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Construction And Demolition Waste Used in Stabilization of Expansive Soil in Road Subgrades

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Abstract- This study focuses on the stabilization of black cotton soil using construction and demolition waste, specifically brick powder obtained from demolished structures. In this study, black cotton soil was collected from Amravati, Maharashtra, and brick powder was obtained from demolition waste. The waste material was processed by crushing and sieving through a 425-micron IS sieve. The soil was mixed with different proportions of brick powder (6%, 9%, 12%, and 15%) to evaluate its effect on soil properties. A series of laboratory tests were conducted, including sieve analysis, specific gravity test, Atterberg limits (liquid limit, plastic limit, shrinkage limit), compaction test (Standard Proctor), free swell index, unconfined compressive strength (UCS), and California Bearing Ratio (CBR) test. These tests were carried out on both untreated soil and stabilized soil samples. The results indicate that the addition of brick powder significantly improves the engineering properties of black cotton soil. The plasticity index decreases, indicating reduced swelling behavior. The maximum dry density increases, while optimum moisture content shows variation depending on the mix proportion. The CBR value increases considerably, indicating improved load-bearing capacity suitable for road subgrade applications. The stabilized soil also shows better strength and reduced compressibility compared to untreated soil. The study concludes that construction and demolition waste, particularly brick powder, can be effectively used as a stabilizing material for expansive soils. This method is economical, eco-friendly, and sustainable as it reduces the need for conventional stabilizers like cement and lime, minimizes environmental pollution, and promotes recycling of waste materials.

Keywords: Construction and Demolition Waste, Soil Stabilization, Expansive Soil, Black Cotton Soil, CBR, Sustainable Construction, Subgrade.

I. INTRODUCTION

India is a fast-developing country where infrastructure development is increasing day by day. A large number of projects such as roads, highways, bridges, buildings, flyovers, and metro systems are being constructed across the country. At the same time, many old and damaged structures are being demolished to make space for new construction. Due to this continuous construction and demolition activity, a huge quantity of waste is generated every year. This waste mainly includes materials like broken bricks, concrete pieces, mortar, plaster, steel, wood, and other debris. These materials are collectively called Construction and Demolition Waste (CDW). In India, the generation of CDW has increased rapidly in recent years due to urbanization, population growth, and modernization. It is estimated that millions of tonnes of CDW are produced annually. However, only a small portion of this waste is properly reused or recycled, while the majority is dumped in open areas or landfills. Improper disposal of CDW creates serious environmental problems. It leads to air pollution, soil contamination, and blockage of drainage systems. It also occupies valuable land space and creates unhygienic conditions in urban and rural areas. Therefore, effective management and reuse of CDW have become very important for sustainable development.

Black cotton soil is known for its high swelling and shrinkage properties. When it absorbs water during the rainy season, it expands significantly, and during the dry season, it shrinks and forms deep cracks. Due to this behavior, black cotton soil creates major problems in civil engineering works, especially in road construction. The subgrade prepared on such soil becomes weak and unstable. As a result, pavements develop cracks, uneven settlement, and deformation. This leads to frequent maintenance and reduces the life of roads. Traditionally, materials like cement, lime, and bitumen are used for stabilizing weak soils. These materials improve the strength and reduce the plasticity of soil. However, these methods are costly and also have environmental impacts due to the emission of greenhouse gases during production. In recent years, engineers and researchers have started focusing on the use of waste materials for soil stabilization. This approach not only improves soil properties but also helps in waste management. Construction and demolition waste contains materials like brick powder and crushed concrete, which have good engineering properties. These materials can act as stabilizers when mixed with expansive soil.

Brick powder, in particular, is easily available from demolished structures and has pozzolanic properties. When it is mixed with black cotton soil, it helps in reducing plasticity, increasing strength, and improving compaction characteristics. It also reduces the swelling behavior of the soil. Therefore, this study focuses on the use of construction and demolition waste, especially brick powder, for the stabilization of black cotton soil. This method is economical, as it uses waste materials, and environmentally friendly, as it reduces pollution and promotes recycling. Thus, this study aims to develop a sustainable and cost-effective solution for road construction by using locally available waste materials. It also supports the concept of green construction and resource conservation, which is very important for the future development of India.

II. RESEARCH METHODOLOGY

The main idea of improvising actually means to use alternative resources in solving a given problem in the absence or shortage of original resources. The objective of this research is to know the significant influence on the soil improvement capabilities of recycled brick obtained from demolition waste. The main reason to use demolition waste instead of others improvisation material such as lime, bitumen etc is because these materials harm the environment directly.

Trail	Percentage of Brick Powder
1	6%
2	9%
3	12%
4	15%

MATERIALS:
This project revolves around the phenomenon of stability of soil using demolition waste or construction waste; the study illustrates the various changes in the physical properties of black cotton soil while the demolition waste is being added into them in different proportions.

BLACK COTTON SOIL:
Expansive soils, popularly known as black cotton soils in India are, amongst the most problematic soil from Civil Engineering perspective. Of the various factors that affect the swelling behaviour of these soils, the basic mineralogical composition is very important. Most expansive soils are rich in mineral montmorillonite and a few in illite. This soil is rich in calcium carbonate potash. The degree of expansion being more in the case of the former. Soil suction is another quality that can be used to characterise a soil's affinity for water on its volume change behaviour. Black cotton soil is heavy clay soil, varying from clay to loam; it is generally light to dark grey in colour. Cotton grows in this kind of soil. The soil prevails generally in central and southern parts of India. The most important characteristic of the soil is, when dry, it shrinks and is hard like stone and has very high bearing capacity. Large cracks are formed in the bulk of the soil. The whole area splits up and cracks up to 150 mm wide are formed up to a depth of 3.0 to 3.5 metre. But when the soil is moist it expands, becomes very soft and loses bearing capacity. Due to its expansive character, it increases in volume to the extent of 20% to 30% of original volume and exerts pressure. The upward pressure exerted becomes so high that it tends to lift the foundation upwards.

