Effect of Placement Moisture Content on Swelling-Shrinkage Behaviour of Expansive Soil

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Abstract: Rapidly increasing infrastructural activities across the world demands suitable land for founding the substructure. The coming era shall face trouble both with the scarcity of suitable land as well as challenges to deal with the existence of problematic soils at the site. Volumetric changes in the form of swelling and shrinkage with moisture variation are most commonly observed in expansive soils. Large damage/distress to the infrastructure founded on this type soils has been observed. Understanding of swelling and shrinkage of expansive soils with moisture variation is of primary importance. This paper presents an experimental study on determination of swelling-shrinkage and its variation with time and placement moisture content. An experimental setup has been designed and developed to accommodate three soil samples of 100 mm diameter and 100 mm height and swelling pressure measurement through constant volume method. Soils were procured from Delhi-Mumbai Expressway site near Ankleshwar, Gujarat, which was later aired dried and pulverized. Soil samples were prepared at three different preparation moisture content (i) at optimum moisture content (ii) 5% on the dry side of optimum and (iii) 5% on the wet-side of optimum. Experimental findings revealed maximum swelling pressure generation within first 24 hours after commencement of the experiment. Swelling pressures of 41.8 kPa, 59.44 kPa and 23.22 kPa were observed for specimen prepared at optimum moisture content, at 5% dry side of optimum and 5% wet side of optimum, respectively. While swelling pressure found to increase till seven days, though at a lower rate and observed swelling pressure values were 55.73 kPa, 83.6 kPa and 37.25 kPa for specimen prepared at optimum moisture content, at 5% dry side of optimum and 5% wet side of optimum, respectively. The % shrinkage area were found as 22 %, 33.8% and 15.2% for the samples prepared at OMC, WSO (OMC+5%) and DSO (OMC-5%) respectively.

Keywords: Expansive Soil, Swelling Pressure, Moisture Content, Experimental Study

1 Introduction

Expansive soil undergoes significant volume change in the form of swelling or shrinkage. The change in moisture content and temperature causes volumetric deformation in the soil with time [1]. Expansive soils are mainly found in arid and semi-arid region of world. The amount of damages caused by such type of soil is alarming such as damages to road, underground utilities, building. The factors

affecting the swelling/shrinkage behaviour of expansive soil includes moisture content, clay mineralogy, dry density, index properties, pore fluid, time. The negative electric charges on the surface of clay minerals, strength of interlayer bonding and cation exchange capacity all contribute to the swelling potential of expansive soil. According to previous studies highest value of liquid limit and shrinkage limit belong to montmorillonite (clay mineral) while this group possess lowest shrinkage limit in the soil [4]. In a swelling type of soil two different processes take place when a swelling soil dries or get saturated. During drying, soil decreases its volume by shrinkage and desiccation cracks appear because of internal stresses in the shrunken and dried soil mass [3]. As a result of shrinkage, soil decreases its height by subsidence. On the other hand during wetting the soil increases its volume by swelling, the cracks are closed and soil level rises [2; 5; 6].

2 Problem Description

Literature review highlighted the fact that very limited studies were performed to understand swelling and shrinkage behaviour of expansive soil and their variation with change in temperature and moisture content. Further, the variation in swelling and shrinkage characteristics of soil with time were not clear. Though a number of studies related to shrinkage behaviour of expansive soil were conducted, most of them were performed on the soil prepared at wet side of optimum and study related to soil sample prepared at dry side of optimum and optimum moisture content is sparse. Hence this study is aimed at evaluating effect of placement moisture content and time on both swelling and shrinkage behavior of expansive soils.

3 Laboratory Scale Modeling

The soil used in this study was procured from Delhi – Mumbai Expressway site near Ankleshwar city. The properties of soil are given below in Table 1.

