifying properties including specific gravity, consistency limits, compaction characteristics and swelling properties. The conclusions drawn from this research show suitability of using the PWS as a good stabilizer by enhancing the overall properties of expansive soil. Besides PWS readily available and inexpensive, the use of PWS materials will be beneficial for the environment while also lessening the cost of stabilizing soils

3. MATERIALS UTILIZED

3.1 Clayey Soil

After 48 hours of oven drying at 105 C^0, the soil sample was pulverized and sieved through a No. 40 (0.425 mm) sieve (U.S.) and used to study and specify the effect of additives on soil properties This study employed only one kind of soil. it was created in a lab by combining natural soil with 70% bentonite. The natural soil, which is a black clayey soil, was transported from Al-Nahrawan City, which is located 23 kilometers east of Baghdad. To ascertain the soil's chemical and physical characteristics, standard tests were run. The soil used had a grain size distribution of 65% clay, 33% silt, and 2% sand. as depicted in Figure 1 As per the U.S.C.S. classification, the soil is designated as (CH). Table1 displays soils' physical and chemical characteristics.

Table 1. physical characteristics used, Natural soil bentonite and prepared soil

Index Property	Test Standard	Natural Soil	Bentonite	Prepared soil
Liquid Limit	[13]	53	512	178
Plastic Limit	[13]	21	38	25
Plasticity Index	[13]	32	474	153
Specific Gravity (G.s)	[14]	2.7	2.26	2.4
Classification (USCS)	[15]	CH	----	
MDD (kN/m^3)	[16]	16.0	-----	13.1
OMC (%)	[16]	20.0	-----	29

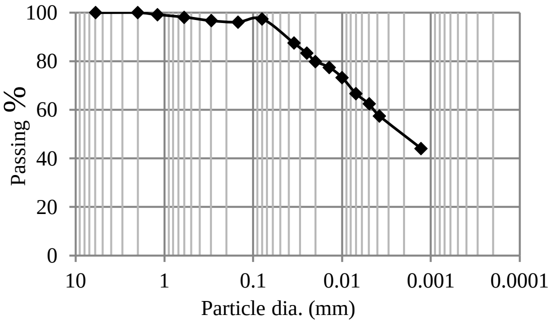


Fig 1. Particle size distribution of soils used.

3.2 Plastic Waste Strips

In the current study, high-density polypropylene water bottles a commonly accessible plastic waste are used due to its accessibility, affordability, and chemical inertness as well as the fact that it doesn't react with soil or absorb water plastic garbage has been taken into consideration. Gradation of plastic waste strips as shown in Figure 2. Table 2 gives a detailed description of the waste plastic strips that were employed in this investigation. Plastic Waste Strips was illustrated in Figure.3.

Table 2. An explanation of the used plastic waste strips.

Description	Value
Compressive strength	Low
Water absorption (%)	0.018
Unit weight, g/cm3	0.88
Ultimate tensile strength, MPa	56
Melting point (°c)	200
Resistance to acid and alkali	Good
Elasticity modulus E, MPa	100-400

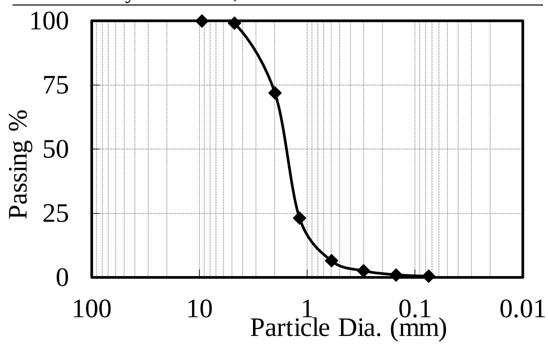


Fig 2. Particle Size Distribution of Plastic Waste Strips.