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This reverse pressure in the foundation causes cracks in the wall above. The cracks are narrow at the bottom and are wider as they go up. The unusual characteristics of the black cotton soil makes it difficult to construct foundation in such soil. Special method of construction of foundation is needed in such soil. Black cotton soil sample collects from at site Amravati, Maharashtra, India.

CONSTRUCTION AND DEMOLITION WASTE (BRICK POWDER):

To improve the strength of soil different kinds of materials can be used such as lime, bitumen, electricity but in this project, we propose the idea of stabilizing the soil using demolition waste**.** Demolition wastes obtained from a structure predominantly consists of concrete, bricks, plaster, foreign matter such as various type of finishes, cladding materials, lumber, dirt, steel, woods, plastics etc. The demolition waste or construction waste (brick powder) used for the series of experiments to know the changes in the physical properties of soil in this study was acquired from a dumping site which is located in Amravati, Maharashtra, India.

Figure 3.1: Wasted Brick Bat Powder

METHODOLOGY:

The present experimental investigations aim at the detailed study of stabilization/ modification of locally available expansive soil using construction and demolition waste. The experimental programme conducted in this study is comprised of index tests, compaction tests, shear tests, unconfined compressive strength tests, CBR tests and consolidation tests in conformity with approved standards on soil alone and also on stabilised soils to evaluate their individual swelling, compaction, strength, compressibility and drainage characteristics. The material properties, sample preparation, instrumentation, testing methods, and the scope of the experimental programme are presented in the following sections.

The methodology involves series of steps-

Collection of material (C&D waste and black cotton soil)
Preparation of soil sample
Conducting tests on soil
Studying the parameters of waste material
Mixing of black cotton soil and C&D waste
Conducting tests on mixed soil sample
California Bearing Ratio Test on both the samples (soil and mixed soil)
Comparing the results

Figure 3.2: Collection of Black Cotton Soil

Figure 3.3: Collection of Brick Powder

Figure 3.4: Brick Powder

Figure 3.5: Mixing the Sample

TEST CONDUCTED:

To determine the characteristics like Grading by Sieve Analysis, Atterbergs Limits i.e Liquid limit using Cone Penetration Method and Casagrande Method, Plastic limit by rolling the sample to 3mm diameter thread, Shrinkage limit using Shrinkage apparatus, Optimum Moisture Content and Maximum Dry Density using Standard Proctor Test and also California Bearing Ratio by the determination of the properties such as liquid limit, plastic limit, shrinkage limit, optimum moisture content, maximum dry density, CBR value and shear strength for different concentration of construction and demolition waste material with black cotton. The pavement thickness design will be done using pavement design catalogues published by IRC SP:20-2002. The different tests were conducted in order to determine the different characteristics and properties of the soil.

The procedure of each of the tests have been explained below.

1. Sieve Analysis of black cotton soil.
2. Specific gravity by pycnometer.
3. Atterberg limit:
    a) Liquid Limit
    b) Plastic Limit
    c) Shrinkage limit
4. Standard proctor test
5. Free Swell Test
6. Shear box test
7. Unconfined compression test
8. California bearing ratio test

III. RESULTS AND DISCUSSION

BLACK COTTON SOIL:

Table 4.1: Various Tests Results on Black Cotton Soil alone

Test Name	Unit	Test 1	Test 2	Test 3	Test 4	Test 5
Liquid Limit	%	65.29	67.28	62.15	64.28	66.69
Plastic Limit	%	35.86	34.20	29.58	30.50	29.88
Plasticity Index	%	29.42	33.08	32.57	33.78	36.81
Shrinkage Limit	%	13.20	14.60	14.12	14.60	15.11
Free Swell Index	%	100	90	95	90	110
UCS	Kg/cm^2	0.600	0.850	0.660	0.820	0.732
Light Compaction (MDD)	g/cc	1.55	1.52	1.50	1.54	1.51
Light Compaction (OMC)	%	20.67	21.00	22.15	21.50	22.86
CBR at 2.5 mm (Soaked)	%	4.98	4.07	3.17	3.62	3.62
CBR at 5 mm (Soaked)	%	4.22	3.92	3.02	3.02	3.32

BC SOIL + 6%, 9%, 12% and 15% OF BRICK POWDER:

Table 4.2: Various Tests Results on Black Cotton Soil with 6%, 9%, 12% and 15% of brick powder

Property	6% Brick Powder	9% Brick Powder	12% Brick Powder	15% Brick Powder
Liquid limit (%)	62.98%	59.64%	52.58%	49.85%
Plastic limit (%)	29.53%	26.5%	21.5%	19.64%
Plasticity index (%)	33.45%	33.14%	31.08%	30.02%
MDD (g/cc)	1.512	1.581	1.613	1.692
OMC (%)	23.3%	21.4%	19.8%	17.2%
Soaked CBR (%)	5.6	11.2	15.2	20.5%

