EXPERIMENTAL STUDY ON THE RELATIONSHIP BETWEEN PLASTICITY INDEX AND EXANSION INDEX

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ABSTRACT*: The objective of the test was to develop a relationship between plasticity index and expansion index, so that the value of expansion index can be obtained from plasticity index to get a general idea about the swelling behavior of soils. For this purpose different types of laboratary tests were carried out which were plasticity index, expansion index, percentage swell and swell pressure first without bentonite and after with bentonite. Initially when no bentinite was added in the soil, the soil samples were non expansive but after the addition of bentonite the soil changes from non expansive to very high expansive and expansion index value goes above 30%. From laboratory test results the graphs were plotted between plasticity index and expansion index and between percentage swell and time. Future research studies are recommended to be carried out to develop a relationship between expansion index and percentage swell. Similarly the relationship between expansion index and swell pressure can also be developed.*

Keywords: Expansive soil; Bentonite; Plasticity index; Expansion index; Percentage swell

1. INTRODUCTION

Expansive soils exist all over the world and cause damage to the foundations and associated structures. The most obvious damage due to expansive soils is foundation damage which results due to uplift pressure exerted by these soils as they swell with increase in moisture content **[1 - 2]**. Expansive soils pose serious threat in those regions which are subjected to wet and dry seasons. The annual cycles of wetting and drying causes soil to shrink and swell each year. Thus the arid regions of the country are more susceptible to damage from expansive soils than regions that maintain moist soil conditions throughout the year **[3]**.

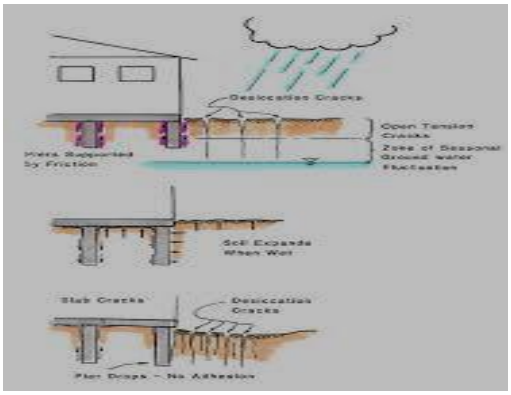

Fig. 1: Damage to home supported on shallow pier

A number of factors are responsible for the expansive behavior of soils which are shrinkage and swelling of clay soils resulting from moisture change, type of clay size particles, drainage, compression of soil strata, pressure of backfill soil, soil softening, weather, vegetation and amount of aging etc. The expansive nature of soil is most obvious near the ground surface where the profile is seasonal and environmental changes.

Mostly the area covered in Pakistan is arid and semi – arid. A survey of local geotechnical literatures and review of geotechnical reports indicated that expansive soils are found in Dera Ismail Khan, Kohat, Khairpur, Chakwal, Dera Ghazi Khan and Sialkot.

Methods to determine the swelling behavior of expansive soils are limited. Both theoretical and empirical approaches are found to be inadequate. A set of semiempiriacal equations was developed for prediction of swellinf behavior of expansive and compacted soils. Both Osmotic and mechanical swelling phenomena were considerd for the development of these equations. The proposed equations give accurate results for swelling potential and swell pressure of a wide variety of soils **[4]**.

The goal of this research was to develop a relationship between plasticity index and expansion index. As plasticity index is a simple test and can be determined by numerical difference between liquid limit and plastic limit, on the other hand expansion index is difficult and time consuming test. By developing a relation between these two parameters an indirect value of expansion index can be determined. Although this value is not accurate yet it gives some idea about expansive behavior of a soil type.

2. IDENTIFICATION OF EXPANSIVE SOILS

The two main factors on the basis of which we can identify the expansive soils are

2.1 Field observations

Expansive soils show cracks during hot weather and with the passage of time due to loss of water, these cracks go a few centimeters into the grounds on the contrary, during rainy seasons when there is plenty of water available, these soils swell. Moisture content near the ground surface in the soils is very close to the liquid limit of the soil, swelling soils have indication like heaving of floors and cracks in boundary walls, the cracks are wide at top and narrow at bottom. Diagonal cracks that develop below windows and above doors are strong indicators of presence of swelling soils

2.2 Analysis of laboratory test data

Swelling soil can also be identifying by index properties values but these values are quite confusing. An expansive soil is suspected to occur if following of the factors are satisfied.

