

## **Field Moisture Content Effects** **on Shrink-Swell of Clays**

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### **ABSTRACT**

Geotechnical engineers have substantial involvement in classification of sites for residential developments in accordance with AS2870-1996 “Residential Slabs and Footings” to aid in footing design.

The standard procedure for site classification is based on soil strata and properties. In Australia, the most commonly adopted model incorporates the AS1289 7.1.1-1998 Shrink-Swell Index test method, which is taken to represent the surface movement per unit depth per unit suction change.

The result of the Shrink-Swell test is assumed to be the same if the soil is sampled at different moisture contents. However, the validity of the results when sampled at substantially dry or wet insitu moisture content is uncertain, particularly for highly reactive clays.

This paper discusses an experimental study to measure Shrink-Swell Index of two heavy clays of varying moisture contents. An experimental model was developed to achieve uniform moisture contents within the samples. The results were compared with those from undisturbed samples of the same clay. Statistically significant results were obtained.

### **INTRODUCTION**

Geotechnical engineers are required to investigate suitability of sites for residential development. The assessment of the site allows the engineer to determine the type of foundation appropriate for residential developments. The demand for foundation assessment, particularly subdivision development has increased with the population, mainly on the east coast of Australia.

Site assessment for residential developments is carried out in accordance with the Australian Standard AS2870-1996 “Residential Slabs and Footings”. This Standard sets out the procedure for site classification of sites and the appropriate foundation type for each class. These categories are based on ground movement limits, which are defined in terms of design surface movement ( $\gamma_s$ ), Cameron et al., (1997).

Design surface movement ( $\gamma_s$ ) is a hypothetical parameter representing the “difference between the surface movement that would occur if the design range of moisture conditions (dry to wet) was experienced.” Cameron et al., (1997). The two moisture extremes of wet and dry would occur at different periods of site development and therefore not simply the range encountered in the field before development.

The main consideration, is the soil behaviour under load from the structure and with variations of moisture content. On the east coast of Australia, foundation materials are typically clay and are prone to variations in the moisture content of drying (receding) and wetting (advancing) the soil causing shrinking and swelling, respectively. The time elapsed in-situ depends upon the soil properties and conditions. For example, Marshall (1967) indicates that some clays in England, continue to swell for about three months after the wet season.

This potential to swell and shrink (expansion or volume change characteristic) affects the structures by causing damage such as cracking and settlement, amounting to millions of dollars throughout the world. Thereby, the engineer is faced with heightened legal accountability.

A lot of emphasis is placed on testing methodologies for determining the characteristics of the soil. In Australia, engineering practices most commonly adopted the model which incorporates the AS1289 7.1.1-

1998 Shrink-Swell Index test method, which is taken to represent the surface movement per unit depth per unit suction change. This method of determining the reactivity or shrink-swell potential theoretically should not vary with variations in moisture content. However, the validity of the results when sampled at substantially dry or wet insitu moisture content is uncertain, particularly for high plasticity clays.

An experimental study was undertaken to develop a model to simulate the in-properties of clay by comparing varying moisture contents with shrink-swell characteristics in a short time frame.

## **EXPERIMENT**

Site classifications is based on the measurement of potential expansion of soil. The common method in Australia for determining the expansive potential of clays, shrink-swell index test, was developed by Cameron, and further confirmed by Fityus in 1996, Cameron et al., (1997). The shrink-swell index ( $I_{ss}$ ) can be determined, by the following equation, after the individual simplified shrinkage test and swell test have been completed.

$$I_{ss} = ((e_{sh}/2) + e_{sw}) / 1.8$$

$I_{ss}$  = shrink-swell index that is the percentage of strain per pF change in suction.  $e_{sh}$  = the total shrinkage strain (%) and  $e_{sw}$  = total swelling strain (%). The factor of 1.8 is an effective suction change for the test, derived by Cameron in 1989 and confirmed by extensive testing carried out by Fityus in 1996.