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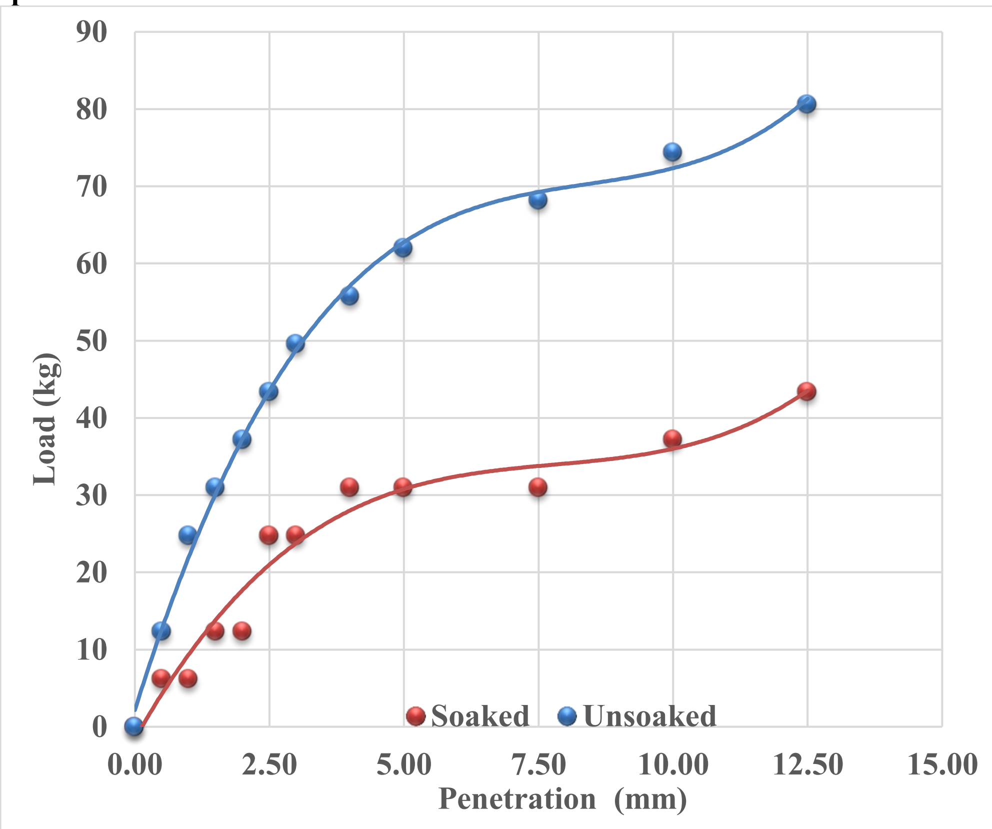
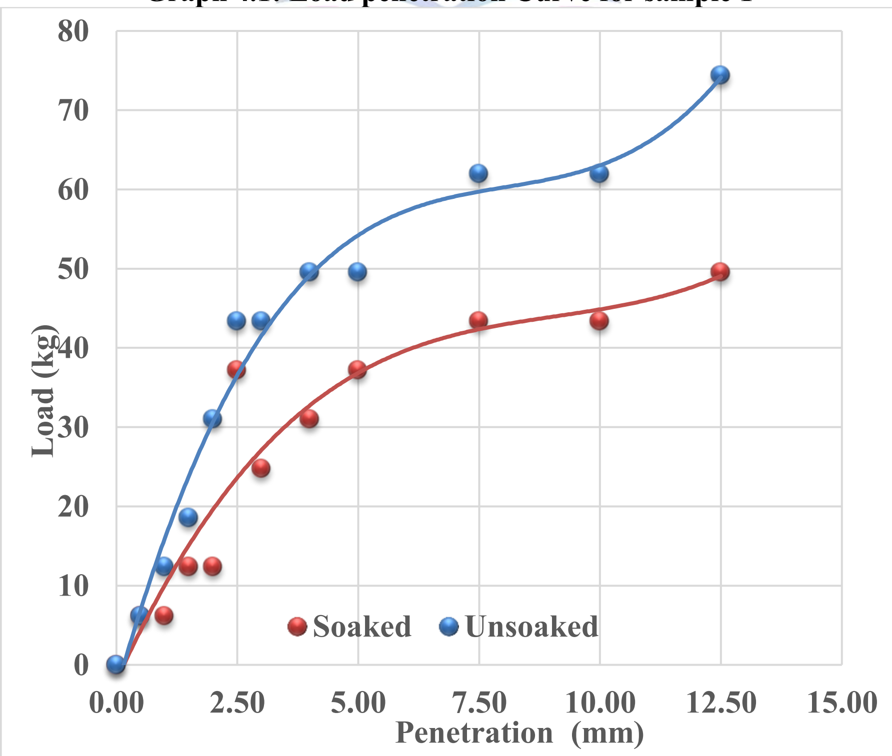
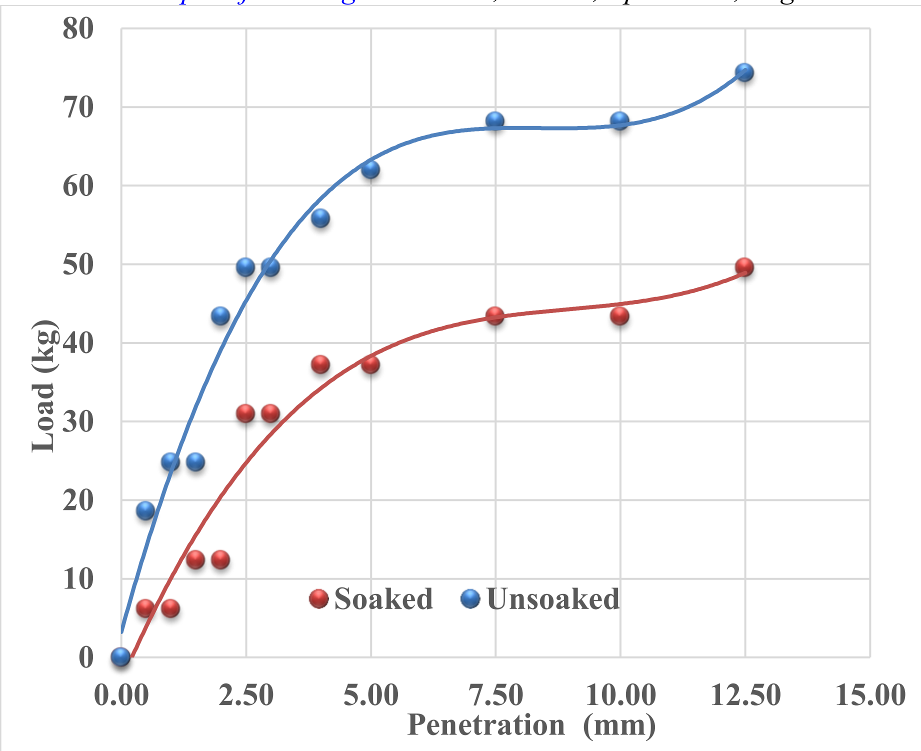
1. CBR Test Graph



