

## ***Swelling Characteristics of Stabilized Expansive Soil: Bio-Enzyme, Lime and Micro – Silica***

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### ***Abstract***

*The black cotton soil seems to be most problematic when it comes in contact with water as it exerts high swelling pressure on foundation systems. The increase in swelling pressure can severely damage the structure if not properly controlled. The various methods available for reducing the swelling characteristics of expansive soil are time consuming as well as uneconomical. The proposed study focused on calculating the swelling pressure of expansive soil by performing series of laboratory swell pressure test on locally available black cotton soil treated with bio-enzyme (DZ-2X), lime and micro – silica. The soil samples were prepared at respective optimum water content and cured for 1, 7, 14, 21 and 28 days respectively. The results of soil treated with DZ-2X, lime and micro-silica was compared with untreated soil. The maximum percentage reduction in swelling pressure of expansive soil for 28 days of curing period treated with different combination such as DZ-2X, DZ-2X along with lime, DZ-2X along with micro – silica and DZ-2X along with lime and micro – silica was 37.45 %, 44.54 %, 24.77 % and 55.64 % respectively. It was found that bio-enzyme stabilized soil can effectively reduce swelling pressure of expansive soil when treated alone and along with lime and micro-silica.*

***Keywords:*** *Swelling Pressure, Expansive Soil, DZ-2X, Lime, Micro-Silica.*

## INTRODUCTION

The expansive or swelling soils encounters with volume change with variation in soil water content. However, these expansive soils encountered in arid and semi-arid regions of the world, where annual evaporation exceeds annual precipitation. In countries like India we mostly cover up with expansive soil more than 20 % of the total land area. The increase in volume of soil mass results in high vertical swell pressure which is exerted on the structure. There is great need to control the swelling pressure exerted by expansive soils on foundations as it may affect the overall stability of structure if not properly controlled. Generally, soil stabilization techniques are mostly used to control the swelling pressure of expansive soils which includes soil stabilization using lime, cement, flyash, and other chemicals. In these techniques, uniform mixing of the stabilizers in soil is carried out to improve the strength properties and to reduce the swelling pressure of such soils. In such cases the curing of stabilized soils also help to achieve desirable results. Sometimes mechanical stabilization of soil (without altering chemical properties) includes controlling the compaction behavior of expansive soils. It was also observed that expanded polystyrene (EPS) geofoam can effectively use to reduce the swelling pressure exerted by soil. However, conventional methods used to reduce swelling pressure of soil are uneconomical, time consuming and not environmental friendly. Now a day's use of plant based environmental friendly bio-enzymes to stabilized expansive soils to reduce swelling pressure is found to be more effective over conventional methods. The method proven to be most economical and innovative and can be used worldwide.

## LITERATURE REVIEW

T. A. Khan et al. (2020) had studied the volume change characteristics of clayey soils treated with Terrazyme and Earthzyme (bio-enzymes) with varying dosages and found that considerable percentage reduction in swell pressure when compared with untreated soil. Shinji Hagi et al. (2020) studied the swelling characteristics of expansive soil on high speed railway project area in India by conducting series of laboratory tests on soil samples to identify the degree of expansive and swelling potential of soil. The test results give idea about the type of soil and its severity on stability of structure. Sanjeev Kumar et al. (2021) carried out experimental investigation to study swelling behaviour of clayey soil stabilized with geocell and jute fiber and found that maximum reduction in both swelling pressure and swelling potential of geocell reinforced soil was observed for 0.80 % and 40 mm fiber length.