Table 1 Summary of soil properties used in experimental study

Property	**Value**
Specific gravity	2.51
Liquid limit	76.12 %
Plastic limit	37.26 %
Shrinkage limit	12.93%
Optimum moisture content	25.81%
Maximum dry density	1.5 g/cm^3

As per Unified Soil Classification System the soil was classified as CH type. Experimental investigation was carried out to observe swelling phenomenon in expansive soil through laboratory scale model setup. The schematic diagram is shown in Fig. 1. The soil sample was compacted in a mould of size 18 cm x 10 cm having porous medium at both top and bottom side and then the mould containing soil sample was placed in a 25 cm high cylindrical container of 25 cm diameter containing water to full height. Above the top porous plate, loading pad was placed and a proving ring was attached with it to monitor swelling pressure variation with time. Swelling pressure was monitored up to 7 days after placing the mould assembly in to the cylindrical container.

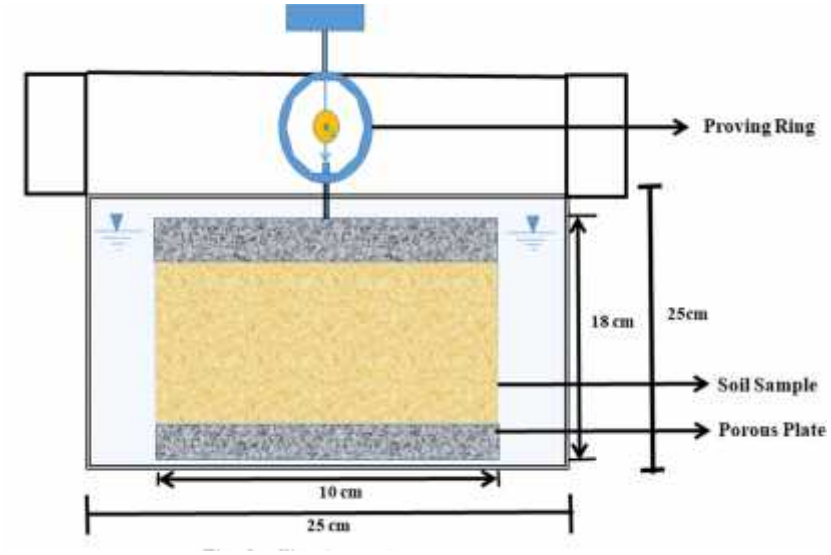


Fig. 1. Swelling apparatus model.

Tests were performed by preparing soil samples at (i) optimum moisture content (OMC) (ii) moisture content 5% dry side of OMC and (iii) moisture content 5% wet side of OMC. Experimental findings revealed maximum swelling pressure generation within first 24 hours after commencement of the experiment. Swelling pressures of 41.8 kPa, 59.44 kPa and 23.22 kPa were observed for specimen prepared at optimum moisture content, at 5% dry side of optimum and 5% wet side of optimum, respectively. While swelling pressure found to increase till seven days, though at a lower rate and observed swelling pressure values were 55.73 kPa, 83.6 kPa and 37.25 kPa for specimen prepared at optimum moisture content, at 5% dry side of optimum and 5% wet side of optimum, respectively.