Graph 4.1: Load penetration Curve for sample 1

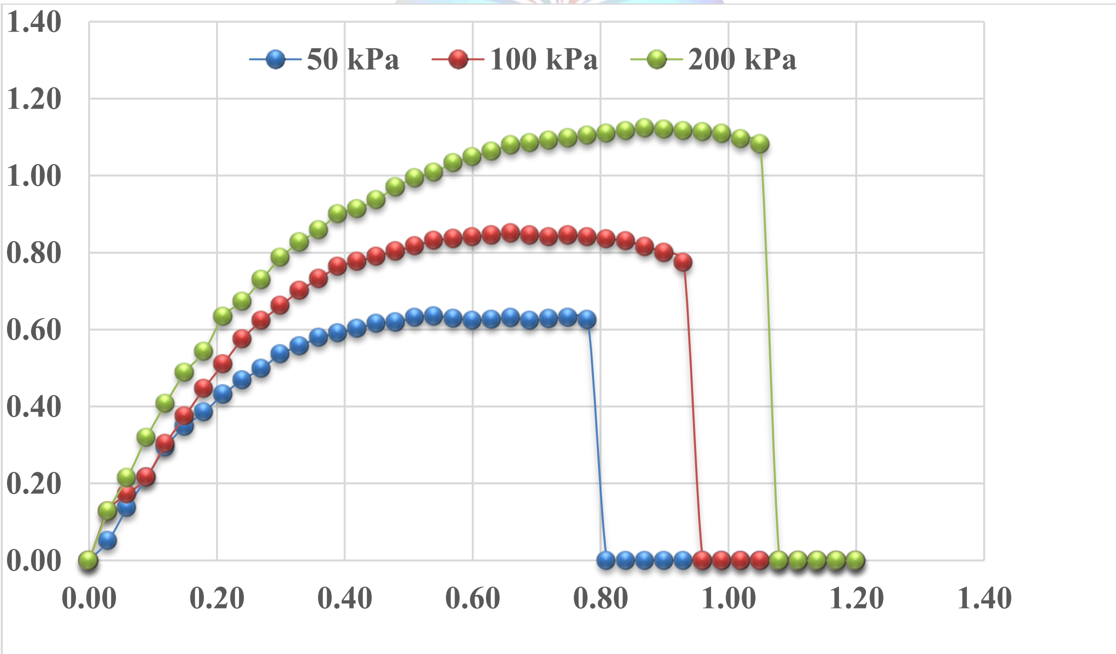


Graph 4.2: Load penetration Curve for sample 2



Graph 4.3: Load penetration Curve for sample 3

2. Direct Shear Test Graph