The validity of the shrink-swell index value gained when the sample is obtained at extremely dry moisture contents and alternatively wet moistures is called into question. The concept of the shrink-swell index ( $I_{ss}$ ) is that the value should be the same regardless of the moisture content. In the field, the period between extreme moistures varies from months to years, depending on the landscape, soil conditions, land use, climate, precipitation etc.

The purpose of this experimental test design was to simulate the extreme drying and alternatively wetting conditions on highly reactive homogenous clay. The model was to achieve these variations in moisture content and then carry out shrink-swell testing. The main constraints of the project were material homogeneity, moisture control and a short time frame.

Two high plasticity clays were sourced from a site near Nowra, NSW, sampled within the individual strata layers and denoted throughout the experiment as Clay 1 and Clay 2. Using the Unified Soil Classification System (USCS) analysis; Clay 1 is (CH) CLAY, high plasticity, red-red/brown, trace fine to medium gravel. Clay 1 was underlain by Clay 2: (CH) Silty CLAY/CLAY, high plasticity, yellow/pale brown. Both clays had field moistures of greater than the plastic limit ( $M > W_p$ ).

Previous shrink-swell index results collected over the last three years from the general site area; for Clay 1 ranged from 2.8% to 5.2% with associated moisture contents ranging from 21% to 29.6%. Clay 2 shrink-swell index results ranged from 2.7% to 5.1% with associated moisture contents ranging from 18.6% to 29.7%, Network Geotechnics Pty Ltd.

### **Experimental model:**

The objective of the experimental model was to simulate the excessively wetting and excessively drying process on homogenous, high plasticity clay, within a very limited time frame and with minimal structural damage to the clay properties.

The model was developed as follows:

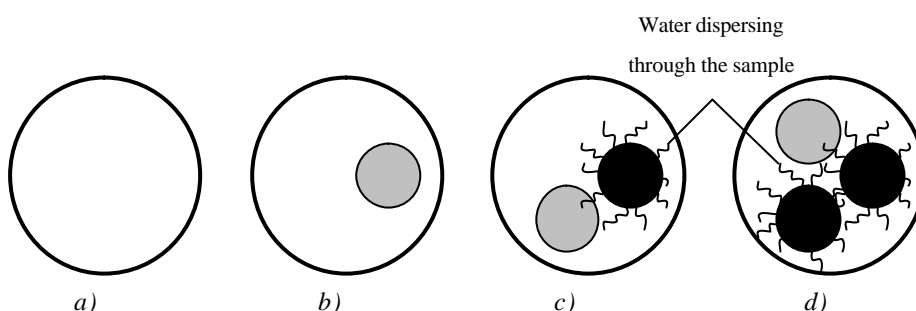
1. Compact the homogenous material into moulds at 100% Standard compactive effort at Optimum Moisture Content (OMC) and allowed to soak (or alternatively air dry) for nominal time periods. All samples were first cured to a homogenous condition at OMC in order to reduce the disturbance of clay. Two sets of three moulds were used for obtaining samples with the desired moisture content. One set was for air drying and the other was soaked for varying lengths of time. In each set, the first mould was used for measuring the moisture profile, the second for obtaining a sample for a swell test and the third to obtain a sample for the shrinkage test.

2. U50 tubes were then to be driven into the samples and moisture contents taken in increments on the extracted sample.
3. The resulting profile was the basis of further testing on selected increments, with the moistures being chosen at dry and alternatively wet values.
4. Carry out the shrink-swell index test in accordance with AS1289.7.1.1(1998) at selected moisture contents in order to meet the objective of the model.

### **Moisture Variation and Control**

As moisture control was the major quality constraint, the model had to try to achieve uniformity and consistent moisture content. In the case of the increasing the moisture content above optimum, water was required to soak uniformly into the specimen for the whole depth. Similar uniformity/consistency conditions were required with the air-dried.

The process was advanced in groups of three moulds, as depicted in Figure 1 below, as a time saving mechanism.



