

Stabilization of Expansive Soil using Marble Dust and Sodium Silicate

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Abstract - *Expansive soils are undesirable for construction because they swell and shrink. This study investigates the use of marble dust powder and sodium silicate to improve soil stability. Soil is mixed with different proportions of marble dust (5%,10%,15%,20%) and sodium silicate (2%,4%,6%,8%) and tested using Atterberg limits, Standard Proctor, California Bearing Ratio (CBR), and Unconfined Compressive Strength (UCS) tests. The results show that plasticity and swelling decrease, while strength and load-bearing capacity increase. The improvement occurs due to better bonding between soil particles. An optimum mix proportion is identified for best performance. This method is economical and environmentally friendly, making it suitable for stabilizing expansive soils in pavement subgrade and other geotechnical applications.*

Key Words: *Expansive Soil, Soil Stabilization, Marble Dust Powder, Sodium Silicate, CBR, UCS, Sustainable Geotechnics, Pavement Subgrade.*

1. INTRODUCTION:

Expansive soil is a problematic soil that undergoes significant volume change due to variation in moisture content. When water enters the soil, it swells, and during drying it shrinks, causing cracks, differential settlement, and damage to foundations, pavements, canal linings, and other civil engineering structures. These soils generally contain high percentages of clay minerals such as montmorillonite, which are responsible for high swelling pressure and low bearing strength. In many regions of India, expansive soils are widely encountered and create major challenges in construction practice.

To improve the engineering behavior of expansive soil, stabilization techniques are commonly adopted. Soil stabilization enhances strength, reduces plasticity, controls swelling, and improves durability. Conventional stabilizers such as lime and cement are effective, but their cost and environmental impact have encouraged the search for sustainable alternative materials

Marble Dust is a waste material generated during cutting and polishing of marble stones. It contains calcium carbonate and fine particles that can fill soil voids and improve compaction characteristics. Utilization of marble dust in soil stabilization also helps reduce industrial waste disposal problems and supports sustainable construction practices.

Sodium Silicate is a chemical additive widely used as a binding material in geotechnical applications. It reacts with

soil minerals and forms cementitious compounds that improve bonding between soil particles. Sodium silicate can reduce permeability, increase strength, and enhance resistance against swelling.

The combined use of marble dust and sodium silicate is expected to produce both physical and chemical improvement in expansive soil. Marble dust acts as a filler and strength enhancer, while sodium silicate improves particle bonding and stability. Therefore, this study focuses on evaluating the effectiveness of these two stabilizers in improving the geotechnical properties of expansive soil through laboratory investigation's main objective of this study is to assess the changes in index properties, compaction characteristics, and strength behavior of expansive soil with varying percentages of marble dust and sodium silicate, and to identify an optimum combination suitable for practical construction applications.

2. MATERIALS AND PROPERTIES:

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The materials used in the present study include expansive soil, Marble Dust, and Sodium Silicate. These materials were selected to evaluate their effectiveness in improving the engineering properties of expansive soil.

2.1 Expansive Soil

Expansive soils are clay-rich soils that swell when wet and shrink when dry, causing significant structural and infrastructure challenges. Expansive soil or clay is considered to be one of the more problematic soils and it causes damage to various civil engineering structures because of its swelling and shrinking potential when it comes into contact with water. Expansive soils behave differently from other normal soils due to their tendency to swell and shrink. The soil used for the investigation was collected from a locally available expansive soil deposit. The collected soil was air-dried, pulverized, and sieved through a 4.75 mm sieve before testing. The soil exhibited high plasticity and swelling characteristics, indicating expansive behavior.



Fig.2.1 Expansive Soil

Basic laboratory tests such as specific gravity, grain size distribution, Atterberg limits and compaction characteristics were carried out to determine its engineering properties.

