# ESTABLISHING RELATIONSHIP BETWEEN SWELLING PRESSURE AND FREE SWELL INDEX OF SOILS – A CASE STUDY

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**Abstract**- Civil engineer's important concern is to predict as accurately as possible the stress volume change behavior of soil when subjected to changes in stress environment. Swelling pressure and swelling index test results are compiled and an attempt is made to find out relationship between them.

**Keywords**- Swelling pressure, Swelling index, Swelling potential.

## I. INTRODUCTION

A major concern of the foundation engineer is to predict the stress-volume change behaviour of soil when subjected to changes in stress environment. Geotechnical engineers practicing in such areas are interested in better understanding of relationships between physical and chemical properties of active clay. This paper is based on results of twelve soil samples taken from different soil groups like CH / MH / MI and Cl. Soils selected are predominantly fine grained and clayey / silt inherited with swelling potential. The samples selected have been tested for index and engineering properties. The results and significance of relationship found are presented as major findings of this study.

## II. LITERATURE REIVEW

Holz and Gibbs (1996) have attributed swelling and swelling pressure characteristics of Expansive Soils to the presence of expanding lattice type structures, of Montmorilonite and Illite clay minerals present in clay fraction of soil. According to Van Olphan (1963) the adsorption of water in the first few mono-layers would cause enormous pressures of the order of 20-40 kg/cm2. Holz and Gibbs indicated that i) Colloidal Content, ii) Plasticity Index, iii) Shrinkage Limit can be qualitative indicators of expansive characteristics. Snethan (1984) based on field and laboratory studies on expansive soils of United States of America used Liquid Limit and Plasticity Index as criteria for identifying expansive soils. Shridharan et al (1985) classified the expansive soils using the free swell index as below:

| **Free Swell Index** | **Swelling Potential** |
|---|---|
| 1.5 | Negligible |
| 1.5 to 2 | Slight |
| 2 to 5.0 | Moderate |
| 5 to 10 | High |
| 10 & above | Very high |

Free swell index is defined as the increase in the volume of soil without any external constraints, on submergence in water.

Huang (1987) in his paper on "Identification and Classification of Expansive Soils in China" has attempted an identification criteria for expansive soils of China based on Free Swell Value. Soils having free swell value > 40% are expansive soils.

Zein found that none of the relationships considered yielded acceptable swell percentage and swelling pressure predictions.

Desai and Katti (1987) have expressed that study for behaviour of swelling soils required new research input for evaluating the modified parameters required for swelling and compression.

Thomas M. Petry and J. Clyde Armstrong (1980) have studied relationships and variations in properties of expansive clays. They have put forward that the two measures of swelling potential, i) Swelling Pressure and ii) Percent Free Swell are directly related, so that they may be used to verify and predict the other.

Rao and Smart (1980) studied 10 soil samples having different clay fractions ranging from 87 % to 9 %. They have stated that all the correlations developed seen to have local validity. None of the approaches provide a universally applicable criteria for identifying and categorizing volume change behaviours.

Swelling potential of clay soils have been intensively studied in recent years (Snethan 1975). The results of these studies have shown that the swelling potential depends up on variety of factors including i) Soil structure, ii) Soil Density iii) Mineralogical Soil Composition, iv) Initial Moisture Content, v) Availability and Properties of Water, vi) Time Permitted for Swelling Potential Development and vii) Temperature.

Swelling pressure is the pressure which an expansive soil exerts, if the soil is not allowed to swell or the volume change of the soil is arrested. The two limiting parameters of swelling potential are:

a) Maximum swelling percentage which is the amount of maximum vertical swell (Expressed as percent of initial sample thickness obtained under zero surcharge)
b) Swelling pressure which is the vertical pressure required to prevent volume change of the sample.

If in addition to the two quantities mentioned above and the swell is measured at intermediate pressures, it is possible to draw a curve of pressure versus swell which aids in the prediction of stress – deformation behaviour of expansive soil.

## III. EXPERIMENTAL DETAILS

Three selected samples each from CH, MH, CL and MI groups were tested for selected physical and swelling properties. The procedure of testing was followed as per the relevant Indian Standards. Swelling pressure tests were conducted on oven dry soil samples. Free swell index tests were also conducted on oven dried soil samples, passing through 425micron I.S. sieve. Soil samples were statically remolded at desired dry density and zero moisture content in a consolidation ring of size 60mm diameter and 20mm height.

For classifying the soil samples, the index tests like Mechanical Analysis, Liquid Limit, Plastic Limit and Specific Gravity were conducted as per the Indian Standards. To have data of other parameters, Shrinkage Limit tests were also conducted on four types of selected samples. The results of different tests conducted are summarized in Table 1.

