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STABILIZATION OF CLAYEY SOIL BY USING WASTES MATERIALS

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Abstract – Clayey soil, which covers approximately 20% of India's total land area. Traditional stabilization methods, such as lime and cement, are often expensive and environmentally unsustainable. This study explores an alternative approach by utilizing industrial and household waste materials brick powder, marble dust, wooden sawdust, and plastic waste to improve the strength and stability of clayey soil. A series of laboratory tests, including compaction, specific gravity, moisture content, and California Bearing Ratio (CBR) tests, were conducted to assess the effectiveness of these waste materials as soil stabilizers. The results indicate that wooden sawdust (4%) provided the highest CBR improvement (9.06%), followed by brick powder (10%) with a CBR of 7.75%. The combination of all four waste materials also showed a significant improvement over untreated soil. The findings of this study highlight the potential of waste materials to enhance the soil properties of clayey soil while promoting environmental sustainability and cost-effectiveness in construction projects. This approach can be applied in pavement subgrades, embankments, and foundation improvements, offering a viable solution for soil stabilization while reducing waste accumulation.

Key words: Soil stabilization, CBR, brick powder, saw dust, marble powder etc.

1. INTRODUCTION

In India Clayey soil is characterized by its high clay content, typically over 30%, making it dense and heavy. It covers approximately 20% of India's total land area, with significant presence in states like Maharashtra, Madhya Pradesh, Gujarat, and parts of the Indo- Gangetic plains. Major part of clayey soil is present in Maharashtra with 27% and Madhya Pradesh, Maharashtra is known for black cotton soil, which is rich in clay and covers a large area and Madhya Pradesh Contains extensive clayey soils, particularly in the Deccan Plateau region.

Soft soil presents significant challenges in construction and engineering due to its weak mechanical properties. One of the primary concerns is its low bearing capacity, particularly in clayey and peat soils, which struggle to support heavy loads, often resulting in foundation settlement and structural instability. Excessive settlements over time can cause severe damage to buildings, roads, and bridges, leading to costly repairs. Another critical issue is poor shear strength, making soft soils highly susceptible to landslides, slope failures, and excavation instability. Their high compressibility further exacerbates construction challenges, as these soils compress significantly under loads, causing differential settlements that can weaken.

Soil stabilization is the process of improving the physical and chemical properties of soil to enhance its strength, durability, and overall performance for construction and engineering purposes. This technique is commonly used in civil engineering and construction to make soil more suitable for supporting structures, roads, and other infrastructure. The process of Soil stabilization is quite important significantly nowadays. Long ago, people can look for the best soil and build a structure over it. Nowadays, the best soils already have structures over them, but people still need to expand, which is why we have no choice but to build over soils even if they are not stable enough. Stabilization of soil on road; Road stabilization not only protects against road maintenance and construction but also against many other things. It also helps for protecting the building against any kind of erosion in different places. Without the process of stabilization of soil, the places wherever the structures are constructed can go down over the time. This would cause a number of cracks inthe structures & then the buildings would become unsafe. This would become a very big loss to the organization who built it. The soils which were not properly stabilized might be quite dangerous. Whenever heavy rains pour down it makes the soil soft that makes it less strong. In case the soil didn't go through the process of stabilization, it might slide-down and also put people inside the building which might be in danger.

2. LITERATURE REVIEW

K. K. Patil & S. Neeralagi, they had conducted research on “Soil Stabilization by using Plastic Waste”, in this they have used plastic bottle strips and plastic bag strips for stabilization. From this study conclusion was made that there is increase in CBR value of a soil and maximum CBR is achieved when 0.75% amount of plastic bottle strips are added to the soil after further addition of the strips there is decrease in the CBR value. In case of plastic bag strips, it has been observed that 2% of the total weigh of the soil is the optimum proportion of the strips, we can also state from this study that strips cut out of plastic bottles are better option than strips of soil bags, to increase the CBR value of the soil**.**

Jasmin Varghese Kalliyath et.al. (2016) studied the effect of plastic fibers. Various tests such as Standard Proctor, UCC were carried out with different samples of silty clay. Authors observed that the replacement of 0.5 % waste plastic fiber to the expansive clayey soil reduce its OMC and increased maximum dry density but UCS of the soil was found to be increased. The test results also showed that with 1% replacement, MDD and UCC were less than the 0.5 % replacement but greater than the untreated soil.

