# Experimental study on the effect of plastic waste strips and waste brickpowder on strength parameters of expansive soils

#### Dr. KHARABELA SWAIN

Associate Professor, Dept. of Civil Engineering, Aryan Institute of Engineering & Technology, Bhubaneswar RABINDRA KUMAR PARIDA

Professor, Department of Civil Engineering, Raajdhani Engineering College, Bhubaneswar, Odisha

## <u>ABSTRACT</u>

Ethiopia has an abundance of expansive soils. This type of soil is weaker, having low strength and load-resisting characteristics in nature due to its difficulty in volume change when exposed to water. As a result, when saturated with water, the volume of such soils expands and contracts during dry seasons. In civil infrastructure construction, such soil should be removed or improved to be used as foundation soil. However, removing the soil leads to the extra costs of construction. On the other hand, improving requires increasing the stiffness and load-carrying capacity of the road by treating it with stabilizers, which help achieve low cost and good performance. This study aimed at treating such soils with waste-disposed materials to improve the soil's resistance to pressure and to reduce pollution. In this study, locally available expansive soil is treated with brick waste powder (20, 30, and 40%) and waste plastic strips with (0.25 %, 0.5 %, and 0.75 %) percentages in weight. Disposed plastic water bottles are used. Atterberg limits, compaction, CBR, and unconfined compressive strength were performed to find an optimum percentage of mixes. Many trials were done by varying the percentages of PWS (plastic waste strips) and BP (brick powder). At the addition of 0.75% PWS and 30% BP, a significant change was observed with a considerable improvement in free swell, CBR, and unconfined compressive strength values. The study reveals plastic waste strips and brick waste powder were found to increase the strength qualities of expansive soils. This could pave the way for the use of waste materials in pavement construction while also lowering the environ- mental pollution.

<u>*Keywords:*</u> Expansive soil Brick waste powder Plastic waste strip Environmental pollution Pavement construction Strength properties

# 1. Introduction

Expansive soils are abundantly found in the most areas all around the globe. Expansive soils have complex properties of volume changes at shallow depths as the moisture content of the soil varies . The most common component of expansive soils is montmorillonite, which expands when exposed to water and contracts when exposed to dry weather.

Many techniques have been used to overcome the complexity of the expansive soils. One is replacing the existing soil with non-expansive material having no volume change, and the other method is mixing or blending the soil with various additives and stabilizers .

Nowadays, stabilization of the soil is increasingly following new approaches. Using environmentally hazardous waste materials that are polluting the environment is one of these new approaches, which is becoming popular, economical, and environmentally friendly. In addition, many constructions demolished wastes, construction by-products, and other wastes have been proven stabilizers with high bearing

values. Using these wastes plays a vital role in minimizing construction costs and solving environmental pollution.

The research done in the past shows that brick waste can be used as aggregates in different layers of pavement, in concrete mixes, and as construction materials. Based on numerous experimental studies, the suitability of brick wastes in improving the strength properties of the soil was proved. Many researchers have found that the mixture of brick powder with other additives shows a signifi- cant improvement in the strength parameters of weak soils. They concluded that brick waste mixed with lime, cement, coir fiber, and fly ash can be used as subgrade and subbase pavement materials .

On the other hand, many researchers have investigated the stabilization of clayey soils with plastic and other additives such as eggshell powder and broken glass powder. They discovered that using plastic waste as a stabilizing agent causes significant changes in the strength parameters of clayey soils. However, there has not been any experimental study done using plastic waste and brick powder together, even though these two wastes are easily available and cheap.

The main objective of this study is to introduce the suitability of waste plastic strips and brick waste powder for improving the strength of expansive soils. In addition to this, the study opens a door to reduce plastic environmental pollution by introducing the way plastic and brick wastes are utilized in subgrade pavement layers, embankments, and foundation constructions.

# 2. Literature reviews

#### 2.1. Crushed brick

In civil engineering areas, brick wastes have been used in various applications such as aggregates in concrete production, aggregates in subbase and subgrade pavement layers, and filter materials in road pavements.