Table 1: Identification of swelling soils

liquid limit	>50%
plasticity index	>30%
shrinkage limit	<10%
free swell	>30%
Black or Blackish grey or grey color	

3. SCOPE OF TEST

This test method covers the determination of expansion potential of disturbed and undisturbed soil samples. This expansion potential will help in practical engineering applications using an index parameter. The values stated in SI units are to be regarded as the standard. The values stated in inch-pound units are approximate. All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D 6026. The method used to specify how data are collected, calculated, or recorded in this standard is not directly related to the accuracy to which the data can be applied in design or other uses, or both. How one applies the results obtained using this standard is beyond its scope. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

4. EXPERIMENTAL PROGRAM

4.1 Collection of soil samples

For the purpose of this research study, undisturbed and disturbed soil samples were collected from Dera Ghazi Khan and Chakwal regions. The reason is that soils reported in these regions are expansive in nature. Upon addition of water there is significant increase in the volume of soil samples. In the field, such soils can be easily recognized in the dry season by the deep cracks, in roughly polygonal patterns, in the ground surface (see Fig. 2). The zone of seasonal moisture content fluctuation can extend from three to forty feet deep (see Fig. 3). This creates cyclic shrink/swell behavior in the upper portion of the soil column, and cracks can extend to much greater depths than imagined by most engineers.

Fig. 2: Polygonal pattern of surface cracks in the dry season.

Fig. 3: This crack is at least 32 inches deep. The yardstick was easily inserted to this depth; narrower, less straight cracks may extend much deeper.

4.2 Addition of bentonite

In order to check the expansive behavior of both type of soils collected from two different regions, different tests such as moisture content, liquid limit and plastic limit tests were performed first with out addition of bentonite and then after addition of different percentages of bentonite. Significant increase in values were reported upon addition of bentonite.

5. Test Performed

In order to check properties of both soil samples different labortary tests were performed, which include liquid limit, plastic limit, percentage swell and swell pressure and expansion index tests. All tests were performed first without addition of bentonite and then after addition of different percentages of bentonite. The objective of all these test tests was to know the swelling behavior of soils and to develop a relationship between plasticity index and expansion index. Ranges of plasticity index give some indication of amount of swelling and shrinkage. On the basis of plasticity index values soils san be classified into different groups. Soils with a high PI tend to be clay, those with a lower PI tend to be silt, and those with a PI of 0 (non-plastic) tend to have little or no silt or clay. Table 2 indcates different ranges of plasticity index.

Table 2: Range of plasticity Index

Non Plastic	0
Slightly Plastic	1 – 5
Low Plastic	5 – 10
Medium Plastic	10 – 20
High Plastic	20 – 40

6. Expansion index Test (ASTM D4829)

Expansion index test is an indication of swelling potential of soil. This test is not used to duplicate any particular field conditions such as soil density, water content, loading, inplace soil structure etc. Consistent test conditions are necessary for this test so that direct correlations can be made between different types of data. Table 3 shows the expansion potential of different types of soils based upon range of Expansion index data.

TABLE 3 Classification of Potential Expansion of Soils Using EI

Expansion Potential	Expansion Index (EI)
Very Low	0 – 20
Low	21 – 50
Medium	51 – 90
High	91 – 130
Very High	>130

7. RESULTS AND DISCUSSION

7.1 Plasticity index and Expansion index Calculation

For the calculation of plasticity index, both undisturbed and disturbed soil samples were undergone through liquid limit and plastic limit tests first with out bentonite and then after addition of bentonite. Tables 3 & 4 shows the calculation of plastic limits, liquid limts, plasticity index and expansion index of both soils.

TABLE 4. CALCULATION OF PLASTICITY INDEX AND EXPANSION INDEX (DERA GHAZI KHAN SOIL)

PL	LL	PI	EI = 1.8 x PI
DERA GHAZI KHAN			
WITHOUT BENTONITE			
18.7	40	21	33.6
WITH 10% BETONITE			
32	54	22	35.2
WITH 20% BENTONITE			
25	62	37	59.2
WITH 30% BENTONITE			
64	112	48	76.8
WITH 40% BENTONITE			
68.69	118	52	83.2
WITH 50% BENTONITE			
47	104	57	91.2
WITH 60% BENTONITE			
57	110	59	94.4

TABLE 5. CALCULATION OF PLASTICITY INDEX AND EXPANSION INDEX (CHAKWAL SOIL)

PL	LL	PI	EI = 1.8 x PI
CHAKWAL KHAN			
WITHOUT BENTONITE			
23	38	15	27
WITH 10% BETONITE			
25	41	16	28.8
WITH 20% BENTONITE			
25	47	18	32.4
WITH 30% BENTONITE			
34	80	44	79.2
WITH 40% BENTONITE			
43	92	49	88.2
WITH 50% BENTONITE			
52	105	53	95.4
WITH 60% BENTONITE			
69	124	55	99

