Investigation on Shrinkage behaviour of kaolin clay

Amin Chegenizadeh
PhD candidate, Department of Civil Engineering, Curtin University of Technology, Perth, Australia; Tel: +61-413165961; Fax: +61 8 9266 2681;Email: amin.chegenizadeh@postgrad.curtin.edu.au
Prof. Hamid Nikraz
Head of the Department of Civil Engineering, Curtin University of

Technology, Perth, Australia; Tel: +61 8 9266 7573; Fax: +61 8 9266 2681;Email: H.Nikraz@curtin.edu.au

ABSTRACT: As evaporation prevails, soils lose water and shrink upon desiccation, which lead to formation of desiccation cracks. The cracking of desiccated clay soils is problematic to many civil structures hence an adequate understanding of the desiccation cracking process is of great significance. To build this understanding, knowledge of how crack forms, their position, orientation and connectivity in space are necessary. This paper aims to investigate shrinkage problem deeply. A series of shrinkage test were conducted. The container dimensions were 50mm X50mm X 50mm. the soil was selected as kaolin clay. Different initial moisture content of 45% and 40% considered. The results proved that water content decreased as desiccation rate increased. The engineering graph of change in water content versus time and shrinkage strain versus change in water content was plotted for each test. The desiccation curves shows similar behaviour for different initial moisture content as finally reached the balance with local climate.

KEYWORDS: Desiccation; clayey soil; cracking

1 INTRODUCTION

Compacted clay is commonly used in embankment dam cores, low permeable barriers in waste landfills, canal sections, foundations and roadways. Areas that are susceptible to damage from expansive soils are those that have large surface deposits of clay and climates characterised by alternating periods of rainfall and drought. Expansive soil is a term used by geotechnical engineers for soils that expand or contract depending on the amount of water that is present. In a research on reactive clayey soil, Nahlawi (2004) found out that the economical aspect of this problem can be significant in Australia. This view was reviewed by Dudal and Eswaran (1988). Soil shrinkage is problematic around the world and poses risks of damage to light buildings, road pavements and clay liners used for waste containment in landfills. Soil shrinkage and shrinkage cracks are caused by a decreasing in soil moisture content through either evaporation from the soil surface in dry climates, lowering of the groundwater table, or desiccation of soil by trees during humid climates. In a study on shrinking and swelling of soils, Holtz and Kovacks (1981) found that as water content decreases, capillary stress in the void spaces enhances due to the increased surface tension. This increased surface tension tends to pull adjacent soil particles closer together resulting in an overall soil volume decrease. The key factors effecting the shrinkage potential of a soil can be evaluated in three different groups, the *soil characteristics* that influence the basic nature of the internal force field, the *environmental factors* that influence the changes that may occur in the internal force system, and the *state of stress* (Kudikarra, 2005,Nelson and Miller, 1992).
In conventional application of reinforcement in soil, the inclusion of tire, bars, grids etc are usually in a preferred orientation. The advances of these materials have usually been considered by an increase in their applications. The randomly discrete fibers are easily added and mixed randomly with soil part, the same way as cement, lime or other additives. Some researches have been done on cement additive (Consoli et.al. 2009; Cai et.al 2006; Lorenzo and Bergado, 2004) and can be used as a pattern of additive usage in soil. Fibre reinforced composite shows more ductility and small losses of peak strength i.e. in compared to unreinforced material. Therefore, fiber-reinforced soil composite is a practical solution in civil engineering projects. The main application of composite soil can be in embankment, subgrade, subbase, and slope stability problems. However, the data concerning the effects of fiber inclusion on the characteristics of compacted native or virgin soils are limited, (Maher and Ho, 1993). This shortage is more considerable in pavement engineering and landfill systems in terms of crack control. Limited

attempts have been made to control clay cracking by fibre reinforcement (Allan and Kukacka, 1995; Al Wahab and El-Kedrah, 1995; Ziegler et al., 1998). Miller and Rifai (2004) studied the effects of fibre reinforcement on the development of desiccation cracking in compacted clay samples. Therefore, the significance this study is to evaluate the effect of fibre inclusion on shrinkage behavior of clayey soil. The application of controlling crack cause significant improvement in land fill systems and pavement engineering as cracking which lead these systems to be failed in the real civil projects.

2 MATERIAL

Composite soils consist of two parts. The first part is soil part which can be dealt as normal soil. The second part is reinforcement part which can be made up of any material which helps soil to have better performance.