The study carried out on an experimental investigation treating expansive soils with burnt brick dust observed that compaction characteristics, atterberg's limits, and swelling properties of the soil were improved. The proportion of burnt brick dust used in the test was 30%, 40%, and 50%. The study found that at optimum percentage of brick (50% brick waste) addition there were decrements in optimum moisture content, swelling potential, plastic limit, liquid limit, and shrinkage limits, while maximum dry density and CBR value increased with the increment of brick dust .

Research conducted on improving engineering properties of black cotton soil with burnt brick dust by varying the percentage of burnt brick dust by weight (30, 40, and 50%) resulted in a reduction in swelling potential, atterberg limits, and OMC . According to a study conducted on the subgrade and subbase layers of pavement in India, using brick kiln dust as a stabilizer for treating expansive soil increases the CBR value by 135%. In addition to this, the study reveals that the material is cost-savings and eco-friendly.

#### 2.2. Brick with other additives

Many investigations have been done on the stabilization of expansive soils using brick waste powder mixed with other stabilizing agents. Ac- cording to a study done, the engineering properties of the soil were significantly changed when the brick waste powder was mixed with varying amounts of cement-stabilized material. It was found that blending 50% of brick powder with a 3% cement stabilized sample satisfies the required criteria set for the local soil to be used as subgrade layer material.

Stabilization of the expansive soil with coir fiber, and brick dust resulted in significant changes in the engineering properties of the expansive soil. Addition of 30% of brick dust and 1% of coir fiber it resulted in a 40% reduction in subgrade layer thickness and a significant improvement in CBR and UCS. The addition of 20% brick powder to lime stabilized expansive soil increased the CBR value by 135%, making the blended material suitable for use as a subbase material.

An investigation performed on examining the engineering properties of fly ash-stabilized expansive soil and brick kiln dust mixture as pavement materials found that 30% brick dust and 20% fly ash provided the best improvements in engineering properties and CBR.

The study was done by using proportions of lime-stabilized expansive soil to brick powder as (0%-20%), (60%-40%), (40%-60%), and (20%-80%). It shows significant improvements were obtained compared to

lime-stabilized expansive soil. Thus, the study concluded that using a mixture of brick powder and lime as stabilizers in subbase material in flexible pavements improves CBR and swelling .

*2.3.* An investigation done by varying the percentage of demolished brick waste from 10% to 50% (10%, 20%, 30%, 40%, and 50%), conducting laboratory experimental studies reveals that 40% is the optimum per- centage of brick waste for achieving maximum CBR and UCS values *Plastic as stabilizer* 

The addition of waste plastic strips to a sandy soil sample, according to Choudhary et al , can increase the CBR values and secant modulus of the soil. When the soil is treated with 4 % plastic waste strips, the values of CBR increases to 41.65 % for aspect ratio 1. With the addition of 4% plastic waste strips, secant modulus increased from 395.2 MPa to 789.5 MPa. This study shows that, the addition of plastic waste strips have a significant improvement on the strength of the soil material . The addition of reclaimed plastic waste material to local available expansive soil increases the Maximum density while using 1.0% plastics strips having an aspect ratio of 3.

The results of e showed that adding waste high-density polyethylene (HDPE) and broken glass to soil enhanced plastic index, compaction characteristics, and strength properties. Therefore, waste cutting HDPE and crushed glass can be used in soil stabilization . Peddaiah investigated that the addition of plastic bottle strips to the locally available soils improves the soil properties such as shear strength, maximum dry density (MDD), and CBR values by adding strips cut from plastic bottles. The study done in Pradesh state, India concluded that for a specific study conducted, 4% of plastic waste content could be considered as the optimum plastic waste content to improve the locally found expansive soil .