Kennedy C. Onyelowe et al. (2021) had studied the swelling behaviour of expansive soil treated with quicklime activated rice husk ash, hydrated lime activated rice husk ash, and calcite activated rice husk ash at varying percentages from 1 to 10 % and found that quicklime activated rice husk ash was most effective over others as percentage reduction is maximum in this case. Amin Soltani et al. (2018) has carried out comparative experimental study for swelling potential of a stabilized expansive soil with lime, cement, polymer and fiber reinforcement and found conventional methods more effective in reducing swelling potential over fiber and polymer stabilized soil. Hassan A. M. Abdelkader et al. (2022) studied experimentally geotechnical properties and micro structure of expansive soil stabilized with waste granite dust varying from 0 to 30 % and found that granite dust can be effectively used to improve soil plasticity and to control the swelling behaviour. V. Vasiya and C. Solanki had carried out experimental investigation of soil treated with Terrazyme and found that free swell index of clayey soil can be effectively reduced with the application of Terrazyme. Ganesh S. Ingle (2021) had studied the swelling behaviour of black cotton soil stabilized with rubber tire and investigated the swelling potential of Black cotton soil and it is found to be decreased by 33.33% for the addition of 15% shredded rubber soil as compared to untreated soil. From the available literature it was observed that swelling pressure of expansive soil can be effectively reduced with use of various stabilizing agent. However, conventional methods are found to be uneconomical and time consuming. Therefore, considering the same the proposed work focuses on reducing the swelling pressure of expansive soil treated with environmental friendly material i.e. advanced bio –enzyme (DZ-2X).

## **EXPERIMENTAL INVESTIGATION**

The experimental investigation was carried out by performing series of laboratory constant volume swell pressure tests on both treated and untreated black cotton soil. The results of treated soil samples were plotted and compare with untreated soil. The detailed experimental testing programme along with materials required is as follows.

### **3.1 Materials used in Experimental Testing Programme**

The various materials required for experimental testing program such as Black Cotton soil, bio-enzyme (DZ-2X), lime and micro – Silica was procured and details of the same are as follows:

### 3.1.1 Black Cotton (BC) Soil

The untreated black cotton soil was collected from the Amravati Region of Maharashtra. Initially, soil was allow to air dry and sieve through 4.75 mm IS sieve to get the representative soil sample. The numbers of laboratory tests were carried out on untreated soil samples to classify the soil as IS classification system. Table 1 shows the results of tests carried on untreated soil.

### 3.1.2 DZ-2X (Bio-Enzyme)

The commercially available bio – enzyme (DZ - 2X) is purchased from Dhara Biotech, Sarsa, Gujarat. The physical and chemical properties of DZ - 2X bio-enzyme are as shown in Table

**Table 1: Geotechnical Properties of Untreated Soil**

| Sr. No. | Test                        | Value                    |
|---------|-----------------------------|--------------------------|
| 1       | Liquid Limit                | 62.80 %                  |
|         | Plastic Limit               | 28.50 %                  |
|         | Shrinkage Limit             | 16.80 %                  |
| 2       | Specific Gravity            | 2.68                     |
| 3       | Optimum Water Content (OMC) | 23.5 %                   |
| 4       | Maximum Dry Density (MDD)   | 14.6 kN/m <sup>3</sup>   |
| 5       | Swell Pressure              | 131.03 kN/m <sup>2</sup> |
| 6       | Free Swell Index (FSI)      | 85 %                     |
| 7       | Soil Classification (ISC)   | CH                       |

**Table 2: Physical and Chemical Properties of Bio-Enzyme (DZ – 2X)**

| Sr. No. | Property                | Details                      |
|---------|-------------------------|------------------------------|
| 1       | Colour                  | Light Brown                  |
| 2       | Specific Gravity        | 1.0                          |
| 3       | Boiling Point           | More than 100 <sup>0</sup> C |
| 4       | PH                      | 4.30 – 4.60                  |
| 5       | Non – Ionic Surfactants | 30 – 50 %                    |

### 3.1.3 Lime

The locally available hydraulic lime has been used for proposed research work and the properties of the same are provided in Table 3.

**Table 3: Physical and Chemical Properties of Lime**

| Sr. No. | Property            | Details      |
|---------|---------------------|--------------|
| 1       | Physical Appearance | White Powder |
| 2       | Specific Gravity    | 1.2 – 1.5    |
| 3       | CaO                 | 80 – 90 %    |

### 3.1.4 Micro – Silica (Silica Fumes)

The micro - silica is provided by Nakoda Enterprises, Indore, Madhya Pradesh (Indiamart) was used for present research work. Table 4 shows the properties of micro –silica.