## IV. RESULTS AND DISCUSSION

### 4.1. Purpose

Purpose of the work reported here is to ascertain the co-relation between measured parameters of the samples selected from different type of clayey soils.

### 4.2. Relationship between Free Swell Index and Swelling Pressure

In order to observe how well Percent Swell and Swelling Pressure are related, these properties are plotted and analyzed. The nature of this relationship is shown in Fig. 1 & 2.

Graphs of Free Swell Index versus Swelling Pressure are plotted separately for each soil type (Fig. 1). The nature of curves indicates increase in Swelling Pressure with increase in value of free Swell Index. For high plasticity soils the nature of the curve is upward concave. While for others the nature of the curve is downward concave.

A single graph for all types of soils tested indicates a band of scattered points (Fig. 2). However, it clearly indicates the increasing trends of swelling pressure with increase in the values of free swell index. The scatter of the points may be attributed to the mineralogical composition of the soils.

### 4.3. Relationship between Clay % and Free Swell Index

The swelling / shrinkage phenomena are exhibited by the clay minerals in the soils. As such, relation between Free Swell Index and Clay Percentage in the soil is tried. The plot of the same is shown in Fig. 3.

The points lie in a conical band having the vertex on clay axis at about 15% value. It is clear from the graph that with increase in clay percentage, the free swell index also increases.

The clay minerals Montmorillonite, Kaolinite, Ellite etc, exhibit different swelling characteristics. Therefore, it is felt that, if the soil samples were from a single location (similar mineralogical composition) the conical band would have been narrower.

### 4.4. Relationship between Clay % and Swelling Pressure

The plot of clay % and swelling pressure is shown in Fig. 4. The plot is similar to the one explained in the section 4.3 above and similar inferences can be drawn.

### 4.5. Relationship between Swelling Pressure and Shrinkage limit

As the swelling potential of a soil increases, the shrinkage limit decreases. Therefore, in the plot of swelling pressure versus shrinkage limit (Fig. 5) the slope of the band obtained is expected to be reverse to that one obtained in case of Swelling Pressure versus Free Swell Index (Fig. 2). This conforms to the theory.

## CONCLUSIONS

The physical and swelling properties of soils have been studied and based on these studies the conclusions are as under –

1. The swelling pressure increases as the free swell index increases.
2. For highly plastic soils the nature of curve of Free Swell Index versus Swelling Pressure is upward concave while for low plasticity soils it is downward concave.
3. As the clay percentage in a soil increases, it exhibits more swelling pressure and free swell index.
4. As the shrinkage limit decreases, the swelling pressure increases.