Graph 4.4: Direct shear test for sample 1

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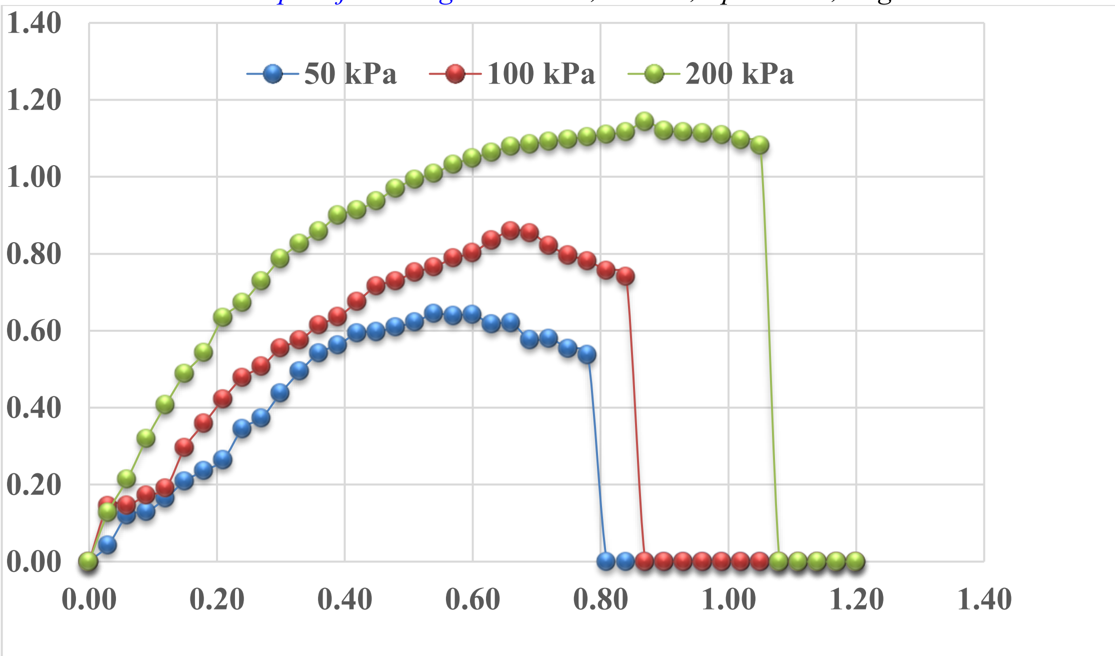
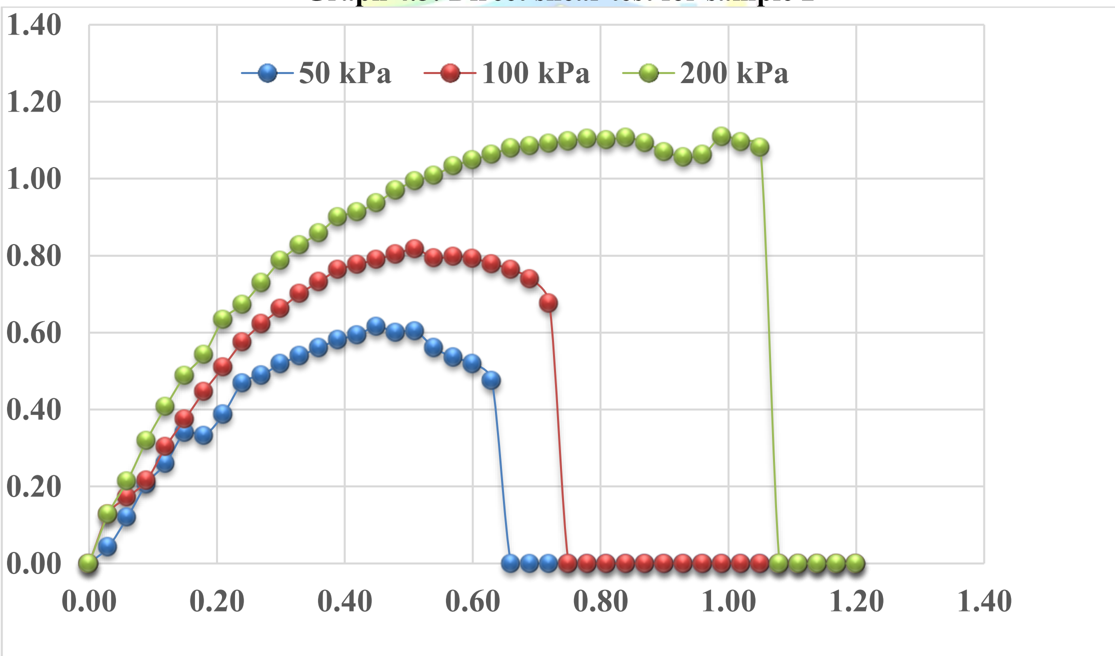
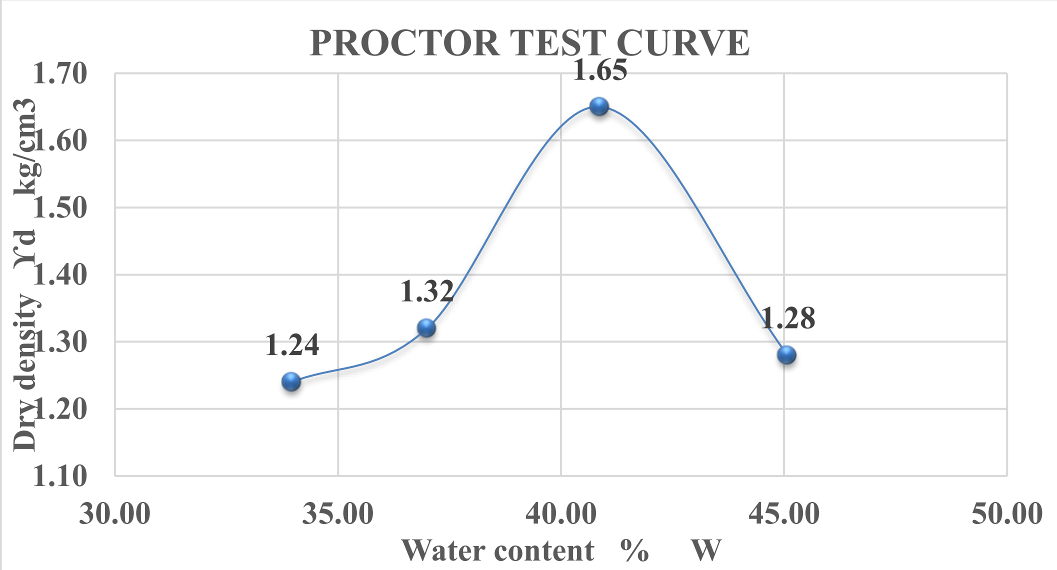