#### 2.4. Plastic with other materials

Plastics Polypropylene fiber mixed with lime can be used fruitfully to stabilize clay soil. Free swell improves with the addition of 5% lime and

0.8 % polypropylene plastic fiber, and the compressive strength of the soil increases by 23.8%, while the CBR value increases by 17.6%. This result can be obtained by utilizing plastic waste strips for stabilization of weak soil is economical and profitable

The study was done on stabilization using eggshell powder and plastic waste fiber, which reveals there were various significant changes in the soil properties. The study showed that CBR, UCS, and shear strength of the soil increased up to certain limits. The better outcome was achieved at 5% of eggshell powder and 1% of plastic waste fibers .

## 3. Experimental study

#### 3.1. Materials

#### <u>3.1.1</u>. Soil

The representative soil sample was collected from selected sites in Jimma town, Oromia region, Ethiopia. Disturbed samples were collected for index property tests and undisturbed soil samples for unconfined compressive strength, and natural moisture content at a depth of 1.5 m for laboratory tests.

The grain size analysis result according to ASTM D 422 shows that the soil is fine-grained . The result of soil classification shows that the soil is classified as highly plastic clay soil .The atterberg limit tests were carried out as per ASTM D4318 . The summary of engineering properties of the soil sample is presented in Table 1. The grain-size analysis results of the soil sample and the waste brick powder are shown in Figure 1 for comparison purposes. The gradation curve shows that the waste brick powder is coarser than the soil sample.

The particle size of the soil sample and brick waste powder used in this study is shown on the same graph Figure 1.

### *3.1.2.* Engineering properties of brick waste powder

The study found that crushed brick contains hematite, silica, quartz, and anhydrite as shown in Table 2. Researchers stated that crushed brick powder contains pozzolanic materials with high water absorption properties .

The brick waste powder was collected from local brick manufacturing places. The result of the grain size analysis is shown in Figure 1. The unit weight of the brick powder was found to be  $13.68 \text{ kN/m}^3$ .

Table 1. Characterization of the soil sample (Source: Author Data).

Description	Parameters	Values
Atterberg limits	Liquid limit (%)	58
	Plastic limit (%)	32. 9
	Plasticity index	25.

	(%)	1
In-situ properties	Specific gravity	2.6 5
	Water content (%)	49
	Dry density	1.2
	(g/cm <sup>3</sup> )	4
Compaction	Maximum dry	1.4
characteristics	density (g/cm <sup>3</sup> )	96
	Optimum moisture	24
	content (%)	
Soil Classification	USCS	CL



Figure 1. Particle distribution curves for brick and soil.

### 3.1.3. Plastic wastes

Local waste collectors from nearby area collected plastic wastes, mostly plastic water bottles, which used in this study. These plastic bottles were cut manually into strips as shown in Figure 2.

For this study, the manually cut strips are used to reinforce the soil at different percentages. Table 3 below shows the details of the properties of the waste plastics used in this study.

## 3.2. Sample preparation and tests

Initially, different field and laboratory tests were performed to characterize the soil sample. Grain size analysis, index properties, and strength properties of the soil sample were investigated.

Then, using this soil sample and the selected stabilizers, various laboratory tests were carried out. To do so, an air-dried soil sample was sieved using a vibrating machine. Plastic

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strips and brick powder were added to the soil in different percentages. First, the required percentage of brick powder was added to the soil and mixed properly. Then, the proportion of plastic waste strips needed for the test trial was mixed uniformly to avoid grouping of the fibers. The proportions of plastic strip considered are 0.25 %, 0.5 %, and 0.75 %, whereas, for brick powder, 20%, 30%, and 40% are considered by weight of the dry soil. The following laboratory tests were carried out to investigate the engineering properties of the treated soil.