Further increase in the plastic replacement showed decrease in the MDD and the UCS. The increase in the MDD of the soil with 1% replacement is due to the decrease in the number of voids with the addition of plastic which leads to effective compaction and also increase in the cohesion. Thus, authors concluded that optimum percentage of plastic was 0.5 % for optimum results.

Jain et al, studied the potential utilization of waste marble dust as a geo-material for improving geotechnical properties of expansive soil and particles interactive mechanism. The results revealed that marble dust could effectively control swelling and improve the plasticity of the soil. The factors responsible for controlling the interactive behavior of marble added soils were the mineralogical, chemical, and elemental composition of marble dust

N. W. Jassim and H. A. Hassan et al, worked on "Soil stabilization by using marble dust powder" Waste marble dust (MD) was extracted from the marble factory's sludge. Marble sludge, a waste product of the marble factory's cutting of marble blocks, was collected from native marble cutting plants, the physical attributes and chemical makeup of marble dust (MD). The marble dust particle size distribution revealed that it contains 15% clay, 25% silt, and 58% sand, indicating that it is classified as sand. As a result, the amount of clay in the combination can be lowered by adding marble dust to the soil sample. The results were the grain size distribution curve shifted downward for the clay soil treated with marble dust (MD) as the sand content increases from 3% to 28%, while the clay content and silt content were reduced by about 42% when the MD content increased from 0% to 15%. The plasticity index decreased by about 22% with the increase in the MD content from 0% to 12%. The results also indicate that using 9% MD reveal further increase in the plasticity index. The maximum dry density MDD of the treated soil mixture increased, whereas the optimum moisture content OMC of the mixture decreased by about 14%, 26% respectively as adding MD to the soil mixture from 0% to 15%.

Altug (2015) conducted study on the possibility of utilizing waste marble dust in stabilizing problematic soils (especially swelling clays). The marble dust addition ratios which have been studied were 0 %, 5 %, 10 %, 20 % and 30 % by weight. Physical, mechanical and chemical properties of soil and marble dust samples were investigated.

Wardana (2009) studied the used marble powder as an added material for clay in Bali and showed that the values of specific gravity, liquid limit (LL) and PI decreased with the addition of 3%, 6%, 9%, 12% and 15% of marble while the plastic limit (PL) value increased. Moreover, the highest design in the CBR test with the addition of 9% marble powder and the compaction energy of 56 strokes was found to be 9%.

Waheed et al. (2021) studied the effectiveness of marble powder waste varied at 5%, 10% and 15% of soil weight. They were used as a soil stabilizer (CL-ML) through physical and mechanical tests. The results showed that the marble powder waste added was able to increase unsoaked CBR value up to 10%, while the value at seven days of curing increased from 6.5% to 11.3%. This shows that curing time has a significant influence on the CBR value. Based on this background, this research was carried out to analyze soil stabilization using a mixture of marble powder waste varied at 0%, 7%, 17% and 27% for curing times of 0, 3 and 7 days. Involving tests of the physical, mechanical and chemical properties of marble dust to deeply understand its characteristics and its influence on soil in enhancing bearing capacity and reducing plasticity.

Ghida Alhakim et al;(2024) worked on the "stabilization of clayey soil by using sawdust and sawdust ash", The aim of this study was to assess and compare the effectiveness of two forms of sawdust, raw (SD) and ash (SDA), in stabilizing clayey soil. Different proportions of each stabilizer (2%, 5%, 8%, 12%, 15%, and 20%) were added to the soil. Subsequently, the resulting mixtures underwent analysis for consistency limits, compaction characteristics, and shear strength parameters which were used to anticipate the soil's bearing capacity. The study yielded the following conclusions: the study found that SDA was more efficient in reducing the plasticity index, whereas SD further improved the soil strength compared to SDA with 5% optimal content for both additives. It was inferred that burning sawdust could be avoided, since SD was more efficient and showed better performance, particularly in terms of strength enhancement. For that reason, using SD as a soil stabilizer for finegrained soils could be a cost-effective, eco- friendly, and efficient soil improvement technique. The sawdust material is biodegradable, and such degradation can lead to strength depletion in the soil matrix over a long period of time. On this particular issue, several approaches including physical or chemical modifications have to be undertaken in future studies in order to mitigate this limitation. And, hence further improves the interfacial adhesion of the sawdust and ensures the long-term durability of the soil composites.