7.2 *Graphs (Expension index v/s Plasticity index)*

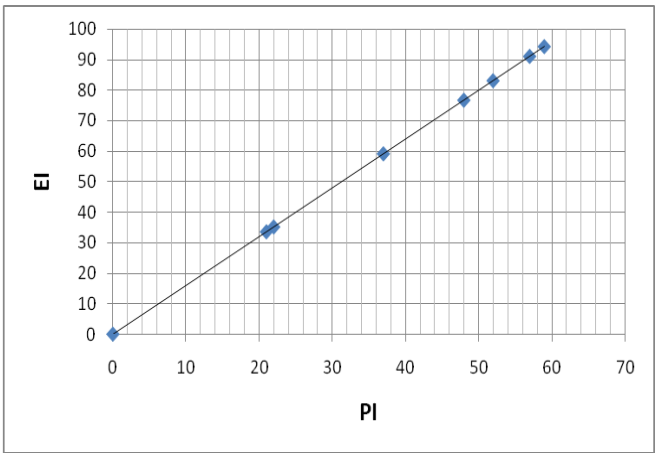

Fig 3: Expension index v/s Plasticity index (Dera Ghazi Khan Soil)

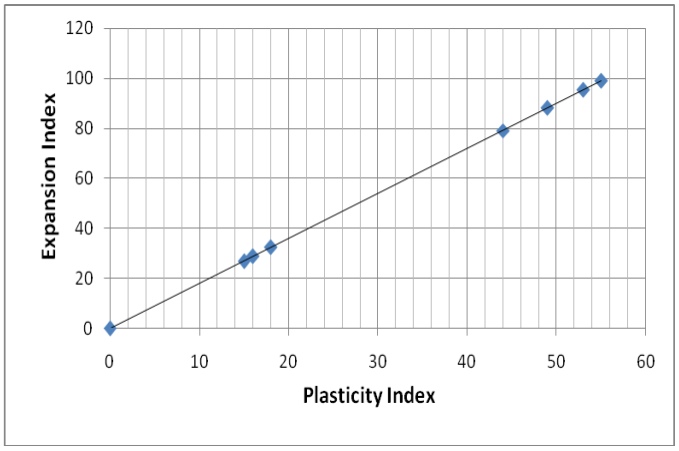

Fig 4: Expension index v/s Plasticity index (Chakwal Soil)

8. CONCLUSIONS

The main focus of our study is to develop the relation between plasticity index and expansion index and to see the swelling behavior of two soils (Dera Ghazi khan, Chakwal). The Experiments show that Expansion index is 1.8 times plasticity index. The effect of bentonite addition in two soil samples to check increase in the value of plasticity index , expansion index and percentage swell and swell pressure was also observed . It was seen that with increase in the amount of bentonite from 10% to 60% the behavior of soil changes from low plastic to high plastic and low expansive to high expansive. Similarly the values of percentage swells and swell pressure also increased by increasing bentonite.

- The values of plasticity index are 21% and 15% for D G Khan and Chakwal soils respectively when no bentonite was added and both soils show medium plasticity .
- By adding 10% of bentonite a slight increase in the values of plasticity index occurs but still both soils show medium plastic behavior
- By increasing bentonite to 20 % D G Khan soil becomes high plastic its value is 37 % (20 to 40%) while Chakwal soil remain medium plastic its value is 18%
- When bentonite content increases to 60 % both soils become very high plastic.
- Similarly the values of percentage swell swell pressure and expansion index also increase to very high values showing the expansiion behavior of soil.
- The value of percentage swell changes from 1.67 % to 73% by increasing bentonite content from 0 to 60 % for D G Khan soil, while the same values change 1.2 to 65 % for chakwal soil.
- The values of swell pressure increase from 5kpa to 70 kpa for D G Khan soil and 3.5kpa to 65 kpa for Chakwal soil by increasing bentonite content from 0 to 60 %.

- Similarly, due to increase in the bentonite content from 0 to 60 % both soils show highly expansive behavior.

8. RECOMMENDATIONS

- As expansion index is very difficult and time consuming so by using the relationship between plasticity index and expansion index value of expansion index can also be found out.
- The relationship between expansion index and %age swell should also be developed. Similarly the relationship between expansion index and swell pressure should also be developed by performing testing on expansive soils collected from various areas of Pakistan.

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