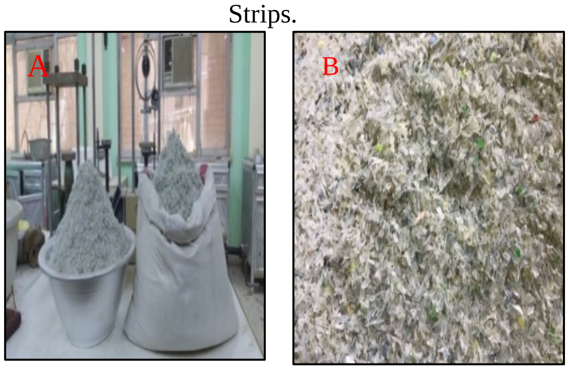


Fig3. Plastic Waste Strips.

4. PREPARATION SOIL MIXTURE

To prepare a sample, the dirt was baked dry at about 105C^{0}for 24 hours before being used in the mixtures and then pulverized by a Los Angeles machine; the expanding clayey soil (which was made in a lab by combining 30% natural soil and 70% bentonite) and PWS in a dry state.

There were four PWS percentages utilized in the clay soil-PWS mixtures: 2, 4, 6, and 8% of the total weight. The data presented in this figure reveals that as the amount of plastic waste strips rises, the specific gravity correspondingly decreases. Every step of the manual mixing process was completed with care to create homogenous combinations.

4.1 Preparation of Free Swell and Swelling Pressure Samples

Test specimens were prepared according to [17] instructions. The pressure needed to return the specimen to its initial height is known as the swell pressure, and the final swell that the specimen attained before applying stress is known as the swell percent. The percentage of free swell is computed as:

Free swell (%) =((H-$H_{O/}$)/H_O)) *100 …………. (1)

Where:
H= The final height of sample, mm.
H_o= The initial height of sample, mm.

4.2 A Swelling's Attributes

A consolation test was utilized in a number of examinations. The following is a list of the methods used to calculate swelling pressure percent. To study the effect of plastic waste strips (PWS), four percentages of PWS were used 2, 4, 6, and 8% on the percentage and pressure of clay soil swelling. The ideal moisture level for these specimens is 20%, and they were compacted at a dry density of 16 kN/m^3.

4.3 The Process of Preparing Specimens

Specimen preparation is done according [17] instructions. The identical method for specimen preparation and static compaction was applied to all of the experiments listed above, on a flat glass plate, a predefined amount of oven-dried soil (105–110 C°) according to BS 1377; 1975, test 1(A)) was deposited. The required amount of additives, expressed as a percentage of the soil's oven-dried weight, were weighed to the closest 0.01 grams and mixed with the soil using a palette knife for around three minutes to produce a well-blended slurry. After that, the necessary amount of de-ionized water is added. Based on the formula (soil + additives), it was computed. Following a thorough manual mixing process in which water is added to the soil-additives mixture, the mixture is then put inside the odometer ring. After applying the static compaction method to compact the specimen to its initial dry density, it was promptly covered in two plastic bags. After that, it was kept in storage for a full day before testing in order to allow any excess pore pressures created during the compression process to equalize and dissipate [18].

5. METHOD OF STATIC COMPACTION

The unconfined compression machine's manually operated loading frame was used. To perform the static compaction technique to prepare the specimens for swelling. Two steel plates were positioned at the top and bottom of the ring to hold the mold in place. The specially designed compressor piston had a metal disc. This disc has a thickness of 5 mm and a diameter of 1 mm less than the inside ring. After that, the ring mold assembly and holding device were put in a compression testing machine to keep the specimen laterally confined during the swelling process, and to get the necessary volume, a 5 mm height differential between the specimen and the consolidation ring was maintained. Static compression was applied gradually until the top rings and upper lip of the disc were level to avoid rebound following the removal of the static stress, after each specimen achieved the desired height, and the load was kept on them for five minutes to allow for swelling. To verify the sample size.

5.1 Percentage of Free Swell Calculation

A specimen's potential swelling after saturation when it is under a normal load is largely dependent on its original moisture content as well as the quantity and kind of additive used. The samples that were prepared were split into two portions. The clay soil specimens with varying Bentonite percentages were included in the first portion. The samples of clay soil with varying plastic waste strips (PWS) and 70% bentonite are included in the second allocation. Following the usual approach outlined by [19], the specimens were inserted into the consolidation apparatus after the test sample had been prepared using the same process as in sections 3.1 and 3.3. The sample was first subjected to a seating pressure of 6.9 kPa, and the dial gauge's reading was zero. Next, de-ionized water was added. and the expansion of the specimen's volume, that is, its height, was then measured until equilibrium was reached.