C. V Dev, Athul Krishnan and Gayathri S, investigated "soil stabilization using wooden sawdust" In general silty soils have proved to be problematic to most Civil Engineering structures. Several researchers have tried to look for different materials which can alter the properties of these poor soils, and among them are lime and cement, which are expensive. Considering the vast quantities of sawdust produced in woodwork departments, they can be used as a secondary stabilizer, thus leading to sustainable technologies. Sawdust not only acts as a cheap stabilizer but also reduces the problem of environmental pollution caused by its poor disposal. This paper examines the geotechnical properties of expansive soil stabilized by sawdust ash. The sawdust used as partial replacement of soil in the ratio of 0, 2, 4, 6and 8% by the dry soil weight. The sawdust used in this study was obtained from the Paracha timber mill at kalady. After collecting the saw dust, it was air dried to remove its moisture content and to facilitate in easy burning it to ash. An incinerator was used to burn the sawdust to ash by pouring all the dried sawdust contents into its container and apply 4-5 hours were given for complete combustion. was obtained that 8% of sawdust ash gives improvement in properties ofsoil.so 8% was selected as optimum percentage. (a) OMC increased and maximum dry density decreased with increase in percentage ofsawdust ash. (b) Unconfined compressive strength increased with increase in percentage of sawdust ash and after 8% it was decreasing. (c) With addition of sawdust ash, there is a considerable decrease.

A. R. Makegaonkar et.al. conducted research on soil stabilization using brick powder, focusing on its potential to improve soil properties. They investigated the potential of brick powder as a soil stabilizer. Their study revealed the Brick powder is increased in the unconfined compressive strength (UCS) of soil by 25-50%, Brick powder reduced the soil's plasticity index by 20-40% and 10-20% of brick powder mixture showed optimal results.

Mohd Furkhan, et.al. investigated the effectiveness of brick powder in stabilizing expansive soils, In the Brick powder has increased the unconfined compressive strength (UCS) by 30-50%, Brick powder reduced the plasticity index by 25 -40% and 12-15% of brick powder mixture showed optimal results. Expensive soil or black cotton soil are one of the most problematic soils from civil engineering construction perspective. So, findings from this paper are that it investigates the use of demolition waste to improve the strength of black cotton soil and summarizes the results of experiment on two clay soils one with high plasticity as well as low plasticity. The tests were performed using different proportions of Demolished Waste which includes 20%, 40%, 50%. At the end tests the results showed that the maximum strength was obtained when 50% of demolished waste was mixed with the soil. This Shows that the maximum the amount of demolished proportion will result in increase in maximum strength compared to less proportions (20% ,40%) which were tested.

3. METHODOLY

Soil stabilization is a crucial process in civil engineering that enhances the physical and chemical properties of soil, making it suitable for construction purposes. This report investigates the use of various industrial waste materials brick powder, marble waste, plastic waste, and sawdust as stabilizing agents for soil. The objective is to evaluate their effectiveness in improving soil strength, reducing plasticity, and promoting sustainable construction practices.

Material Used

1. Soil Sample:

Soil sample used in the project work for the experimental purpose is excavated from a depth of 1.5 m below the ground level from Pote College Campus, Kathora, Amravati, the soil sample collected is black in color. Fig 2.1 shows the Soil used for project work.

Figure 3. 1 Clayey Soil

2. **Brick Powder:**

Brick Powder with its component burnt brick powder is a waste powder generated from the burning of bricks with the soil covered by surroundings. Due to burning of soil bricks it hardened and at the time of removal the set-up we get the powder form of brick. It has red color and fine in nature. It has great ability to reduce the swelling potential of black cotton soil. Brick due to burning of soil bricks it hardened and at the time of removal the set-up we get the powder form of brick. It has red color and fine in nature. It has great ability to reduce the swelling potential of black cotton soil. Fig 2.2 shows the Brick powder collected from the Brick kiln.

Figure 3. 2 Brick Powder

3. **Marble Waste:**

Waste generated from the marble cutting and polishing industry, typically in the form of fine particles. Marble waste is generated during the extraction, cutting, shaping, and polishing of marble stone. The waste primarily comes from the quarrying process, where large blocks of marble are extracted, leaving behind unused stone material, dust, and powder. During the cutting and shaping stages, a significant amount of waste is produced in the form of marble chips and dust, while the polishing stage generates marble slurry, a mixture of fine particles suspended in water. Estimates suggest that approximately 30-40% of the total marble mined can become waste, contributing to environmental concerns. The main forms of waste include fine dust, slurry, chips, and unused blocks that cannot be utilized due to defects or size limitations. Fig 3.3 shows the Marble waste collected from Shriram Marble shop, beside Rangoli lawn, Kathora road Amravati.