### 3.2.1. Compaction test

The standard proctor test was employed to determine the maximum dry density and optimum moisture content of the soil sample according to ASTM D 698 [. For each trial, 3 kg of soil samples was taken and water added gradually. Then, the soil sample was placed in the standard

Table	2.	The	chemical	com	nosition	of	brick	waste	nowder	-
Table	4.	THC	cilcilicai	com	position	01	DITCK	waste	powuei	

SiO	Al <sub>2</sub>	Fe	Са	Μ	Na	K2	Н	LO
2	03	20	0	g	20	0	20	Ι
		3		0				
63.	25.	7.7	0.	0.	0.2	0.	1.	0.9
89	49	3	2	04		9	33	5
			9			5		

compaction mold with three layers, each compacted at 25 blows. After the test is completed, the moisture and density of the soil is measured. At least four trials have been done to obtain the values. Using the data ob- tained from test results, the graph was plotted as dry density on the ab- scissa and moisture content on an ordinate. From the graph, the peak value of dry density and the corresponding moisture content was captured. The maximum dry density (MDD) and optimum moisture content (OMC) obtained from the compaction test were 1.496 g/cc and 24%, respectively.

## *3.2.2.* Unconfined compression test

The Unconfined Compressive Strength Test (UCS) is frequently used to evaluate the compressive strength value of cohesive soil. The axial load was tested using a strain-controlled system following ASTM D 2166. The undisturbed sample was taken using a Shelby

tube with a 38 mm outer and 36 mm inner diameter. The sample was adjusted to 72–80 mm in

length to make sure that the sample's height was greater than twice its

diameter. The test was performed at strain rate of 1.25 mm/min. After the test was carried out, the graph of stress versus axial strain was plotted, from which the peak value on the curve of unconfined compressive strength (qu) was taken at 75 kPa. Depending on the value of qu obtained from the laboratory test, the soil is classified as medium-stiff clay soil .

## *3.2.3.* Swelling potential test

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A free swell test was carried out according to ASTM D 4546 to check the increase in the volume of the soil without applying any external pressure by submerging it in water. The test was conducted by taking a 10-gram representative oven-dry sample and passing it through a 425-micron sieve. Accordingly, the free swell of the soil alone was observed to be 121%, which is categorized under highly expansive soil.

#### 3.2.4. California bearing ratio test

The CBR test was carried out following ASTM D 1883. It is a pressure-bearing capacity test, which determines the soil's bearing capability. First, the dried samples were compacted at maximum dry density and optimum moisture content in CBR molds. Next, the specimens were placed in a container full of water. Then, the prepared sample was soaked for four days by submerging the specimens in water to consider the worst condition of the ground. The CBR value of the soil without any additives was found to be 1.98%. According to Ethiopian road authorities, soil with this rating cannot be used as a subgrade layer material.

# 4. Result and discussion

#### 4.1. Effect of PWS-BP in compaction characteristics

To determine the stabilizers' suitability for improving the soil's strength properties, a compaction test was conducted at different per-centages of plastic strips and waste bricks. For each trial, a soil sample was taken and the required amount of brick was mixed properly. Then, the plastic waste strip added to the soil and placed in the compaction mold with three layers each compacted at 25 blows. After the test is completed, the moisture and density of the soil mix are measured. Using the data obtained from the test results, the compaction curve is plotted. Table 4 shows the MDD and OMC values for the various BP-PWS stabilized and unstabilized soil samples. The variations of MDD and OMC of BP-PWS stabilized samples are shown in Figures 3 and 4, respectively. The MDD decreases as BP and PWS increase, which indicates the unit weight of the solids in the BP-PWS stabilized soil sample mixture is low since plastic is weightless. Because of the low specific gravity of PWS, MDD decreases slightly with increasing

PWS for any fixed BP.

The maximum value of maximum dry density at 40 % BP and 0.25 % PWS was 1.671 gm/cm3, while the minimum value obtained was 1.469



Table 3. Physical and mechanical properties of the plastic wastes.

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Description	Values 1.5	
Compressive strength	Low 5 1.48	
Water absorption, (%)	0.01	
	5	
Unit weight, gm/cm3	<b>0.90</b> $\stackrel{\circ}{\in}$ <sup>1.42</sup>	
Width, mm	1 1.4	23 24 25 26
Length, mm	10	Moisture content (%)
Ultimate tensile strength, MPa	54	
Burning point, (°c)	200	
Acid and Alkali resistance	Goo	
	d	
Modulus of Elasticity, MPa	110-450	

gm/cm3 for untreated soil. The porous features of BP and the accompanying water absorption demands for the pozzolanic interaction be-tween BP and soil particles, on the other hand, result in a rise in OMC as BP increases.