**Figure 1** Stages for obtaining samples with desired moisture content within the given time frame.

For each mould the process was undertaken four stages, whereby *a*) is the initial compacted specimen, *b*) is the mould after one tube sample is taken (say 7 days), *c*) is the mould after say 10 days after the 2<sup>nd</sup> tube sample is taken (note that the first tube hole was filled with sand) and finally *d*) is the mould having the last tube taken.

### **RESULTS & DISCUSSION**

The experimental model adopted was able to provide moisture contents typically ranging from 18% to 33% for Clay 1 and 22% to 27% for Clay 2. Clay 2 was not tested as extensively as Clay 1.

The methodology of reliability assessment incorporated the works of Jaksa et al., (1997) of the first-order Second Moment (FOSM) analysis which found that the model was approximately 70% accurate. The coefficient of variance of the model was 15%, which was very close to the co-efficient of variances of 20% and 17% for the actual swell and shrinkage moistures respectively.

One of the drawbacks of the experimental model for the drying component was that the specimen had the tendency to break at the compacted layer boundaries. The result is that the test becomes invalid. This scenario occurs in the field, in situations such as excessive cracking of soils.

### **Experimental Results**

The compaction requirements of Clay 1 and Clay 2, were to achieve a Maximum Dry Density (MDD) and (OMC) of 1.63t/m<sup>3</sup> at 23% and 1.55t/m<sup>3</sup> at 25% respectively.

Shrink-swell index tests results were compared with the moisture contents. The shrink-swell index results for Clay 1 ranged between 4% to 6%, typically 4.8%. The associated moistures prior to swell testing ranged between 18% and 33%. Clay 2 was not tested as extensively as Clay 1, however, the shrink-swell index ranged between 4 % and 6%, typically at 5% for the moisture variation of 22.5 to 27%.

In order to assess the experimental results, comparison was made with previous site history results, as shown in Figure 2 for Clay 1 and Figure 3 for Clay 2. The experimental results of Clay 1 showed similar trend to actual in-situ test (previous) results, although significantly higher by about 25% to 35% for Clay 1.

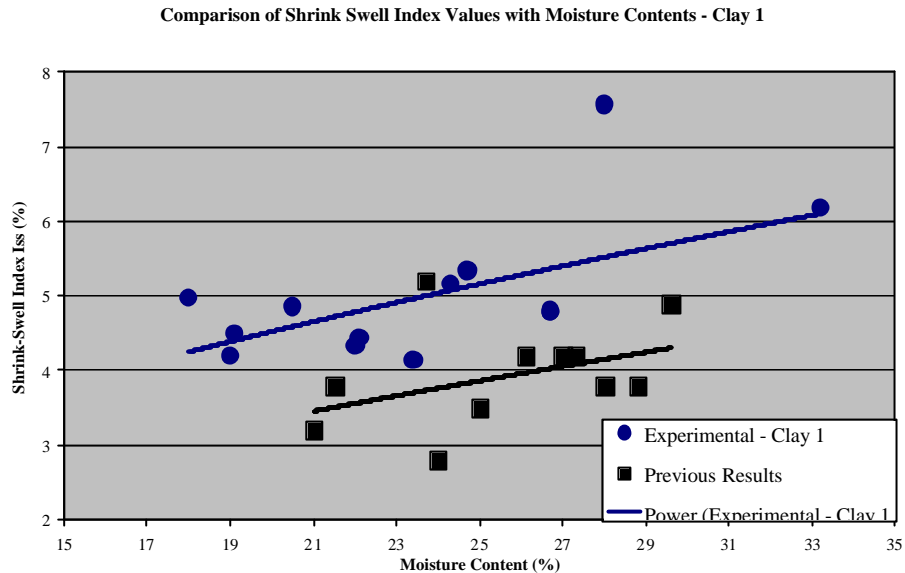


Figure 2 Comparison of Experimental Shrink-Swell Index (Iss) with Previous Clay 1 Results at different Moisture Contents.