Figure 3. 3 Marble Gray Dust

4. **Plastic Waste:**

Plastic waste is generated from several sources, including the production process, consumption patterns, and disposal methods. During manufacturing, excess plastic material such as scraps, trimmings, and rejected items can become waste. The largest portion of plastic waste originates from consumer usage, particularly single-use plastics like bottles, bags, food wrappers, and straws. After use, these plastics are often improperly discarded, ending up in landfills, oceans, or other natural environments. Furthermore, recycling processes can generate additional waste, especially when plastic items are contaminated or unsuitable for recycling. Plastics are categorized into single-use, durable, and hard-to-recycle materials, each contributing to the growing global plastic waste problem. With over 8 million tons of plastic entering the oceans each year, it is crucial to identify and address the sources of plastic waste to mitigate environmental damage and improve waste management systems. Fig 3.4 shows Plastic waste collected from Transport Nagar, Lalkhadi, Amravati.

Figure 3. 4 Plastic Waste

5. **Sawdust:**

Sawdust is primarily generated in the woodworking and sawmill industries as a byproduct of cutting, shaping, sanding, and planning wood. Sawmills, where logs are processed into lumber, produce large quantities of sawdust as they saw, trim, and shape the wood. Smaller-scale woodworking shops and carpenters also contribute to sawdust waste through the manual cutting and sanding of wood. Additionally, forestry operations and wood product manufacturing, including the production of wooden pallets and packaging, generate smaller amounts of sawdust. The waste can vary from fine dust created during sanding to larger coarse particles produced during cutting. While sawdust is often discarded, it can be repurposed for a variety of uses, including the production of particleboard, animal bedding, or as biofuel. The vast quantities of sawdust produced each year highlight the need for more sustainable waste management practices in the wood processing industry. Fig 3.5 shows wooden sawdust collected from Vilas Nagar Amravati.

Figure 3. 5 Wooden Sawdust

There was some procedure which was taken into consideration during the undertaking of the project. The process and the use of the materials for the investigation is listed below:

i. Determination of Moisture content by Oven Drying Method.

ii. Determination of Specific Gravity of Soil by Pycnometer.

iii. Determination of field density by Core-Cutter method.

iv. Determination of compaction properties (Standard proctor test).

v. California bearing ratio Test.

4. PERFORMANCE ANALYSIS

4.1. Test Performed on Original Soil:

To determine the basic index properties of original soil following test were performed on original soil sample.

4.1.1. Determination of Moisture content by Oven Drying Method

4.1.2. Determination of Specific Gravity of Soil by Pycnometer

4.1.3. Determination of field density by Core-Cutter method

4.1.4. Determination of compaction properties (Standard proctor test).

4.1.5. Determination of the grain size distribution of the given soil by mechanical sieve analysis.

Table 4. 1: Property of Soil Used for The Work

Property	**Value**
Water Content	12.8%
Specific Gravity	2.84%
Core Cutter Test	Bulk Unit wt= 17.11kN/m^3 Dry Unit wt= 13.31kN/m^3
Standard Proctor Test	OMC= 14% MDD= 1.42gm/cc
Grain Sieve Analysis	Cu= 3.45 Cc= 0.35
CBR	C.B.R. Value at 2.5mm Penetration= 3.7% C.B.R. Value at 5mm Penetration= 2.9%

4.2. Test Performed on Original Soil & Stabilized Soil:

To evaluate the performance improvement of Original Soil, preliminary CBR Test were performed on Original Soil & to compare the performance improvement the CBR Test were conducted on Soil Stabilization by using Brick powder (10%), Marble waste (15%), Plastic waste (0.5%), Wooden sawdust (6%)

- **California bearing ratio Test**

The California Bearing Ratio Test (CBR Test) is a penetration test developed by California State Highway Department (U.S.A.) for evaluating the bearing capacity of sub grade soil for design of flexible pavement. It is the ratio of the force per unit area required to penetrate a soil mass with a circular plunger of 50 mm diameter at the rate of 1.25 mm/minute to that required for corresponding penetration in a standard material. Standard Material means having a C.B.R. value of 100%. The ratio is usually determined for penetration of 2.5mm and 5mm.