Graph 4.5: Direct shear test for sample 2

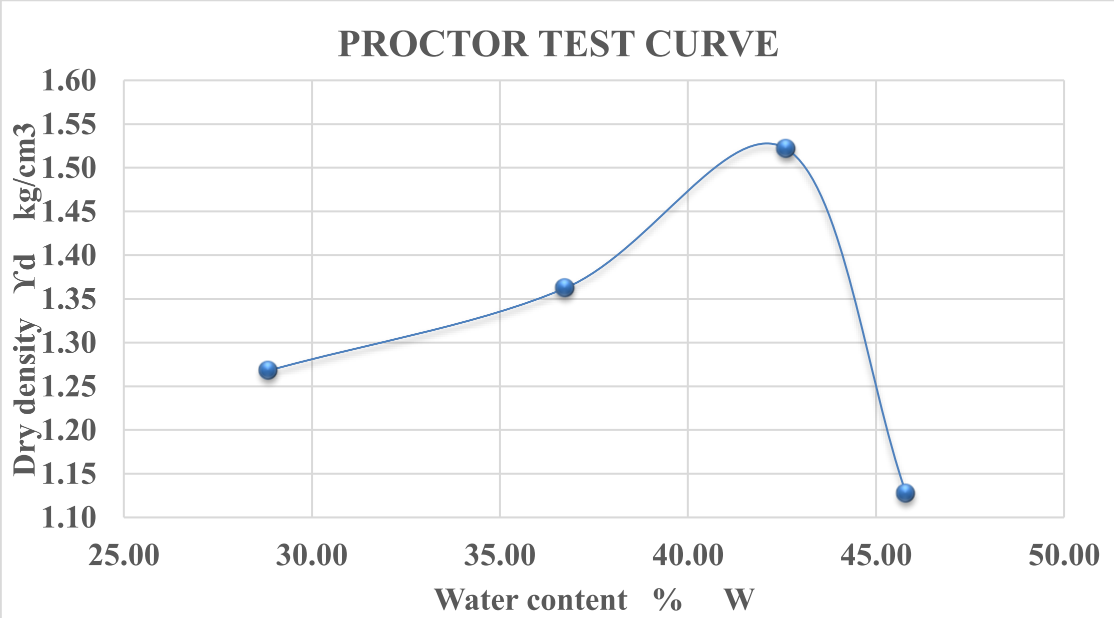


Graph 4.6: Direct shear test for sample 3

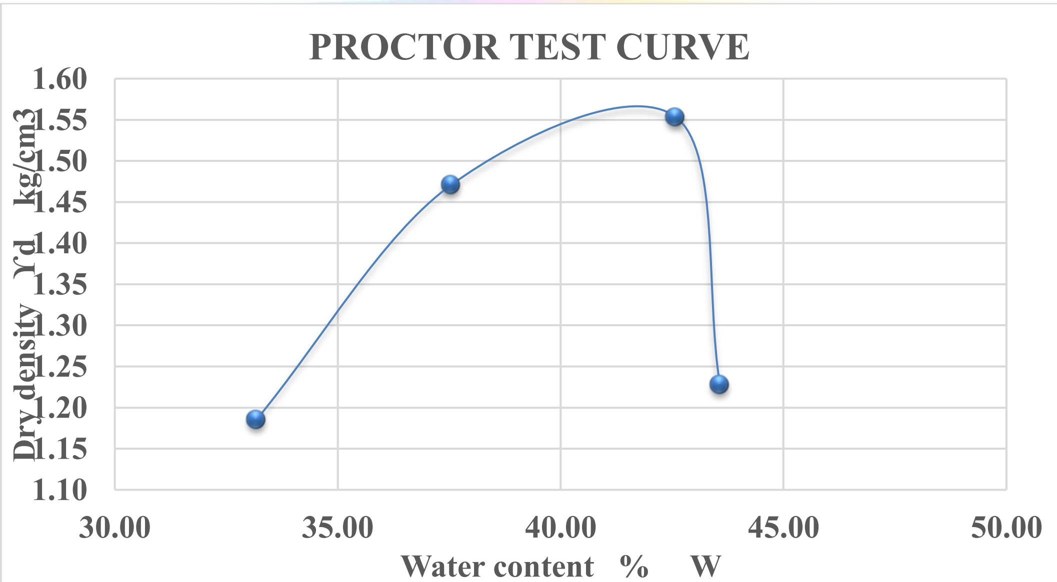
3. Proctor Test Graph



Graph 4.7: Proctor test curve for sample 1

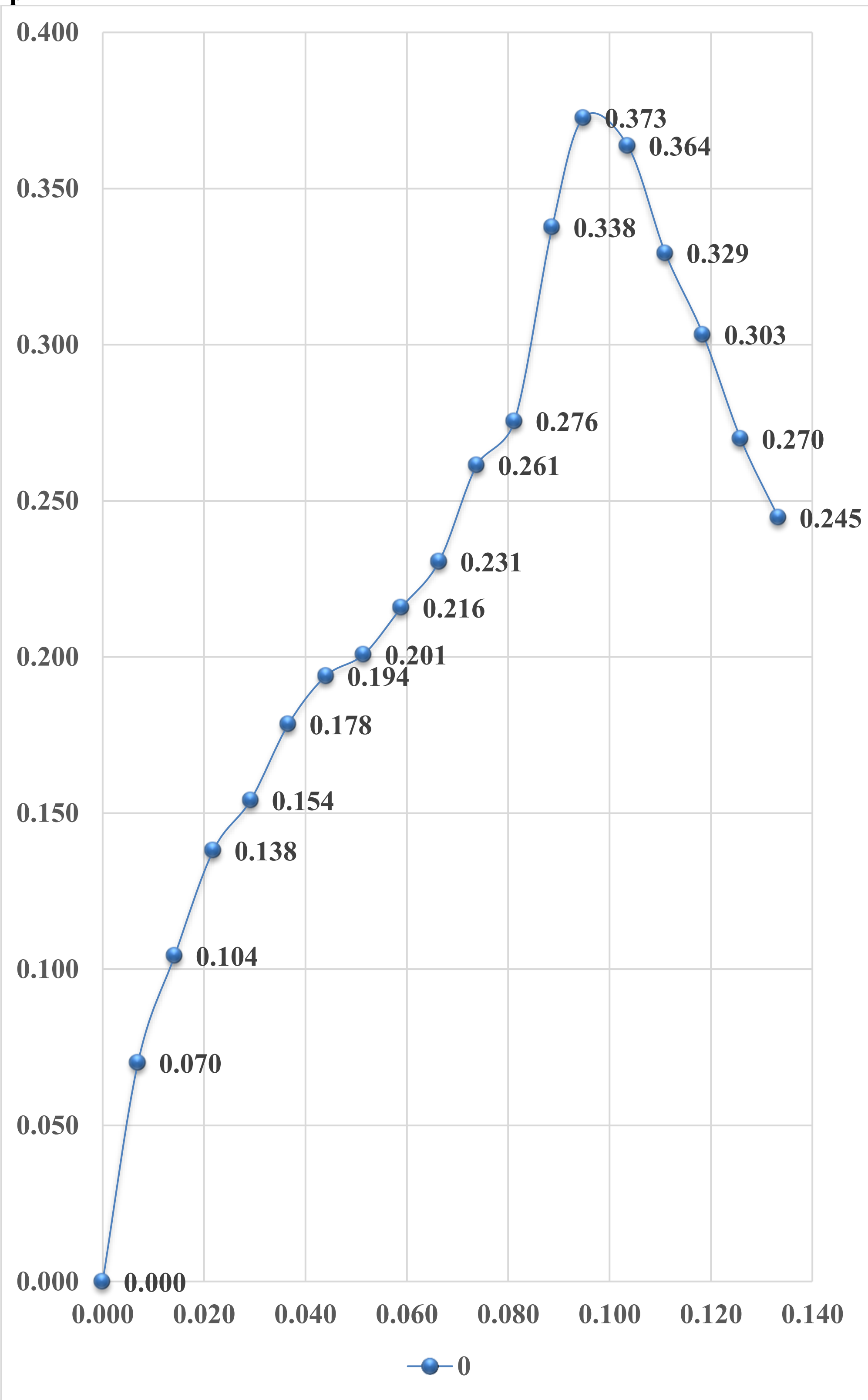


Graph 4.8: Proctor test curve for sample 2

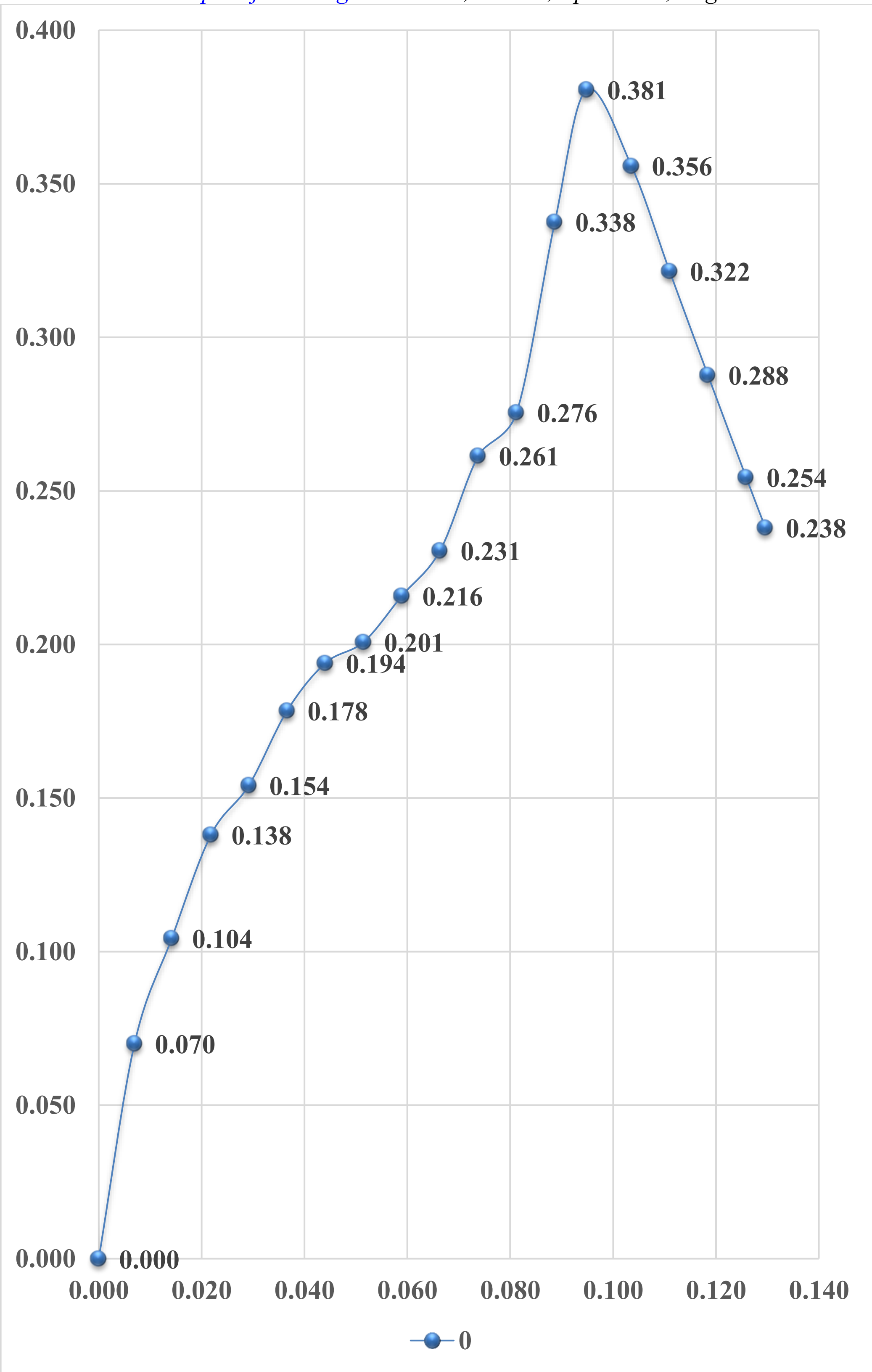


Graph 4.9: Proctor test curve for sample 3

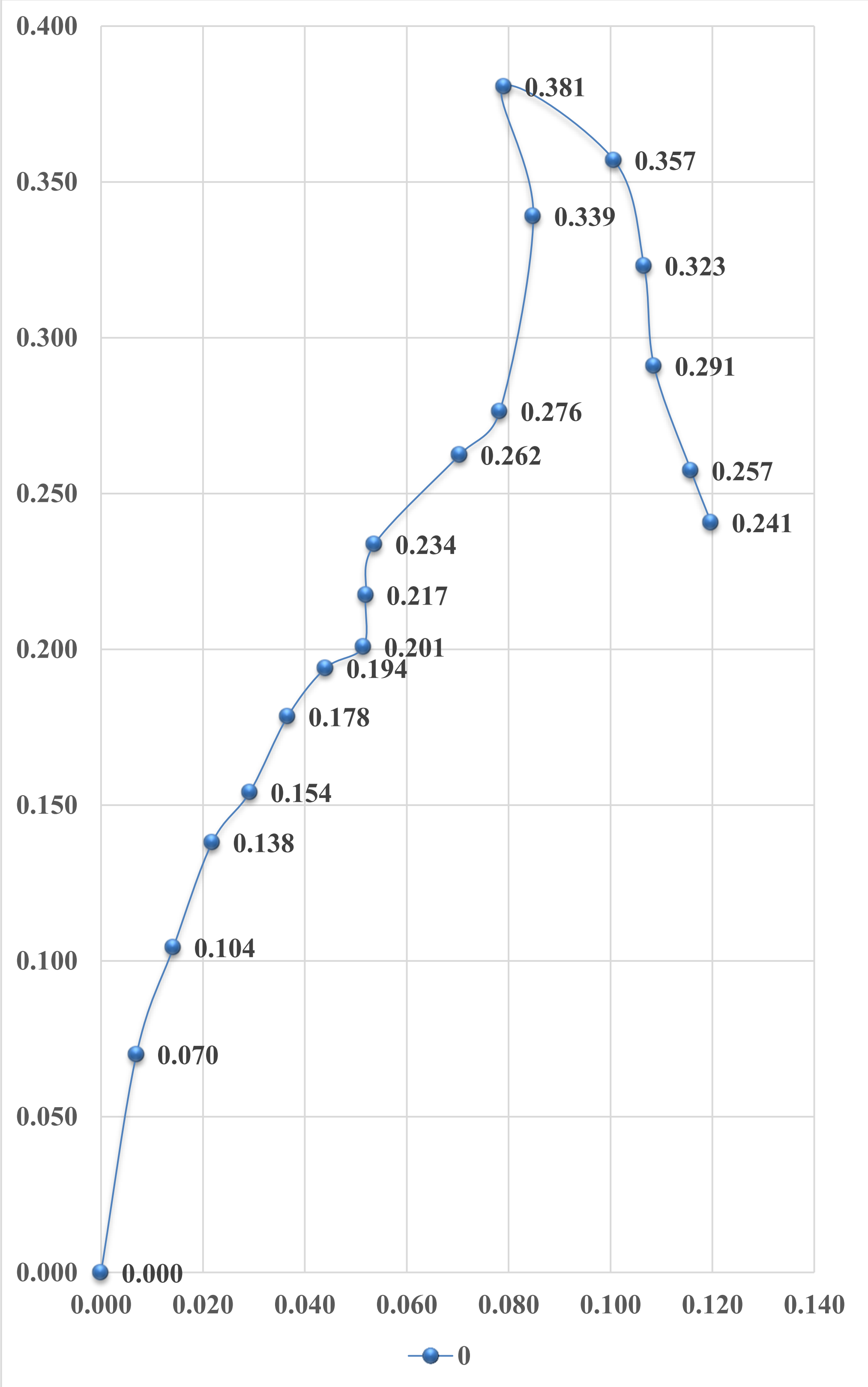
4. UCS Test Graph



Graph 4.10: UCS Test Curve for sample 1



Graph 4.11: UCS Test Curve for sample 2



Graph 4.12: UCS Test Curve for sample 3

COST ANALYSIS:

Calculating the rate of brick powder added to stabilize per km stretch of road

Calculation of Brick Powder Required for 1 km Road Stretch

- Length of road = 1000 m
- Width of road = 3.75 m
- Depth of stabilization = 0.5 m

Volume of Soil

$$\text{Volume} = 1000 \times 3.75 \times 0.5$$

$$V = 1000 \times 3.75 \times 0.5 = 1875\ m^3$$

Brick Powder Requirement

- Brick powder required for 1 m^3 soil = 15.05 kg

$$\text{Total Brick Powder} = 1875 \times 15.05$$

$$W = 1875 \times 15.05 = 28218.75\ kg$$

Total Brick Powder Required

- Total brick powder required for 1 km road stretch = **28,218.75 kg**
- Approximate quantity = **28.22 tonnes**

Estimated Cost

Assuming rate of brick powder = ₹2.5 per kg

$$\text{Cost} = 28218.75 \times 2.5$$

$$C = 28218.75 \times 2.5 = 70546.88$$

Final Cost