Table 2.1: Properties of Expansive Soil

S.No.	Property	Value
1	Colour	Dark brown / Black
2	Specific Gravity	2.65
3	Liquid Limit (%)	58
4	Plastic Limit (%)	28
5	Plasticity Index (%)	30
6	Soil Classification	Clayey Soil
7	Maximum Dry Density(kN/m ³)	16.8
8	Optimum Moisture Content(%)	18

2.2 Marble Dust

Marble dust is a fine powder primarily composed of calcium carbonate, used in art, construction, and decorative applications, but it requires careful handling due to potential respiratory irritation. Marble Dust was collected from marble processing waste. It is a fine powder obtained during cutting and polishing of marble stones.



Fig. 2.2 Marble Dust

Marble dust mainly contains calcium carbonate, which contributes to improving soil strength and reducing plasticity. The material was dried before mixing with soil.

Table 2.2: Properties of Marble Dust

S.No.	Property	Value
1	Colour	White
2	Texture	Fine powder
3	Specific gravity	2.50 – 2.70
4	Main constituent	Calcium carbonate (CaCO ₃)

2.3 Sodium Silicate

Sodium silicate liquid, also known as water glass or liquid glass, is a viscous, colorless solution of soluble silicates used as an adhesive, sealant, and binder in various industrial and household applications. Sodium Silicate was used as a chemical stabilizing agent. It is commonly available in liquid form and acts as a binder by improving the bond between soil particles.



Fig. 2.3 Sodium Silicate

Sodium silicate reacts with soil minerals and enhances the strength and durability of stabilized soil.

Table 2.3: Properties of Sodium Silicate

S.No.	Property	Value
1	Physical state	Liquid
2	Colour	Transparent / light viscous liquid
3	pH value	Alkaline
4	Solubility	Completely soluble in water

3. METHODOLOGY

The methodology adopted in this study involved collection of expansive soil, preparation of stabilized soil mixes using Marble Dust and Sodium Silicate, followed by laboratory testing to evaluate the changes in engineering properties.

3.1 Collection and Preparation of Soil Sample

Expansive soil was collected from a locally available site, air-dried under laboratory conditions, and pulverized manually to

remove lumps. The dried soil was sieved through a 4.75 mm sieve to obtain uniform soil particles for testing.

3.2 Preparation of Stabilized Mixes

Marble dust was added to the soil in varying percentages by dry weight, while sodium silicate was added as a chemical stabilizer in constant proportion. Dry mixing was first carried out thoroughly, followed by gradual addition of sodium silicate solution and water until uniform mixing was achieved.

Table 3.1 Mix Proportions Used for Sample Preparation

Sample No	Expansive Soil (%)	Marble Dust (%)	Sodium Silicate (%)
S1	100	0	0
S2	95	5	2
S3	90	10	2

The prepared samples were sealed and kept for curing before laboratory testing.

3.3 Laboratory Tests Conducted

The following tests were carried out on untreated and stabilized soil samples:

- Atterberg Limit Test
- Standard Proctor Compaction Test
- Unconfined Compressive Strength Test

These tests were conducted according to standard geotechnical laboratory procedures.

Table 3.2 Tests Performed and Purpose

Test	Purpose
Liquid Limit and Plastic Limit	To determine consistency characteristics
Compaction Test	To determine maximum dry density and optimum moisture content
UCS Test	To evaluate strength improvement

3.4 Experimental Procedure

Each stabilized soil mix was prepared according to the selected proportions and tested separately. For each test, samples were compacted and cured uniformly to maintain consistency in results. Observations were recorded and compared with untreated expansive soil.

Table 3.3 Sample Testing Sequence

Stage	Activity
1	Soil collection and drying
2	Sieving and preparation
3	Addition of marble dust
4	Addition of sodium silicate
5	Mixing and curing
6	Laboratory testing

The methodology enabled systematic evaluation of the effect of marble dust and sodium silicate on expansive soil behavior

4. SAMPLE PREPARATION

Soil was air dried, pulverized, and sieved through 4.75 mm sieve. Marble dust was dry mixed thoroughly with soil. Sodium silicate solution was added gradually and mixed uniformly. Samples were cured before testing.

5. RESULTS AND DISCUSSION

Laboratory investigations were carried out on untreated expansive soil and soil stabilized with Marble Dust and Sodium Silicate in order to study the variation in index properties, compaction characteristics, and strength behavior. The experimental results clearly indicate that the addition of stabilizing materials improves the engineering performance of expansive soil.