Figure 4.1 CBR Apparatus

5. RESULT AND DISCUSSION

Introduction

The various properties of Clayey soil had been obtained by performing laboratory tests as per standard procedure given by Indian Standard and as discussed earlier. The observations and results obtained by performing the different tests to determine properties of soil are as given below.

5.1. Determination of Water Content
5.2. Determination of Specific Gravity Table
5.3. Core Cutter Test
5.4. Standard Proctor Test
5.5. Grain Size Analysis Test
5.6. Callifornia Bearing Ratio Test

5.6.1. CBR Test on Original Soil

Table 5.1 Observation Table of Original Soil

Penetration	Proving Ring	
(mm)	Reading	Load (Kg)
0.5	40	9.66
1.0	85	20.527
1.5	130	31.39
2.0	185	44.67
2.5	215	51.92
4.0	238	57.47
5.0	250	60.37
7.5	260	62.79
10.0	350	84.52
12.5	410	99.01

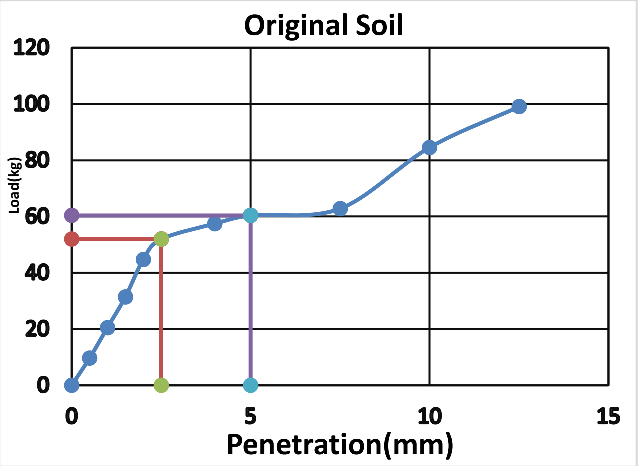

Figure 5.1 CBR Test on Original Soil

CBR Value at 2.5mm penetration= $\frac{\textbf{Total Load}}{\textbf{Standard Load}} * \mathbf{100}$

= 51.92/1370*100

= 3.7%

CBR Value at 5mm penetration= $\frac{\textbf{Total Load}}{\textbf{Standard Load}} * \mathbf{100}$

= 60.37/2055*100

= 2.9%

5.6.2 CBR test on Original Soil + Brick Powder (10%)

Table 5.2 Observation Table of Original Soil+Brick Powder

Penetration	Proving Ring	
(mm)	Reading	Load (Kg)
0.5	60	14.49
1.0	145	35.01
1.5	240	57.96
2.0	340	82.11
2.5	440	106.26
4.0	505	121.95
5.0	570	137.65
7.5	630	152.14
10.0	685	165.42
12.5	738	178.22

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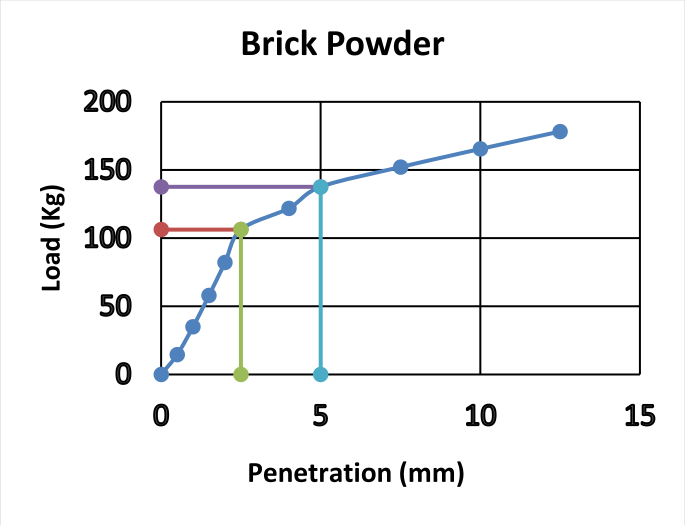


Figure 5.2 CBR Test on Original Soil +Brick Powder (10%)

CBR Value at 2.5mm penetration= $\frac{\textbf{Total Load}}{\textbf{Standard Load}} * \mathbf{100}$

= **106.26**/1370*100

= 7.75%

CBR Value at 5mm penetration= $\frac{\textbf{Total Load}}{\textbf{Standard Load}} * \mathbf{100}$