Fig. 2. Swelling test on soil using apparatus

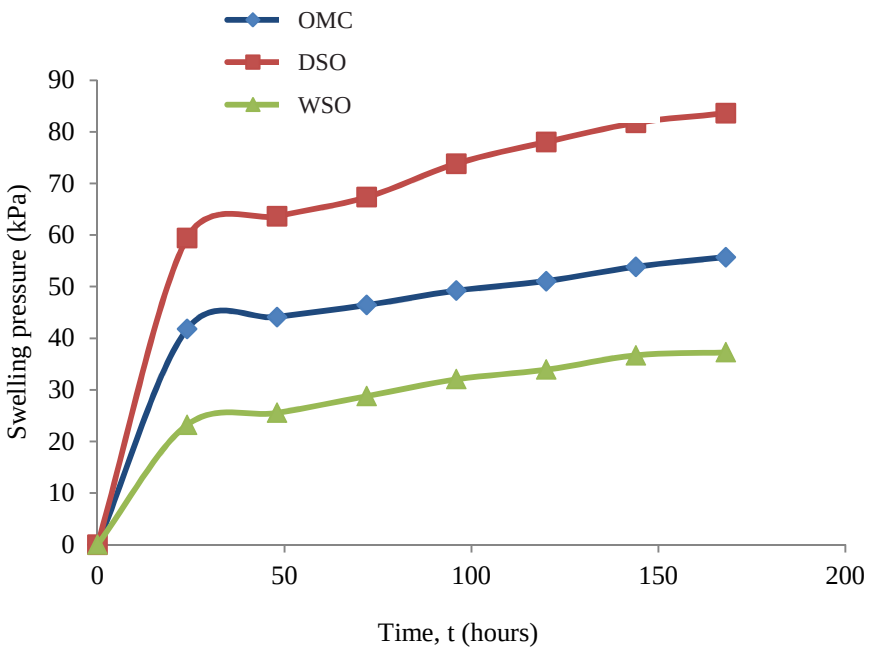


Fig. 3. Variation of swelling pressure with time.

4 Image Analysis Techniques

The process of conversion of raw image into an improved image to obtain the meaningful data is known as Image Processing. Digital camera was used to capture images of soil sample at different time interval and further image processing. Image processing involves converting the initially captured RGB image into grey scale image and then binary image is obtained by thresholding the grey scale image.

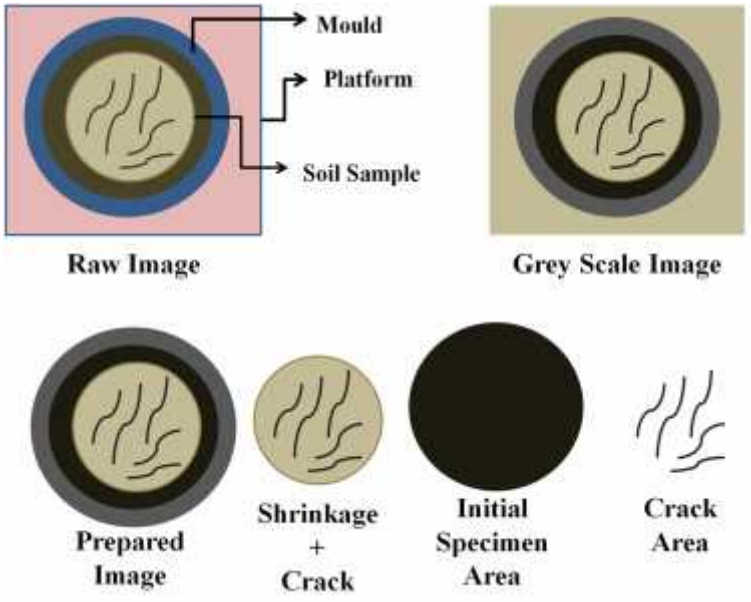


Fig. 4. Various steps involved during image processing.

The steps involved during image processing are mentioned below:

(a) Preparation of raw image:

During preparation of raw image, image enhancement is done by increasing contrast, sharpness and adjusting brightness, saturation and color. It can further be changed into binary images for edge separation.

(b) Grey scale processing:

The picture taken by camera is an RGB (Red green Blue) image. In ImageJ software “circular crop” option can be used to crop any circular area depending upon shape and size of mould. Preparation of image consists of selecting the inner circular area of mould and cropping the outer area to get a centered RGB image with white/black background. This image is then converted to 8-bit grey-scale image by selecting option “Image-type-8 bit”.