The increase in the maximum dry density of untreated soil from  $1.496 \text{ g/cm}^3$  to  $1.671 \text{ g/cm}^3$  when treated shows that the addition of plastic strips and brick powder enhances the density of the soil.

Thus, with increasing PWS, OMC for any given BP exhibits a minor change. OMC reaches a maximum of 21.8 % at 0.25 % plastic waste strips and 30 % brick powder content, and a minimum of 19.6 % at 0.75 % PWS and 20 % BP content as shown in Figure 5.

#### 4.2. Effect of PWS-BP on free swell values

The addition of plastic waste strips and brick waste powder has significantly improved the free swell of the stabilized soil. As the percentages of the plastic waste strip and brick powder increase, the free swell value of the soil inversely decreases. As the percentage of plastic waste strips increases, the swelling of the soil decreases smoothly. In addition to this, the addition of brick waste powder

	Table 4. Strength characteristics of PWS-BP stabilized soil.						
	Trial no.	PWS content(%)	Compaction	parameters	CBR	UCS	
		BP	~~~~~		value	(kPa)	
1	0	0	24	1.496	2.68	75	
2	0.25	20	20.6	1.663	3.64	89	
3		30	21.8	1.669	4.29	102	
4		40	21.1	1.673	5.23	106	
5	0.5	20	20.1	1.659	4.72	97.5	
6		30	21.3	1.664	5.37	125	
7		40	21	1.671	7.08	142.6	
8	0.75	20	19.6	1.651	5.92	116.8	
9		30	20.4	1.661	6.92	128.9	
10		40	20.2	1.665	8.69	138	



## 4.3. Effect of PWS-BP on CBR values

Soaked CBR tests were conducted at maximum dry density and optimum moisture content to determine the bearing capacity of the stabilized soil under pressure. Before the test, the soil sample was carefully mixed with brick powder and plastic waste strips were distributed uniformly. The soaked CBR tests were selected to consider the worst condition of the soil as fully saturated with moisture. The maximum soaked CBR values were 5.23, 7.08, and 8.69% respectively at 0.25, 0.5, and 0.75 plastic waste strips. These values are 3.13, 3.58,





Figure 8. Variation of Unconfined compressive strength of PWS-BP treated s



igure 5. Variation of Optimum moisture content (OMC) of PWS-BP

### 4.4. Effect of PWS-BP on unconfined compressive strength

The soil was mixed with plastic strips and brick wastes evenly with care at different percentages. To determine the soil's UCS, samples were prepared by remolding the soil at maximum dry density and optimum moisture content. Table 4 shows the values of unconfined compressive strength for different percentages of PWS and BP. The result shows,

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as the percentage of BP increases, the UCS value increases; as the percentage of PWS increases, the values of UCS increase up to a specific limit, followed by a slight decrease. For a constant percentage of PWS, an addition of BP increases the value of UCS from 97.5 kPa to 125 kPa for a 0.5% of PWS addition. This shows that, for the increments in UCS values, both PWS and BP have a significant role.

The variation of UCS values of the treated soil at different PWS and BP percentages is shown in Figure 8. The optimal percentages of PWS and BP for obtaining significant changes were 0.75 and 30%, respectively. The maximum improvement in UCS value obtained was

142.6 kPa, corresponding to a 90.13 % improvement. Thus, for all percentages of BP, the value of UCS increases as the content of PWS increases.



Figure 7. Variation of Californian Bearing ratio values of PWS-BP treated soil.

## 5. Conclusion

The combined effect of adding plastic waste strips and brick powder on some of the soil's engineering properties was investigated in this study. Laboratory tests like compaction properties, unconfined compressive strength, free swell, and CBR have been conducted to investigate the effects of PWS and BP on the strength properties of the soil.