=**137.65**/2055*100

= 6.69%

5.6.3 CBR test on Original Soil + Saw Dust (4%)

Table 5.3 Observation Table of Original Soil+Saw Dust

Penetration	Proving Ring	
(mm)	Reading	Load (Kg)
0	0.0	0.0
0.5	0.35	6.9
1	1.41	27.5
1.5	2.46	48.3
2	4.22	82.8
2.5	6.32	124.2
3	8.78	172.5
4	15.46	303.6
5	23.54	462.3
7.5	45.67	897.0
10	65.70	1290.3

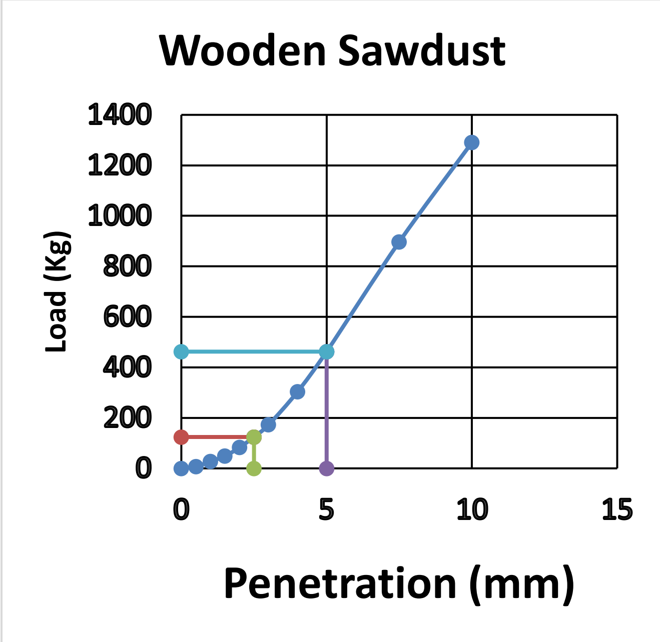


Figure 5.3 CBR Test on Original Soil +Sawdust (4%)

CBR Value at 2.5mm penetration= $\frac{\textbf{Total Load}}{\textbf{Standard Load}} * \mathbf{100}$

= **124.2**/1370*100

= **9.06** %

CBR Value at 5mm penetration= $\frac{\textbf{Total Load}}{\textbf{Standard Load}} * \mathbf{100}$

=**462.3**/2055*100

= **22.49** %

5.6.4 CBR Test on Original soil +marble powder (15%)

Table 5.4 CBR Test on Original soil +marble powder (15%)

Penetration	Proving Ring	
(mm)	Reading	Load (Kg)
0.5	13	3.13
1.0	31	7.486
1.5	57	13.765
2.0	84	20.286
2.5	118	28.497
4.0	190	45.885
5.0	231	55.786
7.5	339	81.868
10.0	424	102.29
12.5	487	117.61

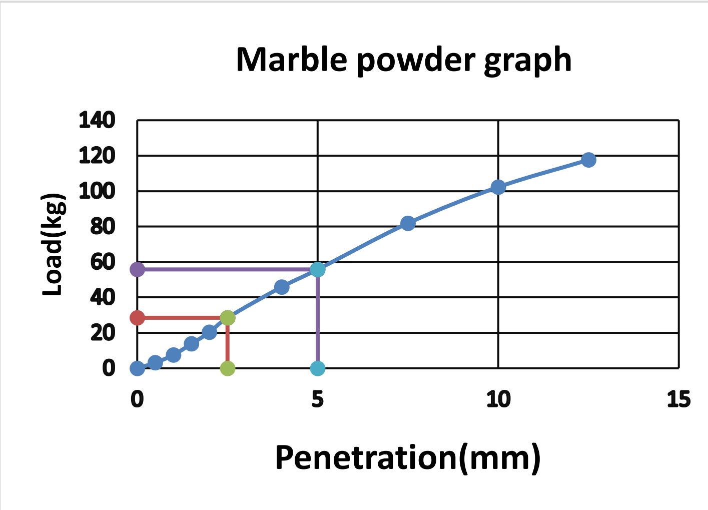
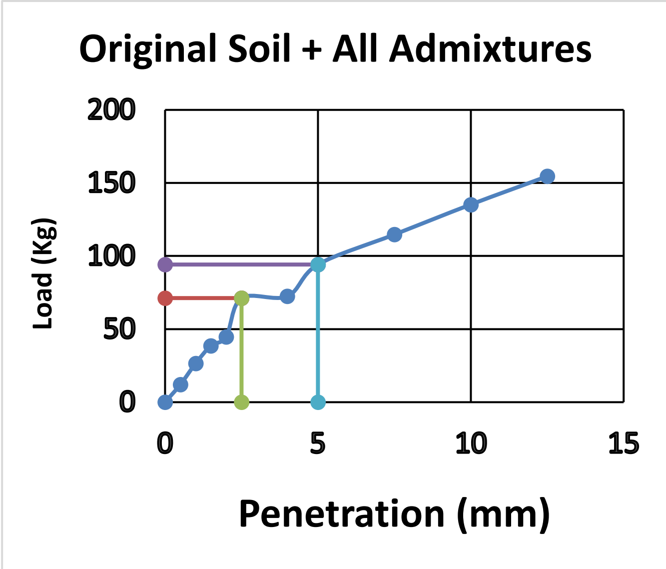