- Estimated cost of brick powder for 1 km road stretch = **₹70,547 (Approx.)**

CONCLUSION

It can be clearly concluded that there is a strong need to utilize waste materials obtained from construction and demolition activities in soil stabilization. Due to rapid urbanization, a large quantity of construction and demolition (C&D) waste is generated every year, and improper disposal of this waste leads to serious environmental problems such as land pollution and blockage of drainage systems. Therefore, using this waste in civil engineering applications like soil stabilization is a practical and sustainable solution. In this study, construction and demolition waste in the form of brick powder was used to improve the properties of black cotton soil. The experimental investigation was carried out by mixing different proportions of brick powder such as 6%, 9%, 12%, and 15% with the soil. Various laboratory tests were conducted to evaluate the engineering properties of the stabilized soil, including strength and compaction behavior. The results clearly indicate that the addition of brick powder improves the engineering properties of black cotton soil. As the percentage of brick powder increased, there was a noticeable improvement in soil strength and stability. This is mainly because brick powder acts as a filler material and improves the gradation of soil by reducing void spaces between soil particles. It also enhances the bonding between particles, which results in better compaction and increased load-bearing capacity. Among all the proportions tested, the maximum strength was achieved when 15% of brick powder was mixed with the soil. The results show that increasing the percentage of demolished waste leads to an increase in strength when compared to lower proportions such as 6%, 9%, and 12%. This indicates that 15% is the optimum percentage for achieving the best performance under the given test conditions. The increase in strength at higher percentage is due to better particle interlocking and improved soil structure. The improvement in strength is very important for road construction, as it directly affects the performance of subgrade soil. Higher strength means higher California Bearing Ratio (CBR) values, which helps in reducing pavement thickness and overall construction cost. Therefore, the use of brick powder not only improves soil properties but also makes the construction more economical. In addition to engineering benefits, the use of C&D waste also provides environmental advantages. It reduces the amount of waste disposed in landfills, conserves natural resources, and promotes sustainable construction practices. It also reduces the use of traditional stabilizers like cement and lime, which are costly and have negative environmental impacts.

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