2.1 *Soil Type*

The soil type in this study was kaolin clay. The properties of clay are presented in table 1. This type of kaolin clay is widely used in industrial project and research activities in Western Australia.

Table 1. Clay properties

No.	Size (cm)	
1	Soil type	Clay
2	Liquid Limit	49
3	Plastic Limit	23
4	Pl. Index	26

2.2 *Fiber Type*

The plastic fiber has been used for this investigation. Figure1 shows the used fiber. The used fiber has good potential to absorb energy and good adhesion with soil particle.

Figure. 1 Plastic fiber

3 TEST PROGRAM

Test program in this study includes a series of shrinkage test were conducted to investigate the effect of fibre inclusion on shrinkage phenomenon.

3.1 *Main Equipments*

- Metal container for shrinkage test
- Balance

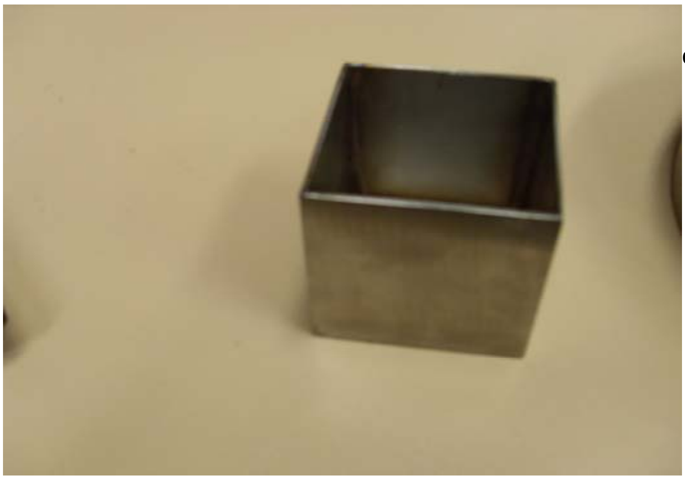

Figure 2. Metal Container used for shrinkage test

4 SAMPLE PREPARATION FOR SHRINKAGE TEST

Isotropic shrinkage tests were conducted on clay samples. This rather contemporary method involved compacting soil into small moulds to produce blocks of soil compacted to a specific density (Nahlawi et. al. ,2006). Compacting soil at specific moisture content to a specific density may be ideal when trying to model landfill conditions. The aim of this test is to determine the shrinkage strain of compacted clay as time elapses with different starting moisture content and sizes, and generate desiccation curves. Accordingly, this will determine what size sample(s) will be good for carrying out further testing. Specimens were compacted at 40% moisture content and 40% moisture content. Ideally we would want to compare slurry clay to compacted clay for this test however, since the dry density is unknown for moisture content beyond 45%, a comparison of clay at 45% and 40% was carried out. Moreover to an unknown dry density, slurry state clay would not hold its shape once the moulds are removed. Shrinkage tests were undertaken in a constant temperature room in the civil engineering laboratories. 50 mm x 50mm x 50 mm size blocks clay, were left to dry under similar environmental conditions. Their weight and shrinkage were recorded over time. The following section will explain in detail the experimental procedures.

5 TEST METHODOLOGY AND PROCEDURE

5.1 *General steps*

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Once the soil had been compacted into the moulds, 'cling wrap' was used to wrap the sample to prevent moisture loss. Water was then sprayed, and soil was put in sealable plastic bags to cure overnight. Approximately a day later the soil specimens were isolated from the moulds. Firstly the lid of each mould was carefully removed, and excess soil was cut with a wire. Once the entire soil was exposed, metal tacks were positioned in the centre of each face of the block using glue as a reference point for measuring shrinkage in two dimensions with a calliper. The soil blocks were then put on a metal rack in a constant temperature room where the soil was to undergo drying at a constant temperature of 24°C and relative humidity of 40%. The degree of shrinkage and weight of each sample were recorded each day until the samples reached equilibrium with the local climate or cracked. Same procedure was applied with putting fibre inside the clayey soil and effect of fibre also investigated on shrinkage behaviour. The fibre length was selected as 10 mm and fibre content varied during the tests. (i.e. 1% , 2% and 3%)

5.2 *Shrinkage analysis*

Desiccation curves were plotted by weighing the soil specimens over time to determine the water loss.(Kudikara ,2005) The change in water content in each sample was determined by applying Equation 1, where w_i is the initial water content and w_t is the water content at the specific desiccation time.

$$W = Wi - Wt \quad (1)$$

Shrinkage strain also recorded as ratio of changing in length to initial length.