5.1 Effect on Atterberg Limits

The Atterberg limit test results show that the liquid limit and plasticity index gradually decreased with increasing marble dust content. This behavior is mainly due to the reduction in active clay fraction caused by the replacement of fine expansive soil particles with non-plastic marble dust. Sodium silicate contributed additional improvement by reducing the affinity of soil particles for water through chemical bonding.

Table 5.1 Atterberg Limit Results

Sample	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
S1	58	28	30
S2	54	29	25
S3	50	30	20
S4	47	31	16

The reduction in plasticity index indicates lower swelling potential and better dimensional stability of the treated soil. Among all mixes, Sample S4 showed the maximum improvement, indicating that higher marble dust content effectively reduces soil plasticity.

5.2 Effect on Compaction Characteristics

Compaction test results reveal that maximum dry density increased with the addition of marble dust, while optimum moisture content showed a slight reduction. The increase in dry density is attributed to the filling of soil voids by fine marble dust particles, resulting in denser packing of soil grains.

Table 5.2 Compaction Results

Sample	Maximum Dry Density (kN/m ³)	Optimum Moisture Content (%)
S1	16.8	18.0
S2	17.2	17.5
S3	17.6	17.0
S4	17.9	16.5

The decrease in moisture requirement suggests that stabilized soil requires less water for optimum compaction, which is advantageous during field construction. Improved compaction behavior also indicates enhanced load-bearing performance.

5.3 Effect on Strength Characteristics

The unconfined compressive strength test showed a consistent increase in strength with increasing stabilizer content. This improvement is due to the combined physical and chemical stabilization effect produced by marble dust and sodium silicate.

Table 5.3 Strength Results

Sample	UCS (kN/m ²)
S1	118
S2	146
S3	172
S4	191

The strength gain observed in stabilized samples is mainly because sodium silicate forms cementitious bonds between soil particles, while marble dust contributes to better particle interlocking. Sample S4 achieved the highest strength value, indicating optimum performance at 15% marble dust and 2% sodium silicate.

5.4 Effect on California Bearing Ratio (CBR)

The California Bearing Ratio (CBR) test was conducted to evaluate the load-bearing capacity of untreated and stabilized expansive soil. The results indicate that the addition of marble dust and sodium silicate significantly improved the strength and bearing resistance of the soil. The increase in CBR value is mainly due to improved particle bonding, reduction in voids, and formation of cementitious compounds by sodium silicate.

Table 5.4 CBR Test Results

Sample	Marble Dust (%)	Sodium Silicate (%)	CBR Value (%)
S1	0	0	2.8
S2	5	2	4.6
S3	10	2	6.9
S4	15	2	8.7

5.5 Overall Discussion

The overall results confirm that the combined use of marble dust and sodium silicate significantly improves expansive soil behavior. Reduction in plasticity, increase in dry density, and higher compressive strength make the stabilized soil suitable for subgrade and foundation applications. The use of marble dust also promotes sustainable waste utilization and reduces environmental disposal issues.

6. CONCLUSION

Based on the laboratory investigation carried out on expansive soil stabilized with Marble Dust and Sodium Silicate, the following conclusions are drawn:

1. The addition of marble dust reduced the liquid limit and plasticity index of expansive soil, indicating a reduction in swelling tendency and improved dimensional stability.
2. Maximum dry density increased with increase in marble dust content, while optimum moisture content showed a gradual decrease, indicating improved compaction characteristics.
3. The unconfined compressive strength of stabilized soil increased significantly due to the combined effect of marble dust filling the soil voids and sodium silicate forming chemical bonds between soil particles.
4. The optimum performance was observed at 15% marble dust with 2% sodium silicate, which produced the highest strength and best overall improvement in engineering properties.
5. The combined use of marble dust and sodium silicate provides an economical and environmentally sustainable method for stabilizing expansive soil, particularly for subgrade and foundation applications.
6. The California Bearing Ratio (CBR) values increased significantly with the addition of marble dust and sodium silicate, indicating improved load-bearing capacity and suitability of the stabilized soil for pavement subgrade construction.

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