6. PRESENTATION AND DISCUSSION

6.1 Impact of Plastic Waste Strip on Prepared Soil Specific Gravity

Figure 4 shows how different percentages of plastic waste strip influence the specific gravity of the generated soils., with values reported gravity of the produced soils, with values reported in Table 3. The data presented in this figure reveals that as the amount of plastic waste strips rises, the specific gravity correspondingly decreases. Because the plastic waste strip covers the spaces between the soil particles, this shows that the soil-plastic waste strip mixture is lighter than it would be in the natural environment. [20], who employed a combination of lime and silica fume, reported similar outcome.

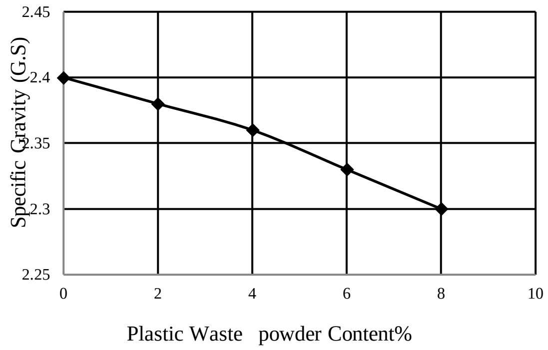
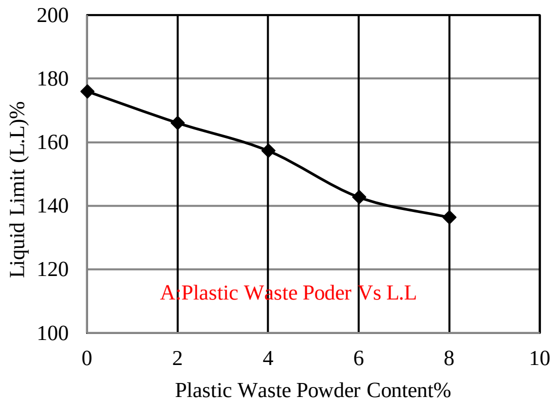
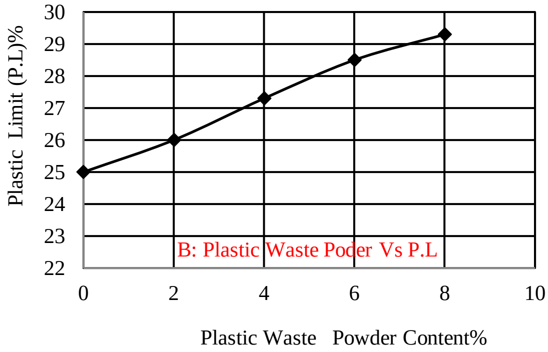


Fig4. Effect of plastic waste powder on specific gravity

6.2 Plastic Waste Strip's Effect on Consistency Limits of Prepared Soil:

The effects of adding plastic waste strips the soil on Atterberg's boundaries is shown in Figure 5. This implies that the soil samples' flow properties are gradually decreasing. For prepared soil (70% Bentonite), the plastic limit of these mixes increases from (25%) to a maximum of (29.4%), and the liquid limit changes from (178%) to the lowest value of (138%) with an increase in the content of plastic waste strips from (0%) to (8%). The cation exchange reaction and flocculation-aggregation for a higher amount of Bentonite-plastic waste strips content, which lowers the soil's plasticity index, are responsible for this shift in the Atterberg limit. Swell potential is significantly reduced when the plasticity index is reduced, and some of the water that clay minerals may absorb is also removed. Table 3 displayed the results. Similar observation by [21]