**Table 4: Physical and Chemical Properties of Micro –Silica**

| Sr. No. | Property            | Details                     |
|---------|---------------------|-----------------------------|
| 1       | Physical Appearance | Grey Powder                 |
| 2       | Specific Gravity    | 2.20 – 2.30                 |
| 3       | SiO <sub>2</sub>    | 85 – 90 %                   |
| 4       | Bulk Density        | 375 – 420 Kg/m <sup>3</sup> |

**Table 5: Experimental Testing Programme for Proposed Research Work**

| Sr. No. | Soil Condition           | Dosage of Stabilizer                                  | Test Performed                                                    |
|---------|--------------------------|-------------------------------------------------------|-------------------------------------------------------------------|
| 1       | BC Soil                  | Untreated                                             | Consistency limits, Compaction test, Swell pressure test          |
| 2       | BC Soil + DZ-2X          | 1000 ml per 9.0, 8.0, 7.0, 6.0 and 5.0 m <sup>3</sup> | Compaction test                                                   |
| 3       | BC Soil + DZ-2X          | 1000 ml per 9.0, 8.0, 7.0, 6.0 and 5.0 m <sup>3</sup> | UCS test for 7 days of curing period                              |
| 4       | BC Soil + Lime           | 2, 4, 6, 8 and 10 % (8)                               | UCS test for 7 days of curing period                              |
| 5       | BC Soil + Micro - Silica | 1, 3, 5, 7, 9 and 11 % (7)                            | UCS test for 7 days of curing period                              |
| 6       | Soil + DZ-2X             | Optimum of DZ-2X                                      | Swell pressure test for curing period of 1, 7, 14, 21 and 28 days |
| 7       | Soil + DZ-2X + Lime      | Optimum of DZ-2X and Lime                             | Swell pressure test for curing period of 1, 7, 14, 21 and 28      |

|   |                                      |                                           |                                                                   |
|---|--------------------------------------|-------------------------------------------|-------------------------------------------------------------------|
|   |                                      |                                           | days                                                              |
| 8 | Soil + DZ-2X + Micro – Silica        | Optimum of DZ-2X and Micro – Silica       | Swell pressure test for curing period of 1, 7, 14, 21 and 28 days |
| 9 | Soil + DZ-2X + Lime + Micro – Silica | Optimum of DZ-2X, Lime and Micro – Silica | Swell pressure test for curing period of 1, 7, 14, 21 and 28 days |

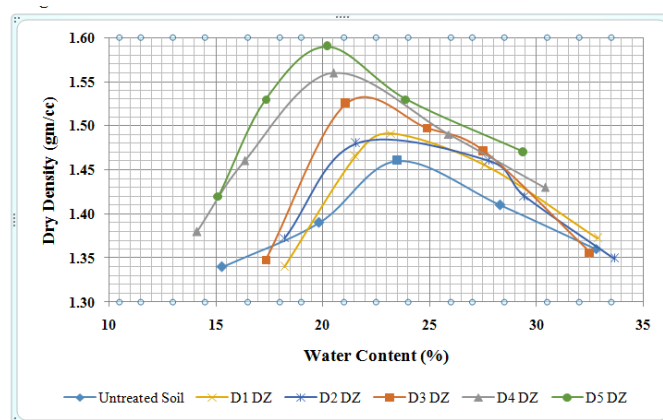
### 3.2 Methodology used in Experimental Testing Programme

The collected black cotton soil was initially treated with varying dosages of DZ-2X (1000 ml per 9.0, 8.0, 7.0, 6.0 and 5.0 m<sup>3</sup>) which was selected based on literature review and data provided by suppliers. The standard proctor compaction test for each dosage of bio-enzyme was performed to determine the variation in compaction characteristics of soil treated with DZ-2X. Further, soil samples were prepared with varying dosages of DZ-2X, lime and micro-silica for curing period of 7 days to perform series of laboratory unconfined compressive strength (UCS) test to get the optimum dosage of each soil stabilizer. The swelling characteristics of treated soil was further checked by performing constant volume swell pressure test for optimum dosage with different combination of stabilizer with varying curing period of 1, 7, 14, 21 and 28 days. Table 5 shows detailed experimental testing programme carried out for proposed research work.