The experimental shrink-swell results for Clay 1 were higher by about 30% within the range of  $\pm 2\%$  dry/wet of OMC. The equilibrium moisture content of clay underlying other strata layers is typically  $\pm 2\%$  dry/wet of OMC, consistent with most earthwork compaction specifications. At the extremities, the range increased to about 35%, having receded about 4% dry of OMC. Alternatively, the range decreased slightly to about 25% greater than the actual for a corresponding moistures 6% wet of OMC.

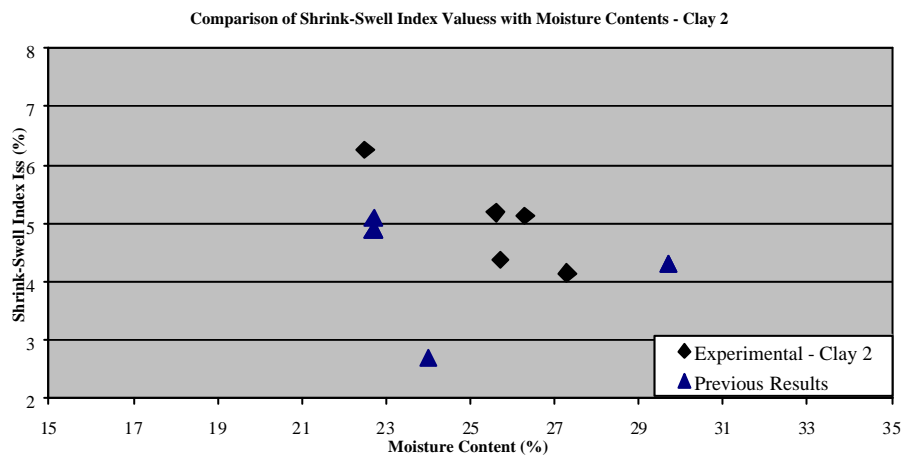


Figure 3 Comparison of Experimental Shrink-Swell Index (Iss) with Previous Clay 2 Results at different Moisture Contents.

Although Clay 2 was not tested as extensively as Clay 1, the results did not show the same trend as shown in Figure 2. However, as an indication, when plotted with the data of Clay 1, it showed that the results thus far follow a similar trend in relation to the moistures. For example, the moisture range of 21% to 29% is

tending towards Iss values of 5% to 5.6%, which is higher than the previous results typically ranging between 2.5% and 5%.

The homogeneity of clay used for the experiment generally showed less scatter than the previous site results, with the exception of one outlier in Clay 1. In regard to the use of high plasticity clays for applications of earthworks such as compacted fill, the shrink-swell index value should be increased, based on the trend encountered in this experiment. This is also the case for situations where sourcing parent material for application to fill would need to be increased by a *confidence factor (%)*. The numerical value of the confidence factor would need to be determined after extensive testing of various sites and plasticities of clay, before being adopted by engineering practices. As an indication from this experiment, of limited tests, the confidence factor would be in the order of about 10% to 15%.

The trend of the shrink-swell index values were lower at lower moisture contents, and conversely higher shrink-swell values at higher moistures. Particularly at the extremities, which proves that the confidence should be reduced in the use of shrink-swell index test AS1289.7.1.1-1998 when sampled at excessively dry or alternatively wet moisture contents.

## CONCLUSION

In conclusion, the shrink-swell index values of the selected high plasticity clays vary with the moisture variations. Typically the lower the moisture, the lower the shrink-swell index and the reverse was true for higher than optimum moisture contents.

The greatest variation is in the difference between in-situ sampled clays compared to compacted clays. Although the homogenous nature of the material used in the experiment reduced the scatter of results, the shrink-swell values were significantly higher.

The experimental results set out in this report are site specific. However, the measured variations of 25-35% in shrink-swell index values is statistically significant enough to warrant further study. Further investigation may be directed to establish a modifying factor for shrink-swell index when the moisture content of the sample is substantially different to the expected equilibrium moisture content.

The above moisture content effects are disconcerting in terms of the amount of confidence placed on the shrink-swell index value in relation to geotechnical engineering practices.

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