In this study, after the addition of plastic waste strips and brick powders to the soil, significant changes in compaction properties, CBR, free swell, and unconfined compressive strength were observed. An increase in plastic waste strips increases the subgrade strength of the soil as CBR values increase with rise in PWS. In addition to this, the swelling potential of the soil decreases with increases in PWS and BP. An increase in BP causes a slight increase in both MDD and OMC, while an increase in PWS resulted in a decrease in both MDD and OMC. Depending on the results and discussion, the optimum per- centage of PWS and BP required to get significant improvement is 0.75

% and 30 %, respectively. Generally, using PWS and BP together as soil stabilizers for expansive soils has significant changes in the clayey soil's shear strength parameters, strength characteristics, and swelling potential.

The study introduces the significance of plastic waste and waste bricks in improving the strength properties of the expansive soil. This improvement can pave the way for the utilization of waste plastic and brick materials in pavement construction, embankments, and foundations while reducing the environmental pollution.

## **References**

- <sup>1)</sup> B.S. Albusoda, A.J. Al-Taie, Statistical estimation of the compressibity of Baghdad cohesive soil estimation and evaluation of soils engineering properties using soft computing and statistical methods view project improving difficult soils for foundation purposes view project, J. Eng. 16 (4) (2010).
- <sup>2)</sup> \* Abbas, J. Al-Taie, Practical aid to identify and evaluate plasticity, swelling and collapsibility of the soil encountered in Badrah, Shatra and Nassirya cities, J. Eng. Dev. 20 (1) (2016) [Online]. Available: www.jead.org. (Accessed 20 July 2021).
- <sup>3)</sup> D. Al-Jeznawi, M. Sanchez, A.J. Al-Taie, M. Zielinski, Experimental studies on curling development of artificial soils, J. Rock Mech. Geotech. Eng. 11 (6) (Dec. 2019) 1264–1273.
- F. Khademi, Expansive soil: causes and treatments, i-manager's J. Civ. Eng. 6 (3) (2016).

- <sup>5)</sup> C.H.S. Gourly, C. H, D. Newill, Expansive Soils: TRL's Research Strategy, 1993.
- 6) C.S. Poon, D. Chan, Feasible use of recycled concrete aggregates and crushed clay

brick as unbound road sub-base, Constr. Build. Mater. 20 (8) (Oct. 2006) 578-585.

- <sup>7</sup>) F. Debieb, S. Kenai, The use of coarse and fine crushed bricks as aggregate in concrete, Constr. Build. Mater. 22 (5) (May 2008) 886–893.
- <sup>8)</sup> A. Arulrajah, J. Piratheepan, T. Aatheesan, M.W. Bo, Geotechnical properties of recycled crushed brick in pavement applications, J. Mater. Civ. Eng. 23 (10) (Apr. 2011) 1444–1452.
- <sup>9)</sup> A. Arulrajah, J. Piratheepan, M.M. Disfani, M.W. Bo, Geotechnical and geoenvironmental properties of recycled construction and demolition materials in pavement subbase applications, J. Mater. Civ. Eng. 25 (8) (Aug. 2012) 1077– 1088.
- <sup>10)</sup> A.P. Sachin Bhavsar, Hiral Joshi, Effect of burnt brick dust on engineering properties on expansive soil, Int. J. Res. Eng. Technol. 3 (4) (2014) 433–441.
- <sup>11</sup> D.N. Lakshman Teja, Shraavan Kumar, Stabilization of expansive soil using brick dust, Int. J. Pure Appl. Math. 119 (17) (2018) 903–910.
- B. Depaa, Stabilization of pavement material using waste brick kiln dust, Int. J. Eng.Res. Technol. 2 (4) (2013) 1684–1691.

M.M. Disfani, A. Arulrajah, H. Haghighi, A. Mohammadinia, S. Horpibulsuk,