## RESULTS AND DISCUSSIONS

### 4.1 Compaction Characteristics of Bio-Enzyme Stabilized Soil

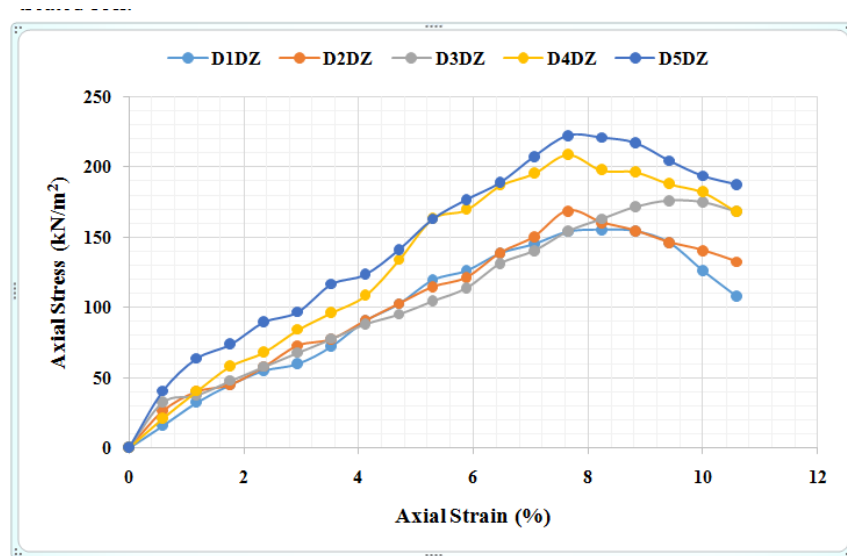
The compaction curves were plotted for each dosage of DZ-2X from D1DZ to D5DZ and found that for enzyme stabilized soil, optimum moisture content decreases and maximum dry density increases. Fig. 1 shows compaction curves for varying dosages of DZ-2X.



**Figure 1: Compaction Curves for Bio-Enzyme Stabilized Soil**

## 2Effect of DZ-2X on Unconfined Compressive Strength of Expansive Soil

The UCS tests were performed on soil treated with varying dosage of DZ- 2X for curing period of 7 days and found that with increase in dosage from D1DZ to D5DZ (1000 ml 1000 ml per 9.0, 8.0, 7.0, 6.0 and 5.0 m<sup>3</sup>), UCS of treated soil increases. However, there was marginal increase in UCS values after D4DZ dosages i.e. (1000 ml per 6 m<sup>3</sup>) thus it was considered as optimum dosage for further testing program. Fig. 2 shows the variation of axial stress to axial strain for 7 days of curing period for DZ-2X treated soil.



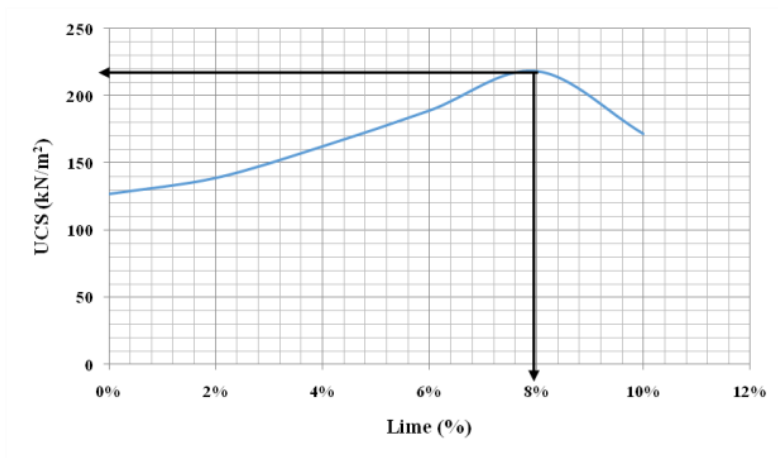
**Figure 2: Stress vs Strain Curves for Bio-Enzyme Stabilized Soil (7 Days Curing Period)**