Figure 5.4CBR Test on Original Soil + Marble Powder (15%)



CBR Value at 2.5mm penetration= $\frac{\textbf{Total Load}}{\textbf{Standard Load}} * \mathbf{100}$

= **28.497**/1370*100

= **3.7%**

CBR Value at 5mm penetration= $\frac{\textbf{Total Load}}{\textbf{Standard Load}} * \mathbf{100}$

=**55.786** /2055*100

= **2.9%**

5.6.5 CBR test on Original Soil + Plastic Waste (0.5%)

Table 5.5 Observation Table of Original Soil + Plastic Waste (0.5%)

Penetration	Proving Ring	
(mm)	Reading	Load (Kg)
0.5	42	10.143
1.0	90	21.735
1.5	98	23.667
2.0	133	32.119
2.5	150	36.225
4.0	216	52.164
5.0	232	56.028
7.5	278	67.13
10.0	352	85.008
12.5	373	90.079

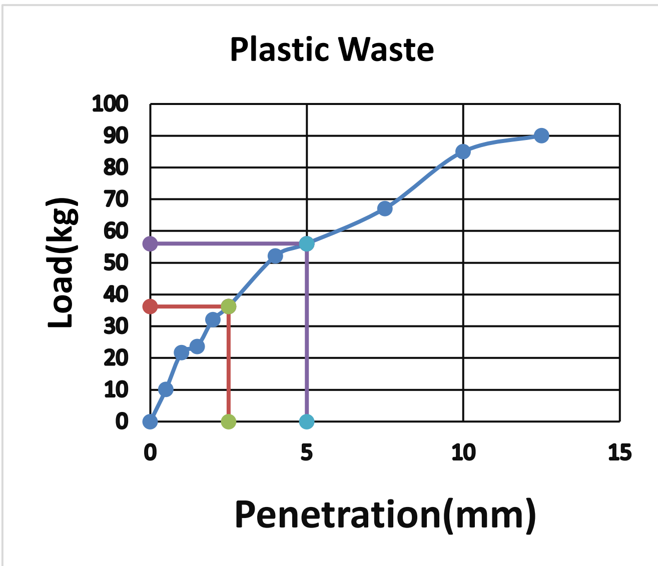


Figure 5.5 CBR Test on Original Soil +Plastic Waste (0.5%)

CBR Value at 2.5mm penetration= $\frac{\textbf{Total Load}}{\textbf{Standard Load}} * \mathbf{100}$

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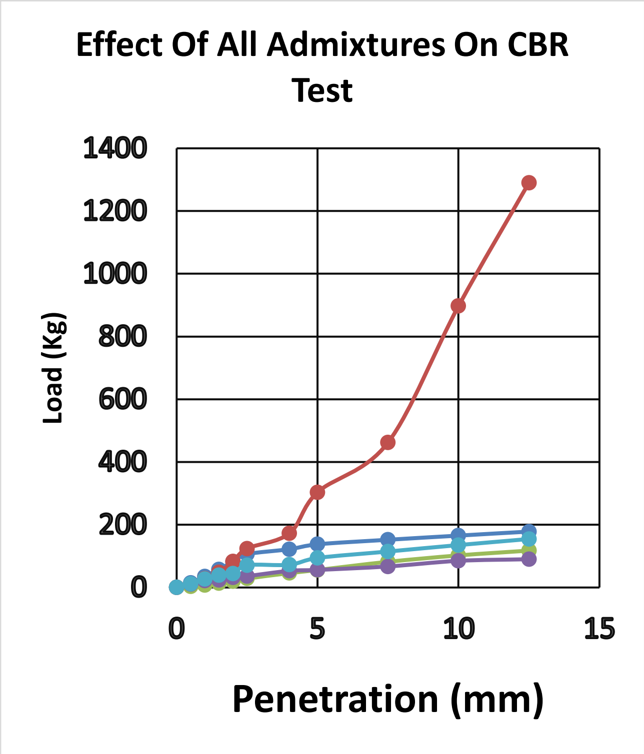
= **36.225**/1370*100