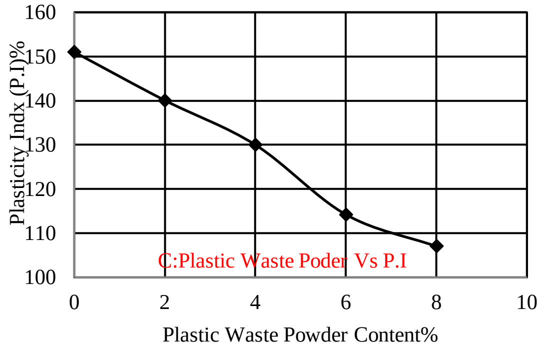
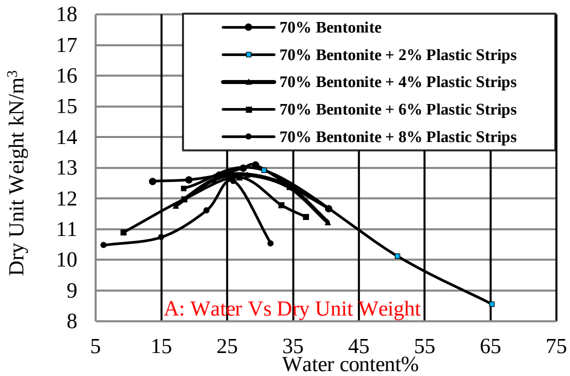


Fig5. Effect of plastic waste powder content on consistency limit

6.3 Impact of Plastic Waste Strip on Prepared Soil Compaction Parameters:

Figure 6 illustrates how the dry unit weight and moisture content of stabilized samples with plastic waste strips vary. With the inclusion of plastic waste strips, it can be seen that the drop in optimal moisture content balances the reduction in maximum dry density. The reason is due to the addition of less dense material, which is the plastic lightweight compared with the soil's weight might have decreased the density of the soil. Because plastic waste strips have a low capacity to absorb water, as seen in Table 2, their optimum moisture level likewise falls as the quantity of plastic waste strips increases. Similar observed by [22].

Results of specific gravity, consistency limits and compaction characterization were summarized in Table 3.



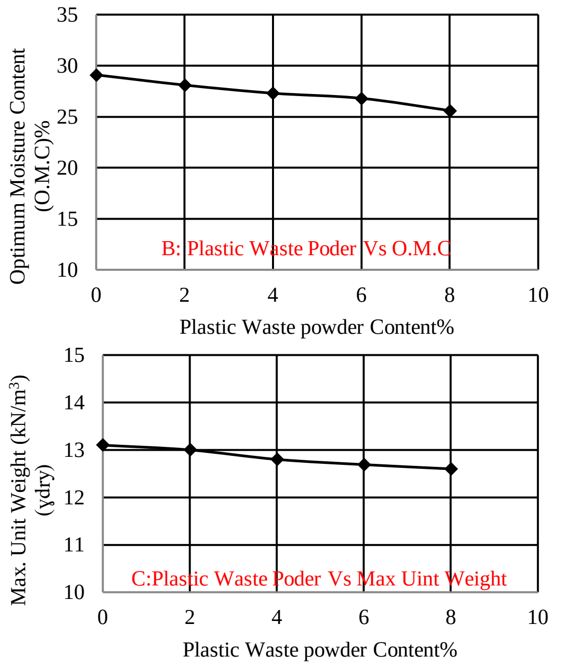


Fig6. Effect of plastic waste powder content on compaction parameters.

Table3. Results of specific gravity, consistency limits and compaction characterization.

Soil type +% plastic waste strips	L.L	P.L	P.I	GS	Dry unit weight (γ_{dry}) kN/m^3	Optimum moisture content %
Prepared Soil	178	25	153	2.4	13.1	29
Soil + 2% PWS	167	26	141	2.38	12.8	28
Soil + 4% PWS	158	27.1	110	2.36	12.6	27
soil + 6% PWS	144	28.8	115	2.33	12.3	26
soil + 8%	138	29.4	108	2.3	12.4	25.5