## 4.3 Effect of Lime on Unconfined Compressive Strength of Expansive Soil

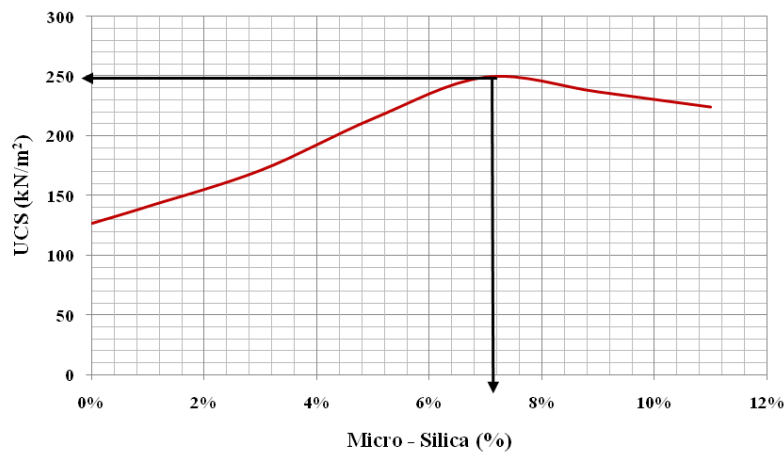
From the results of UCS tests performed on soil treated with lime with varying percentages as 2, 4, 6, 8 and 10 %, it was found that the best results were obtained for 8 % of lime and it was considered as optimum percentage for further testing program. Fig. 3 shows variation of UCS values with respect to varying percentages of lime.

## 4.4 Effect of Micro - Silica on Unconfined Compressive Strength of Expansive Soil

From the results of UCS tests performed on soil treated with micro – silica with varying percentages as 1, 3, 5, 7, 9 and 11 %, it was found that the best results were obtained for 7 % of micro – silica and it was considered as optimum percentage for further testing program. Fig. 4 shows variation of UCS values with respect to varying percentages of micro –silica.

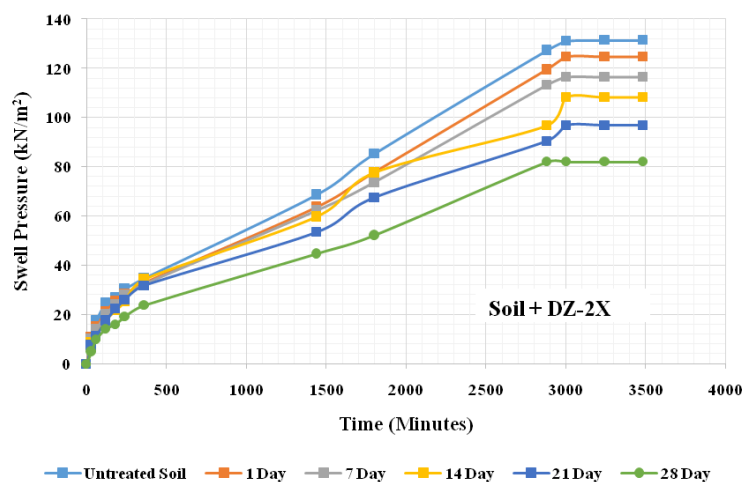


**Figure 3: UCS Values of Lime Stabilized Soil (7 Days Curing Period)**



**Figure 4: UCS Values of Micro – Silica Stabilized Soil (7 Days Curing Period)**

#### 4.5 Effect of Bio - Enzyme (DZ-2X) on Swelling Pressure of Expansive Soil



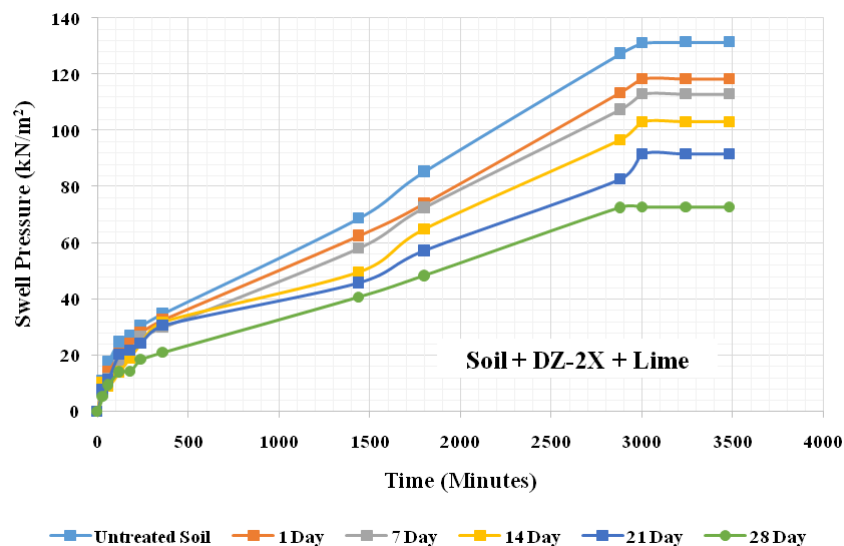
**Figure 5: Swell Pressure Test Results for Bio-Enzyme Stabilized Expansive Soil**

The soil samples were prepared at optimum dosage of DZ - 2X i.e. (1000 ml per 6 m<sup>3</sup>) and tested for constant volume swell pressure test with curing period of 1, 7, 14, 21 and 28 days.

