Testing and Quantifying the Modified Expansive Index Changes for a Polymer Treated Field CH Soil with High Plasticity Index

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Abstract: In this study a field CH soil with a liquid limit, plasticity index and natural moisture content of 72%, 43.5% and 27% respectively was treated with polymer and tested for free expansion compacted at a moisture content dry of optimum. Based on free swelling test, the expansion index of the untreated soil compacted at dry of optimum, was characterized as highly expansive soil (ASTM D 4289). Also the changes in the modified expansion index (MEI) with time were modelled using the Vipulanandan model. With the polymer treated CH soil the MEI reduced from 14.7% (untreated soil) to 2.0% (polymer treated soil), 86% reduction in the modified expansion index and characterizing the polymer treated soil as very low expansive soil.

1. Introduction

Expansive soils cover one-fourth of the surface area of the United States and are found in every state (Jones et al., 1987). Compared to other natural disasters and hazardous this is probably the least publicized of the natural hazards. The expansive soils inflict at least $2.3 billion in damages to houses, buildings, roads, and pipelines. It indicated that damages from expansive soils are more than twice that which is caused by floods, tornadoes, and earthquakes (Jones et al., 1987).

According to the National Science Foundation, expansive soil ties with hurricanes for second place among America's most destructive natural hazards in terms of dollar loss to buildings. Economic loss due to expansive soil is currently only surpassed by hurricane Harvey and Irma (year 2017 hurricanes) damages. The building losses from expansive soils will increase to over 4.5 billion dollars per year by the end of the twentieth century. The annual costs of damage to buildings, structures, and roads caused by expansive soils are estimated to be approximately $0.15 billion and $1 billion in the U.K. and U.S. respectively.

Expansive soils cause problems in certain areas with repeated periods of rainfalls and droughts. Expansion of clays in the presence of moisture is a problem that causes extensive damages to physical infrastructure, such as dams, irrigation canals and roads (Inyang et al., 2007). Wet and dry cycles in clayey soils would cause volumetric changes which may result in considerable damage to the surrounding structures. To overcome the swelling problems caused by expansive soils, many innovative techniques such as stabilization by chemical additives, pre-wetting, squeezing control, overloading, and moisture control have been suggested (Al-Rawas et al., 2005).

Distress caused to the infrastructure when constructed on expansive soils is significant and is well recognized by the research community (Pedarla et al., 2011). The swelling properties of clayey soil are dependent on its mineralogical composition, the volume fractions of such minerals, absorbed cations and the physicochemical environment to which the soil is exposed. Stabilization of these problematic soils by employing a suitable additive is one of the preferred techniques of dealing with such soils (Inyang et al., 2007; Vipulanandan et al. 2016).

As such, a variety of additives, which are being employed to stabilize the expansive soils for some time, can broadly be classified into three main categories: cementitious, non-cementitious and chemical additives. Many studies have shown that addition of lime increases optimum water content, shrinkage limit, shear strength, and reduces maximum dry density, swelling potential, liquid limit, and plasticity index of the soil (Bell et al., 1996; Al-Rawas et al., 2005). Although, lime stabilization is well suited for almost any type of expansive soil and is economically available additive, constructability issues and long-term durability issues often make its usage not feasible for all conditions. In addition, effective lime-soil reaction demands elevated temperature that is greater than 40^{o}F. Below this temperature, lime usually remains in a dormant state and does not initiate the reaction (Reddy et al., 2015).

A new method of stabilization has been developed using water soluble polymer (Mohammed and Vipulanandan 2014) which was found to be effective, economical and time-saving. Electrical resistivity could be established as an indicator for quality control and characterizing the polymer, soils and the polymer-treated soils.

2. Objectives

Overall object was to polymer treat and test a highly expansive field CH soil. Also model the free expansion with time for the untreated and polymer treated soil. The soil was characterized and also treated with polymer and then tested for free expansion

3. Materials and Method

The moist field soil was treated with 4.5% polymer (based on the weight of solids in the soil). The expansion index test for the field soil was carried in accordance with ASTM D4829-11. Three samples for the expansion index test, were prepared with a moisture content wet of OMC, dry of OMC and at OMC, for the treated and untreated soils. To perform this test, sample with natural field density was used in the consolidation ring and the excess soil was carved off from the ring. A seating pressure of 1 psi was used and the dial gage reading was made to be zero. The readings of the dial gage were taken with time as the soil underwent swelling. Initial readings were taken with shorter time intervals for the first 24 hours and later one reading was taken for every 24 hours until the dial gage reading showed no appreciable change.

In the case of samples which were proposed to be wet of OMC and dry of OMC, 1 lb of the field soil was taken and dried in the oven at 110℃ for 24 hours. The dried soil was used to perform the expansion index test for the proposed set of tests and the density used to mold the specimen was proctor density. The expansion index (EI) according to ASTM D 4829-11, is defined as (Eqn.1);

$$\boldsymbol{EI} = \frac{\boldsymbol{\Delta H}}{\boldsymbol{H_1}} . 1000 \,, \tag{1}$$

where, H_1 – initial height of the specimen (in or mm)

ΔH – change in height of the specimen (in or mm) and

Classification of soils according to the expansion index is detailed in Table 3.7.

Table 1. Classification of expansive soils based on expansion index (ASTM D 4829)

Classification of Expansion of soils	
EI	Potential
0-20	Very low
21-50	Low
51-90	Medium
91-130	High
> 130	Very High

The tests were performed three moisture contents (wet of OMC, dry of OMC and at OMC) and at least three samples were tested under each condition. Later the polymer treated soil was tested only at a moisture content dry of OMC (for 4 field soils). The polymer dosage used was 4.5% pure polymer based on the weight of dry solids. For a better interpretation the scale of expansive index was brought down to a maximum limit of 100 replacing the original scale of 1000. The new scale is termed as 'Modified Expansion Index (MEI)'.