= **2.64 %**

CBR Value at 5mm penetration= $\frac{\textbf{Total Load}}{\textbf{Standard Load}} * \mathbf{100}$

=**56.028**/2055*100

= **2.72 %**

5.6.6 **CBR Test on Original Soil + All Admixture (Brick powder 10%, Marble Dust 15%, Wooden Saw Dust 4%, Plastic waste 0.5%)**

Table 5.6 Observation Table of Original Soil+All Admixture

Penetration	Proving Ring	
(mm)	Reading	Load (Kg)
0.5	50	12.07
1.0	110	26.56
1.5	160	38.64
2.0	185	44.67
2.5	295	71.24
4.0	300	72.45
5.0	390	94.18
7.5	475	114.71
10.0	560	135.24
12.5	640	154.56

Figure 5.6 CBR Test on Original Soil+all Admixtures

CBR Value at 2.5mm penetration= $\frac{\textbf{Total Load}}{\textbf{Standard Load}} * \mathbf{100}$

= **71.24**/1370*100

= **5.2%**

CBR Value at 5mm penetration= $\frac{\textbf{Total Load}}{\textbf{Standard Load}} * \mathbf{100}$

=**94.18**/2055*100

= **4.58%**

Discussion:

- The CBR value of original sample of soil was found to be 3.7% at 2.5 mm.
- The CBR tests revealed a range of values, with 10% brick powder exhibiting the highest CBR of 7.75%, while 0.5% plastic wastes showed the lowest CBR of 2.64%.
- The combination of 10% brick powder, 15% marble dust, 4% wooden saw dust and 0.5% plastic wastes had a CBR value of 5.2%, which was the second highest recorded.
- The CBR value of 10% marble dust was found to be 3.7%.

6. CONCLUSION

This research investigates the efficacy of using industrial and domestic waste materials—namely brick powder, marble dust, plastic waste, and wooden sawdust—for the stabilization of clayey soil, specifically targeting improvements in strength as measured by the California Bearing Ratio (CBR).

Laboratory testing revealed that all additives influenced the soil's engineering properties to varying degrees. Among them, brick powder at 10% content yielded the highest CBR improvement, increasing the value from 3.7% (untreated soil) to 7.75%, indicating a significant enhancement in load-bearing capacity. Wooden sawdust at 4% also produced a substantial CBR increase to 9.06% at 2.5 mm penetration, though plastic waste alone resulted in a slight decrease in performance. Interestingly, a combination of all four admixtures (brick powder 10%, marble dust 15%, wooden sawdust 4%, and plastic waste 0.5%) achieved a CBR value of 5.2%, suggesting that certain combinations may yield synergistic effects while others may neutralize benefits. The study confirms that waste materials, particularly brick powder and sawdust, can be effectively reused for soil stabilization.

This approach not only enhances soil strength but also addresses environmental challenges associated with waste disposal. Thus, adopting such sustainable methods in geotechnical engineering projects can reduce material costs and environmental impact, while offering improved structural performance.

7. Future scope

In future, research should focus on evaluating the long-term performance of these waste materials under varying environmental conditions. Additional testing, such as permeability and durability assessments, Swell tests, Compaction Tests, Atterberg Limits, Unconfined Compressive Strength (UCS), is recommended. Stabilization techniques, such as the addition of binders, should be explored to improve the CBR of waste materials with lower strength characteristics. Further Research can be carried out on this topic by adding certain other easily available materials like lime, gypsum etc. Increased utilization of fly ash, slag, and other industrial waste materials as pozzolanic stabilizers can be studied. In addition to RHA and cement and also by performing other major tests used in pavement design for future study.

Application

The study introduces the significance of brick powder, marble dust, wooden saw dust, plastic wastes and combination of these four wastes in improving the strength properties of

the expansive soil. This improvement can pave the way for the utilization of waste materials in the following fields:

- Pavement sub grade
- Embankments
- foundations while reducing the environmental pollution.

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