6 RESULTS AND DISCUSSIONS

Desiccation curves were plotted for each soil sample to identify the desiccation rate. The graph plotted for 40% and 45% moisture content.

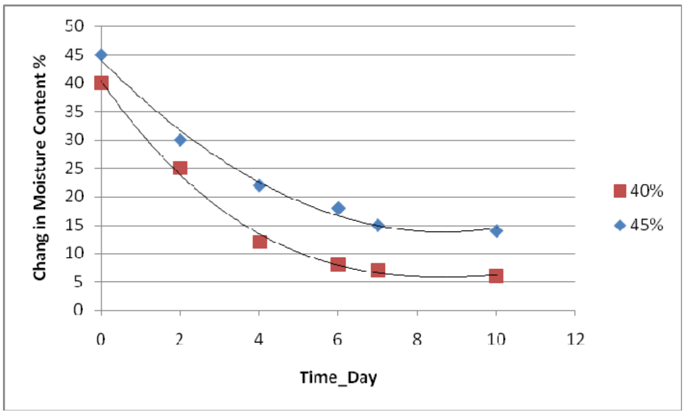

Figure. 3 Changing in moisture content in shrinkage test

The degree of shrinkage was calculated in all 3 directions with a calliper on each specimen and an average shrinkage strain was recorded. The graph of the drying process and strain evolution of soil samples were derived as indicated in Figure 4. The shrinkage strain versus change in moisture content, Δw was plotted in figure 4.

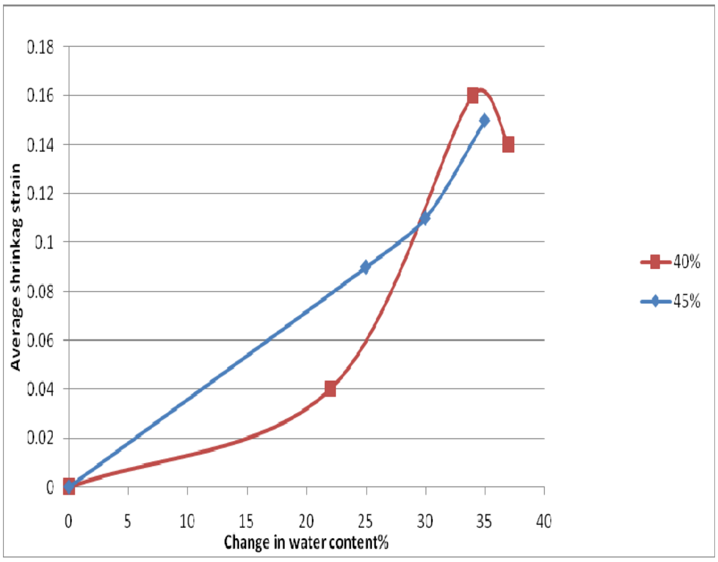

Figure. 4 Changing in moisture content in shrinkage test

6.1 *Effect of fibre inclusion*

A series of shrinkage tests was conducted to find out the effect of fibre inclusion on linear shrinkage behavioure. Figure 5 shows the effect of fibre content which changed from 1% to 3%. The results proved that with increasing in fibre content linear shrinkage was reduced.

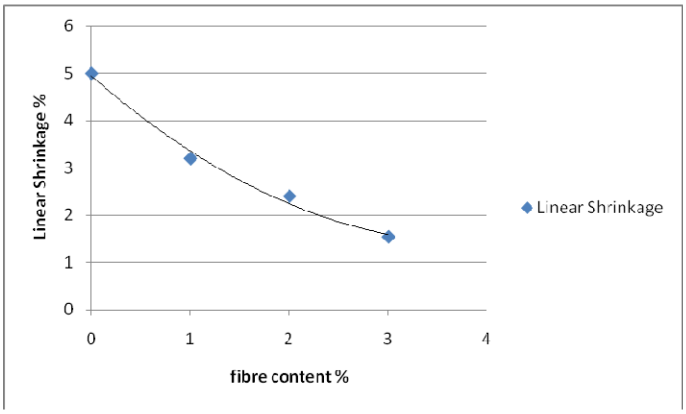

Figure. 5 Effect of fibre content in shrinkage test

7 CONCLUSION

A series of shrinkage test on a block sample of clayey soil was conducted and following results obtained:

- Kaolin clay experiences shrinkage in all directions, and shrinkage of the clay layer was followed by cracking due to desiccation.
- Using fibre caused huge decrease in crack intensity factor
- Increasing in fiber content directly decreased the linear shrinkage.

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