4. Results and Discussion

During the testing higher percentage expansion of the soil was observed at lower moisture content (dry of OMC) and it reduced when the compacted soil moisture content was increased (Fig. 1). The field soils showed a high expansion in the first 48 hours followed by a reduction in the rate of swelling. The expanding (swelling) behavior of soils, before and after treatment was best represented by the Vipulanandan correlation model (Vipulanandan et al. 2014 and 2016) and the relationship is represented as follows:

$$MEI = \frac{t}{L + M.t} \quad , \qquad (2)$$

where, MEI = modified expansion index (MEI) at time t (hr)
t = time (hr)
L, M = model parameters (hr/%)

The variation of MEI with time for soil compacted at different moisture contents are shown in Fig. 1. The soil with a moisture content dry of optimum had a MEI of 14.7 %. The model parameters are summarized in Table 1. The model predictions are compared to the experimental results in Fig. 1.

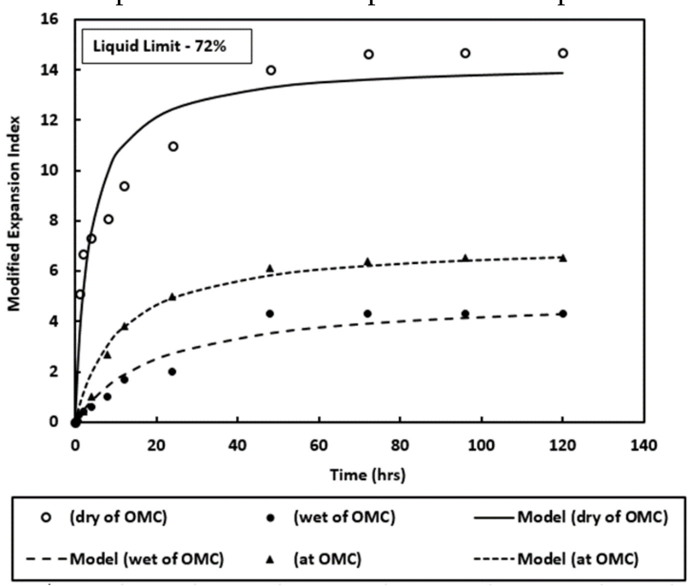

Figure 1. Variation of Modified Expansion Index with time for soils compacted at different moisture contents.

Table 2. Model parameters for the field soil different moisture content

Parameter	Dry of OMC	OMC	Wet of OMC
L_5	0.25	1.50	4.00
M_5	0.07	0.14	0.20
R^2	0.924	0.975	0.953
RMSE	1.251	0.417	0.400

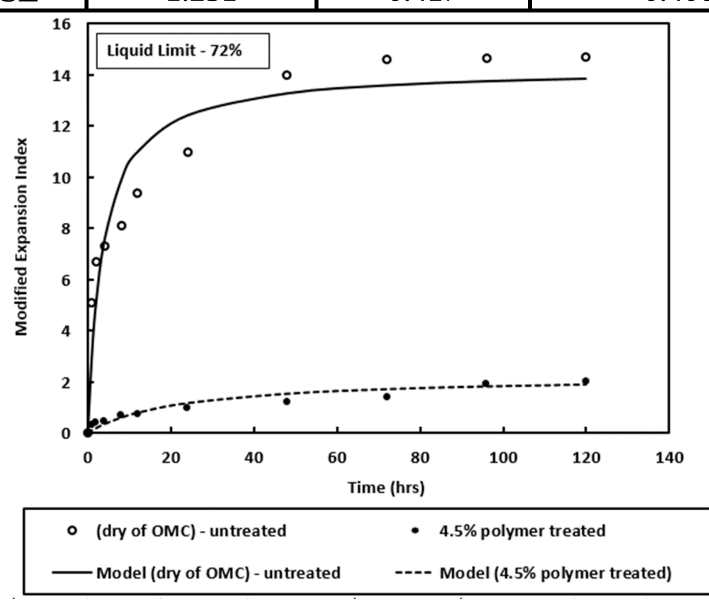

Figure 2. Modified Expansion Index after 4.5% pure polymer treatment.

Table 3. Model parameters before and after treatment of the field soil

Parameter	Dry of OMC	4.5% treated (Dry of OMC)
L_6	0.25	10.00
M_6	0.07	0.45
R^2	0.924	0.908
RMSE	1.251	0.195

Although the polymer treated soils will be compacted wet of optimum moisture contents during construction, over the service life the soil may lose the moisture due to the hot weather conditions in Houston. Hence it is important to evaluate the performance of polymer treated soil at a moisture content dry of optimum. The behavior of 4.5% polymer treated soil was tested with dry of optimum moisture content is showing substantially reduced MEI (Fig. 2). With the polymer treated soil the MEI reduced from 14.7% to 2.0%, 86% reduction in the modified expansion index. Also the model predictions (Eqn. 1) are compared to the experimental results in Fig. 2 using the model parameters summarized in Table 2.

5. Conclusions

After 4.5% pure polymer treatment, the maximum value of modified expansion index (MEI) of the for CH soil (plasticity index of 43.5%) reduced from 14.7% to 2%, a 86% reduction in the expansion index and making the polymer treated soil as very low expansive soil.

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7. References

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