The result shows with addition of optimum dosage of DZ – 2X, swell pressure decreases with increase in curing period. The maximum percentage reduction of 37.45 % in swell pressure of bio-enzyme treated soil was observed for 28 days of curing period. The variation in swell pressure of bio-enzyme treated soil with respect to time is as shown in Fig. 5.

#### 4.6 Effect of Lime on Swelling Pressure of Bio - Enzyme Stabilized Soil

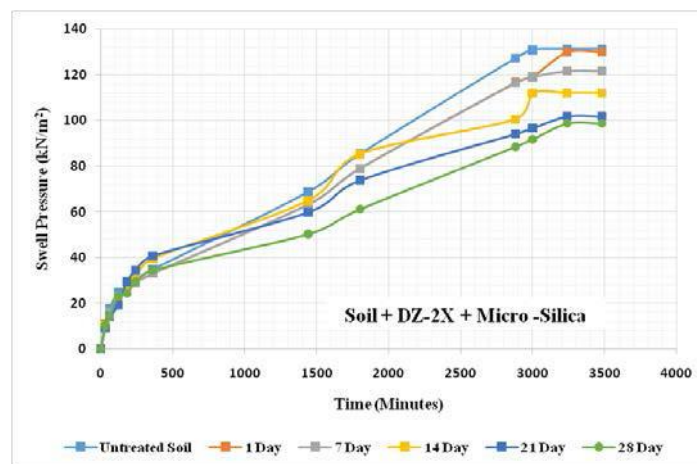
The soil samples were prepared by adding optimum dosage of lime (8%) in DZ-2X stabilized soil and tested for constant volume swell pressure test with curing period of 1, 7, 14, 21 and 28 days. The result shows with addition of optimum dosage of lime into bio-enzyme stabilized soil, swell pressure decreases with increase in curing period. The maximum percentage reduction of 44.54 % in swell pressure of lime treated bio-enzymatic soil was observed for 28 days of curing period. The variation in swell pressure of lime treated bio-enzymatic soil with respect to time is as shown in Fig. 6.



**Figure 6: Swell Pressure Test Results for Lime Treated Bio – Enzymatic Soil**

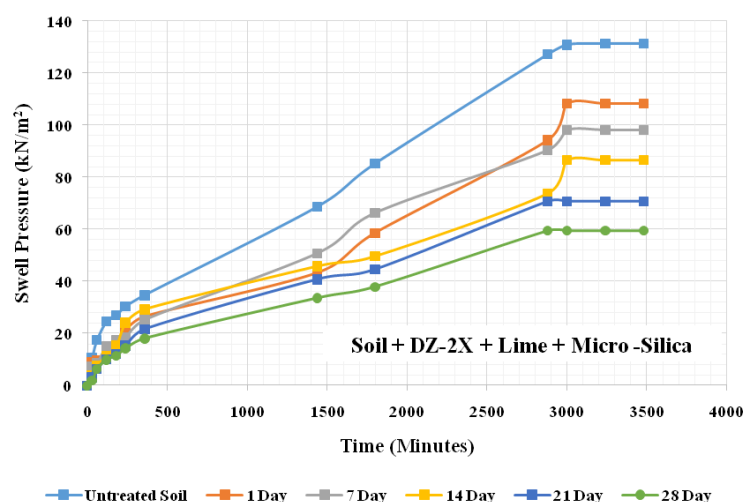
#### 4.7 Effect of Micro - Silica on Swelling Pressure of Bio - Enzyme Stabilized Soil

The soil samples were prepared by adding optimum dosage of micro - silica(7 %) in DZ-2X stabilized soil and tested for constant volume swell pressure test with curing period of 1, 7, 14, 21 and 28 days. The result shows with addition of optimum dosage of micro - silica into bio-enzyme stabilized soil, swell pressure decreases with increase in curing period. The maximum percentage reduction of 24.77 % in swell pressure of micro – silica treated bio-enzymatic soil was observed for 28 days of curing period. The variation in swell pressure of micro - silica treated bio-enzymatic soil with respect to time is as shown in Fig.7.