(c) Image segmentation:

Image segmentation is done to separate the crack and shrinkage area from intact soil. It is done by thresholding the grey scale image with a fixed threshold value. In ImageJ it can be done by going to the option Image-Adjust-Threshold**.**

(d) Determination of shrinkage area:

The shrinkage area (%) can be determined by the equation given below:

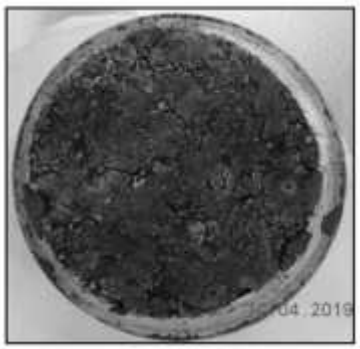
$$\% \ SA \ = \left(\frac{S_a}{I_{sa}} \right) \times 100 \qquad (1)$$

SA (%) = Shrinkage area (square pixel);

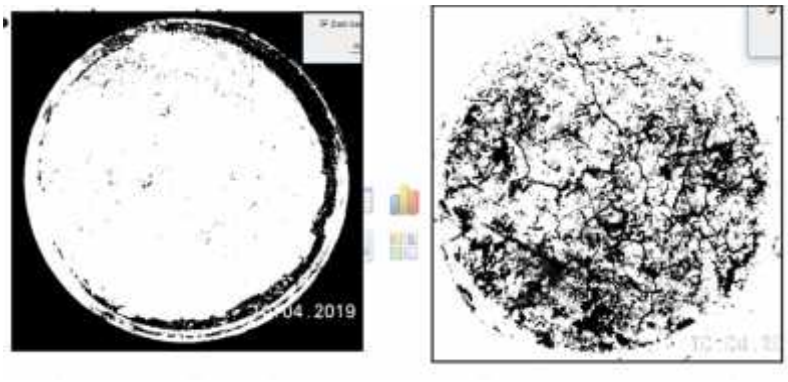
I_{sa} = Initial specimen area;

For the preparation of soil specimens, the soil samples were mixed at different moisture content i.e. DSO (OMC-5%), OMC, WSO (OMC+5%) and these mixes were kept in air-tight polythene bags for 48 hours to homogenize the moisture content without any loss of water due to evaporation. Specimens were prepared in the properly greased cylindrical mould of dia. 10 cm and thickness 1.5 cm. Before placing them in mould they were suitably compacted to the maximum density by means of compactor and collar. After compaction collar was removed and specimen surface was levelled by using knife. All specimens were kept at two different temperature of 27°C & 40°C for drying at least for 72 hours. Specimens were brought to the setup where camera was placed on a platform. Bubble tube was used to ensure that the camera was placed perfectly. Raw images obtained were then processed and analyzed by using image analysis technique. For this purpose a high resolution digital camera 'Canon Coolpix B700' was used and images were captured from a fixed height of 15 cm**.**

(a) Raw image



(b) 8-bit grey scale image



(c) Threshold Image (d) Skeletonized image

Fig. 5. Outcomes of image analysis techniques.

Fig. 5 presents various steps of image processing. In order to determine the shrinkage area soil samples were prepared at different moisture contents i.e. DSO (OMC-5%), OMC, and WSO (OMC+5%) and image processing was performed using ImageJ software. The samples were kept under the influence of two different temperatures i.e. 27°C and 40°C. The shrinkage area of the soil samples were quantified at various time interval. The results are shown in Fig. 6, Fig. 7, and Fig. 8 for samples at dry side of optimum, optimum moisture content and wet side of optimum respectively.