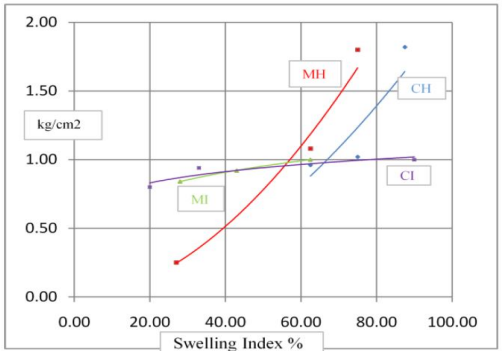


**Fig.1 Graphs of Free Swell Index versus Swelling Pressure**

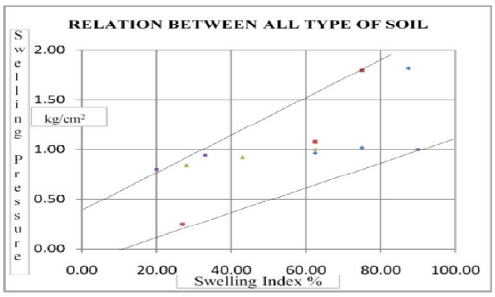


**Fig. 2 Graphs of Free Swell Index versus Swelling Pressure**

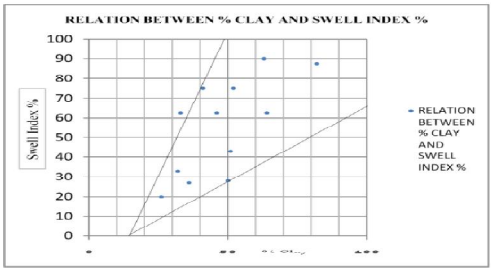


**Fig. 3 Relationship between Clay % and Free Swell Index**

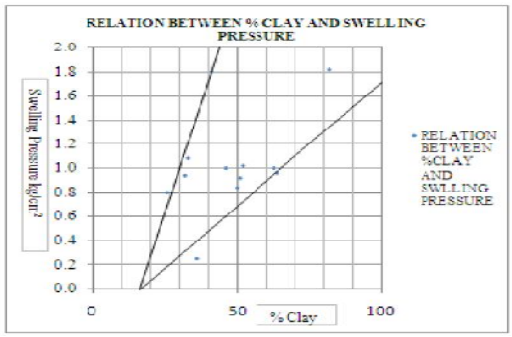


**Fig. 4 Relationship between Clay % and Swelling pressure**

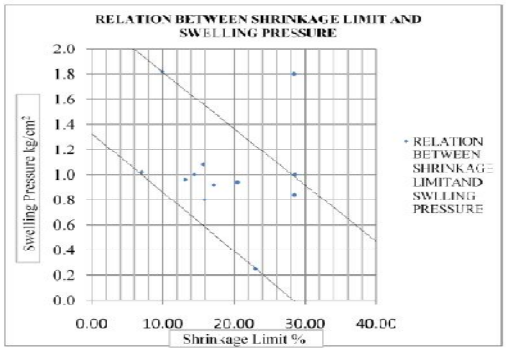


**Fig. 5 Relationship between Swelling Pressure and Shrinkage limit**

## Table 1: Test Results

| Sr. No. | Classification | Name of Project | Mechanical Analysis | | | | Atterbrg's Limit | | | Specific Gravity | Shrinkage limit | Shrinkage ratio | Compaction | | Swelling | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Gravel | Sand | Silt | | | | | | | | | | | |
| | | | 60mm to 4.75mm | 4.75mm to 0.075mm | 0.075mm to 0.002mm | Clay less than 0.002mm | Liquid Limit | Plastic Limit | Plasticity Index | | | | O.M.C. | O.D.D. | Pressure | Index |
| | | | % | % | % | % | % | % | % | % | % | % | % | g/cm$^3$ | kg/cm$^2$ | % |
| 1 | CH | New Panzara, Dhule | 1 | 12 | 32 | 52 | 67 | 29 | 38 | 2.76 | 7.02 | 1.88 | 22.00 | 1.53 | 1.02 | 75.00 |
| 2 | CH | New Panzara, Dhule | 2 | 22 | 12 | 64 | 60 | 30 | 30 | 2.75 | 13.15 | 1.87 | 22.50 | 1.55 | 0.96 | 62.50 |
| 3 | CH | Mhasrul Site, Nashik | 1 | 9 | 8 | 82 | 77 | 31 | 46 | 2.62 | 9.90 | 1.99 | 25.58 | 1.45 | 1.82 | 87.50 |
| 4 | MH | New Panzara, Dhule | 0 | 19 | 45 | 36 | 62 | 41 | 21 | 2.64 | 22.99 | 1.64 | 14.50 | 1.81 | 0.25 | 27.00 |
| 5 | MH | New Panzara, Dhule | 1 | 19 | 47 | 33 | 62 | 39 | 23 | 2.64 | 15.67 | 1.80 | 19.00 | 1.66 | 1.08 | 62.50 |
| 6 | MH | Gad, Ratnagiri | 19 | 19 | 21 | 41 | 52 | 38 | 14 | 2.68 | 28.45 | 1.47 | 27.00 | 1.42 | 1.80 | 75.00 |
| 7 | MI | Gad, Ratnagiri | 12 | 31 | 7 | 50 | 48 | 34 | 14 | 2.67 | 28.50 | 1.44 | 21.50 | 1.52 | 0.84 | 28.00 |
| 8 | MI | Gad, Ratnagiri | 14 | 24 | 14 | 46 | 49 | 36 | 13 | 2.66 | 28.59 | 1.44 | 25.00 | 1.41 | 1.00 | 62.50 |
| 9 | MI | New Panzara, Dhule | 4 | 40 | 5 | 51 | 49 | 29 | 20 | 2.63 | 17.19 | 1.77 | 18.00 | 1.68 | 0.92 | 43.00 |
| 10 | CI | New Panzara, Dhule | 3 | 67 | 4 | 26 | 37 | 23 | 14 | 2.66 | 15.85 | 1.88 | 16.50 | 1.85 | 0.80 | 20.00 |
| 11 | CI | New Panzara, Dhule | 10 | 52 | 6 | 32 | 34 | 23 | 11 | 2.64 | 20.47 | 1.72 | 16.00 | 1.88 | 0.94 | 33.00 |
| 12 | CI | New Panzara, Dhule | 1 | 15 | 21 | 63 | 42 | 25 | 17 | 2.74 | 14.42 | 1.87 | 21.90 | 1.54 | 1.00 | 90.00 |

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