**Figure 7: Swell Pressure Test Results for Micro - Silica Treated Bio – Enzymatic Soil**

#### 4.8 Effect of Lime and Micro - Silica on Swelling Pressure of Bio - Enzyme Stabilized Soil

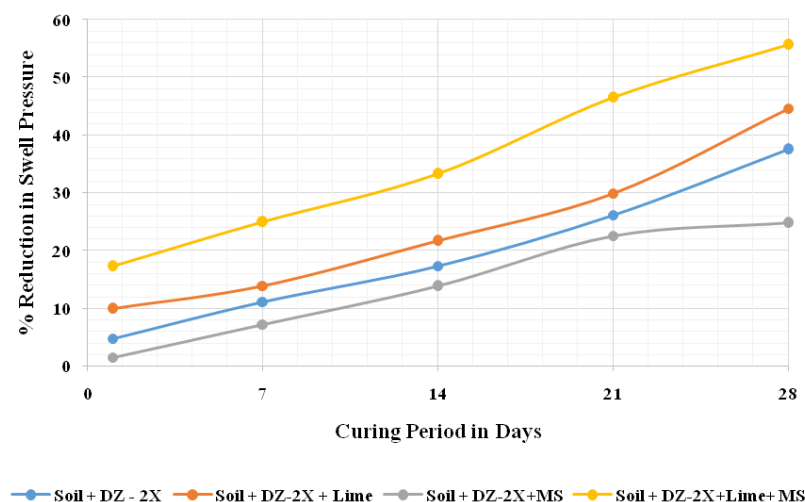


**Figure 8: Swell Pressure Test Results for Lime and Micro - Silica Treated Bio – Enzymatic Soil**

The soil samples were prepared by adding optimum dosage of lime (8 %) and micro - silica (7 %) in bio-enzyme stabilized soil and tested for constant volume swell pressure test with curing period of 1, 7, 14, 21 and 28 days. The result shows with addition of optimum dosage of lime and micro - silica into bio-enzyme stabilized soil, swell pressure decreases with increase in curing period.

The maximum percentage reduction of 55.64 % in swell pressure of lime and micro – silica treated bio-enzymatic soil was observed for 28 days of curing period. The variation in swell pressure of lime and micro - silica treated bio-enzymatic soil with respect to time is as shown in Fig. 8.

From the series of laboratory swell pressure tests performed on black cotton soil treated with optimum dosages of DZ-2X, lime and micro-silica, it was clearly observed that bio-enzyme along with chemical admixtures can effectively reduce the swelling characteristics of expansive soil. Fig. 9 shows the variation in percentage reduction of swell pressure of expansive soil with varying curing period of 1, 7, 14, 21 and 28 days.



**Figure 9: % Reduction in Swell Pressure of Expansive Soil Treated with DZ - 2X, Lime and Micro – Silica**

## CONCLUSIONS

- The black cotton soil can exhibit high degree of expansiveness which can ultimately reduce with the addition of traditional and non- traditional admixtures into the soil.

- The optimum dosage of DZ-2X, lime and micro-silica for treating expansive soil was found to be 1000 ml per 6 m<sup>3</sup>, 8 % and 7 % respectively.
- The swell pressure of black cotton soil treated with bio - enzyme alone can effectively reduce to 81.96 kN/m<sup>2</sup> when compared with untreated value i.e. 131.03 kN/m<sup>2</sup>.
- The swell pressure of bio - enzyme stabilized soil treated with lime can effectively reduce to 72.67 kN/m<sup>2</sup> when compared with untreated value i.e. 131.03 kN/m<sup>2</sup>.
- The swell pressure of bio - enzyme stabilized soil treated with micro - silica can effectively reduce to 98.57 kN/m<sup>2</sup> when compared with untreated value i.e. 131.03 kN/m<sup>2</sup>.
- The swell pressure of bio - enzyme stabilized soil treated with lime and micro - silica can effectively reduce to 58.12 kN/m<sup>2</sup> when compared with untreated value i.e. 131.03 kN/m<sup>2</sup>.
- The maximum reduction in swell pressure of expansive soil for all combination of treatment was found for 28 days of curing period.

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