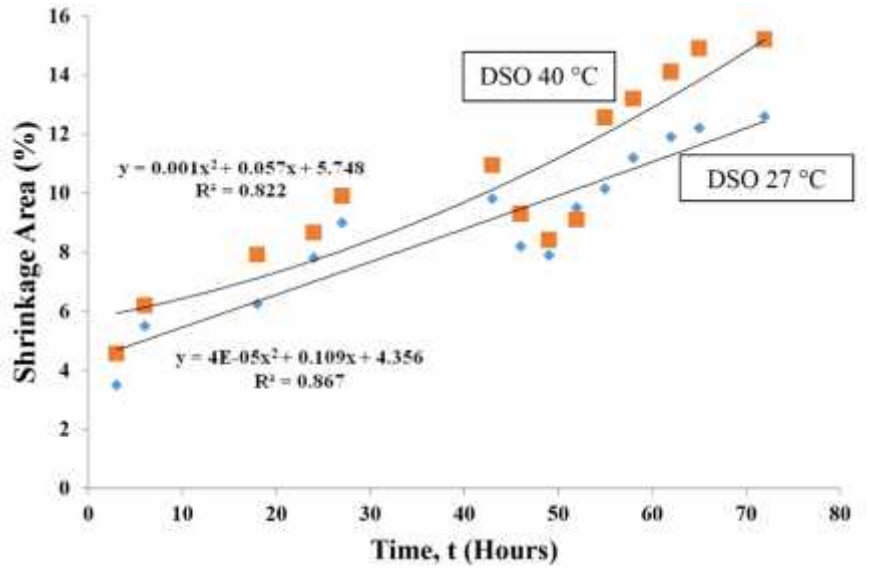


Fig. 6. Variation of shrinkage area with time at different temperature for DSO samples.

The Fig. 6 represents the variation in shrinkage area with time and temperature variations while maintaining sample preparation moisture content i.e. DSO (OMC – 5%). As presented, the sample placed at 40°C shows higher shrinkage area compared to the sample placed at 27°C. During first three hours, % shrinkage area for the samples placed at room temperature (27°C) was found to be 3.5%, while for the sample placed at 40°C was observed to be 4.57%. After 72 hours, the percentage shrinkage area was found as 12.6% and 15.2%, for samples maintained at 27°C and 40°C, respectively.

Fig. 7 presents the variation in shrinkage area with time and temperature variations while maintaining sample preparation moisture content i.e. at OMC. As presented, the sample placed at 40°C shows higher shrinkage area compared to the sample placed at 27°C. During first three hours, % shrinkage area for the samples placed at room temperature (27°C) was found to be 5%, while for the sample placed at 40°C was observed to be 6.5%. After 72 hours, the percentage shrinkage area was found as 15% and 20.9%, for samples maintained at 27°C and 40°C, respectively.

As presented in Figs. 6 – 7, drop in the shrinkage area was observed during 40 hours to 50 hours. This phenomenon was not expected to associate with variation in placement moisture content or drying temperature and further studies are required to reconfirm the observed behavior.

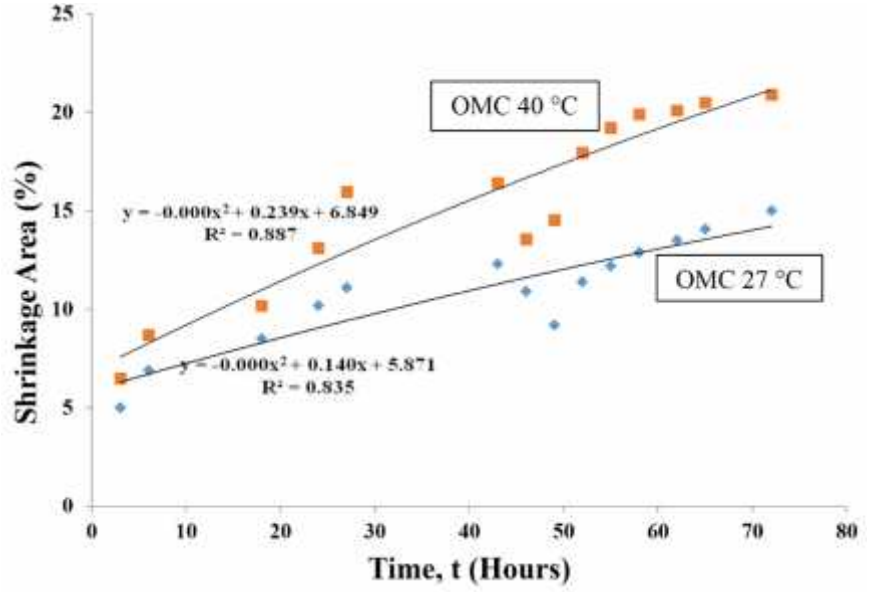


Fig. 7 Variation of shrinkage area with time at different temperature for OMC sample.