6.4 Effect of Plastic Waste Strip on Swelling of Prepared Soil

Figure 7 displays the swelling pressure and free swell test results following the therapy. An increase in plastic waste powder is directly correlated with a considerable decrease in swelling pressure values and free swell. Non-expansive size particles were incorporated into the expansive soil, as well as because of the soil's interaction with plastic waste powder particles, the improved soils exhibited decreased swelling and swelling pressure values. The bulk The plastic debris utilized in this experiment was a powder made up of round non-crystalline silicate, aluminum, and iron oxides, as well as some microcrystalline components and unburned carbon (see Table 3). This formulation reduces the specific surface area and water affinity of soil samples under study, contributing to a decline in swell-shrinkage characteristics like free swell and swelling pressure. The clay mineral content of the composite samples is decreased by this chemical treatment. The plastic waste components decreased the composite samples' specific surface area (SSA) and cation exchange capacity (CEC), which resulted in low water holding capacity and swelling. The test results' values were compiled in Table 4.

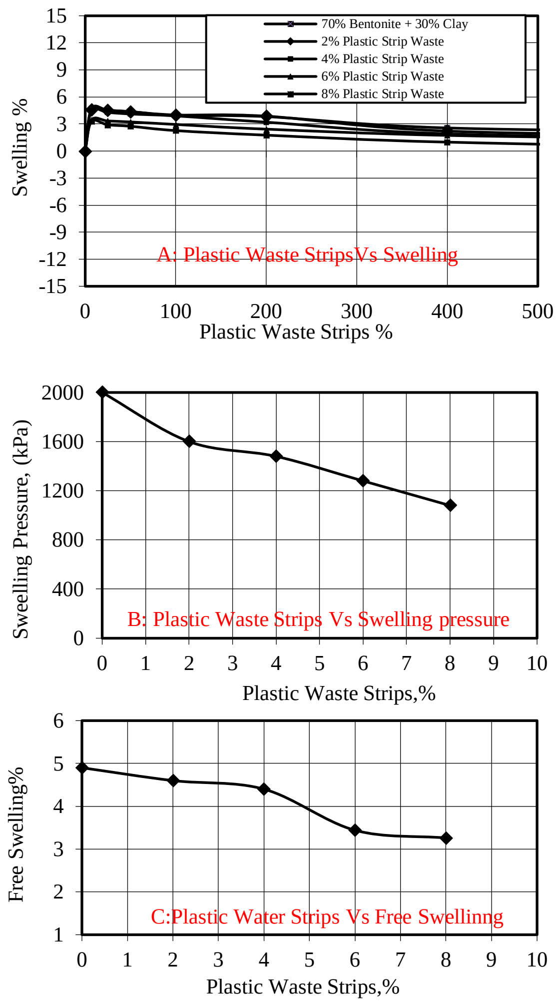


Fig7. Effect of plastic waste powder content on Prepared Soil.

Table 4: Swell pressure and percentage values of free swelling for soil that has been treated soils

Soil type +% plastic waste strips	Swell pressure (kN/m^2)	Free swelling,%
Prepared Soil	2000	5
Soil + 2% PWS	1600	4.6
Soil + 4% PWS	1500	4.4
Soil + 6% PWS	1250	3.48
Soil + 8% PWS	1050	3.4

7. CONCLUSIONS

The current study examined how expanding clay's engineering properties were affected by plastic waste strips (PWS). It is possible to conclude the following:

1. The specific gravity decreases with increasing plastic waste strip (PWS) percentages from 2.4 at 0%PWS to 2.3 at 8% PWS.
2. While plastic waste strip (PWS) increased from 0% to 8%, decreased L.L. and P.I. (178-138) and (153-108.9), respectively. Plastic limit, however, rise by 17.6%.
3. Treatment with plastic waste strip (PWS) showed a general reduction in the maximum dry unit weight and optimum moisture content with an increase in the plastic waste strip (PWS) content to minimum values by about 5.3% and 12% respectively at 8% plastic waste strip (PWS) content.
4. By employing plastic waste strips, free swell, and swell pressure were significantly improved. The amount of plastic waste strips in the mixture decreased by around 32% and the amount of free swell by 47.5% as the concentration rise to 8%.
5. The study concludes that plastic waste strip is a useful material for modifying expanding soil's characteristics to make them appropriate for building.

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