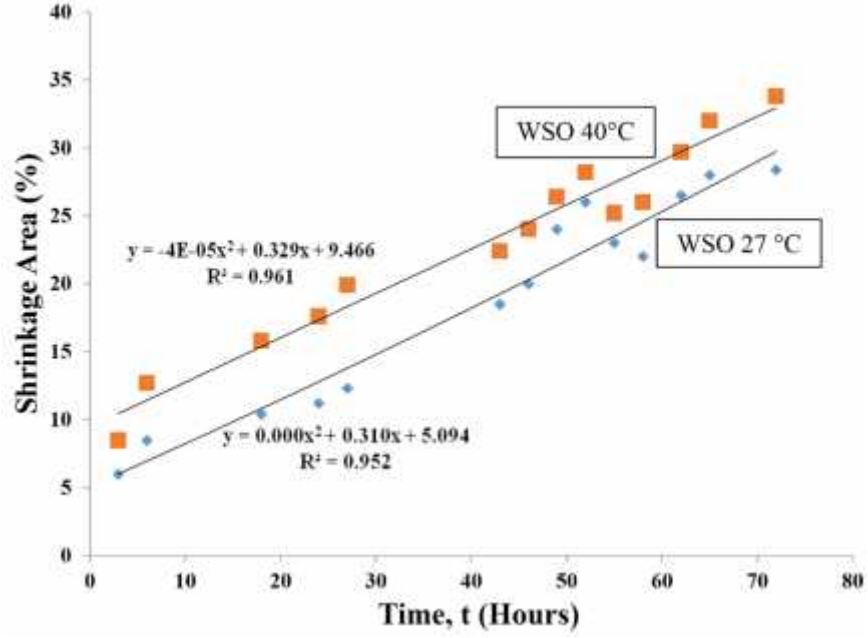


Fig. 8 Variation of shrinkage area with time at different temperature for WSO sample.

The Fig. 8 presents the variation of shrinkage area with time and temperature variation while maintaining sample preparation moisture content i.e. WSO (OMC + 5%). As presented, the sample placed at 40°C shows higher shrinkage area compared to the sample placed at 27°C. During first three hours, % shrinkage area for the samples kept at room temperature (27°C) was found to be 6%, while for the sample placed at 40°C was observed to be 8.5%. After 72 hours, the percentage shrinkage area was found as 28.4% and 33.8%, for samples maintained at 27°C and 40°C, respectively.

5 Conclusions

Based on experimental investigation following conclusions were made:

- Among the samples tested the swelling pressure was maximum in case of soil sample prepared at DSO (OMC-5%), and minimum in soil sample prepared at WSO (OMC+5%).
- Experimental findings revealed that maximum swelling pressure generation was within first 24 hours after commencement of the experiment. Swelling pressures of 41.8 kPa, 59.44 kPa and 23.22 kPa were observed for specimen prepared at optimum moisture content, at 5% dry side of optimum and 5% wet side of optimum, respectively. While swelling pressure found to increase

till seven days, though at a lower rate and observed swelling pressure values were 55.73 kPa, 83.6 kPa and 37.25 kPa for specimen prepared at optimum moisture content, at 5% dry side of optimum and 5% wet side of optimum, respectively.

- Among the samples tested the shrinkage area is maximum in case of soil sample prepared at wet side of optimum and minimum in case of soil sample prepared at dry side of optimum. The sample kept at greater temperature shows greater area of shrinkage irrespective of initial moisture content.
- The % shrinkage area were found as 22 %, 33.8% and 15.2% for the samples prepared at OMC, WSO (OMC+5%) and DSO (OMC-5%) respectively.

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