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INTRINSIC COMPRESSION CHARACTERISTICS OF AN EXPANSIVE CLAY FROM WESTERN AUSTRALIA

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ABSTRACT: Intrinsic compression behaviour of an expansive clay from Western Australia is investigated using the intrinsic framework in this study. Oedometer results conform with the intrinsic concept at post-yield phase. However, there is a great impact of initial water content on the compression curves at pre-yield stage. It specifies that there is an initial structure similar to a natural clay structure which resists applied forces at this phase and it is related to the amount of initial water content at the preparation stage. Nonetheless, this interparticle bonding is demolished when vertical stress becomes greater than remoulded yield stress. The findings also show that the remoulded yield stress of a reconstituted clay decreases non-linearly with the increase of initial water content, and is remarkably affected by its clay mineralogy. The remoulded yield stress of a soil with the predominant clay of smectite is far greater than those of other clay minerals despite having the same normalised initial void ratio value (e_0/e_L). Moreover, remoulded yield stress of an expansive soil with main clay mineral of smectite decreases more abruptly than for other clay minerals reported in the literature. Reconstituted compression indexes (C_c^*, e_{100}^*) for clays with a considerable amount of smectite are also greater than respective values for other clay minerals.

Keywords: Reconstituted clays, Consolidation, Expansive, Compressibility, Laboratory tests

1. INTRODUCTION

Expansive soils are a major problem in new residential developments in some arid and semi-arid areas all over the world. These types of soils, which mostly contain a considerable amount of smectite (montmorillonite), are very sensitive to the change of their water content. They expand with an increase in their moisture content while contract as they dry. Every year, millions of dollars are expended on both financial losses and stabilisation of these problematic soils. Overall, expansive soils damage dwellings, roadways, irrigational waterways, and other assets so significantly that the cost of the damage is greater than the cumulative cost of loss caused by natural disasters such as typhoons, cyclones, floods, earthquakes, and so forth [1].

As the population of Western Australia has been increasing continuously during past decades, the need for new affordable housing grows rapidly. The answer to this amplified demand has been found in developing new residential communities near Perth city. Several new suburbs and cities have been constructed both to the south and the north of the capital city in the recent years. Some of these new suburbs are being constructed on expansive soil layers, where expansion of these problematic soils is a real challenge to the geotechnical engineers of those projects. As stabilisation methods consist of laying sand cover layers, and chemical treatments are costly and cumbersome, new research on understanding the compressibility of these expansive soils is worthwhile to develop more efficient methods of stabilisation. In this study, several samples were collected from Baldivis, a newly-developed suburb in the south of Perth, to investigate the compression behaviour of this highly expansive soil by using the intrinsic concept.

Burland, 1990 [2] proposed a very convenient framework for predicting the compressibility of natural clays by introducing a so-called intrinsic compression line (ICL). He coined the term “intrinsic” to indicate that the corresponding parameters were independent of the initial state of the investigated clay. However, it has been understood lately that the compressibility behaviour of a reconstituted clay is also affected by other factors, such as the initial state. Intrinsic parameters and ICL were firstly introduced in the 1990s, yet they are still being used by several researchers around the world as a basic concept for presenting the results and characterising the compression behaviour of various types of clays such as sedimentary clays, remoulded clays, dredged slurries, and marine clays (for example, [3]-[5]).

A reconstituted clay is defined as the one has been completely mixed at a moisture content equal to or more than its liquid limit (w_L), ideally at $1.25w_L$ [2]. Thus, the compressibility parameters for interpreting characteristics of such a reconstituted clay, which has been destructured at a moisture content between its liquid limit and 1.5 times its liquid limit, is referred as intrinsic parameters. Burland, 1990 [2] also introduced two invariants of C_c^* (intrinsic compressibility) and I_v (void index) to normalise the intrinsic compression curves of reconstituted clays. An asterisk (*) here is used to distinguish between the intrinsic compressibility of reconstituted clays and compression index of natural clays.

$$C_c^* = e_{100}^* - e_{1000}^* \tag{1}$$

$$I_v = \frac{e - e_{100}^*}{C_c^*} \tag{2}$$

where the values of e_{100}^* and e_{1000}^* are the void ratios relating to the vertical stresses of 100 kPa and 1000 kPa respectively. Burland, 1990 [2] stated ICL is a unique line for a wide range of liquid limits. Nonetheless, recent research suggests that the contrary is true especially at high initial water content [3]. Burland, 1990 [2] also presented a polynomial relationship for calculating the ICL for a broad range of liquid limits, varying from 25% to 128%:

$$I_v = 2.45 - 1.285(\log \sigma_v') + 0.015(\log \sigma_v')^3 \tag{3}$$

where σ_v' is the effective vertical stress. Burland, 1990 [2] also advocated an indirect method for deriving intrinsic parameters C_c^* and e_{100}^* by performing regression analysis on the results of oedometer tests presented by Skempton and Jones [6]. This method makes it possible to simply derive the ICL indirectly without conducting one-dimensional (1-D) consolidation tests by knowing e_L (the void ratio at liquid limit). This pragmatic method can be very helpful because 1-D consolidation tests for clayey soils are always ponderous and costly.

$$e_{100}^* = 0.109 + 0.679e_L - 0.089{e_L}^2 + 0.016{e_L}^3 \tag{4}$$

$$C_c^* = 0.256e_L - 0.04 \tag{5}$$

The above equations are presented for e_L between 0.6 to 4.5 (namely w_L =%25 to %160 correspondingly) and for those clays that lie above the A-line in a plasticity chart.

Hong et al., 2010 [3] conducted a comprehensive consolidation program on three different clays from China. They used a wider range of initial water content, varying from 0.7 to 2.0 times liquid limits. They also took into account the effect of low consolidation stress on compression curves. Hong et al., 2010 [3] also modified the ICL relationship based on regression analyses as follow:

$$I_v = 3.0 - 1.87(\log \sigma_v') + 0.179(\log \sigma_v')^2 \tag{6}$$

Yin and Miao, 2013 [7] collected the oedometer tests results of 42 different clays from China in which the ratio of initial moisture content over their liquid limits ranged from 0.7 to 2.0. They performed multiple linear regression analyses to derive relationships for intrinsic parameters, and also verified the new relationships by independent data from five different sources, totalling 40 samples. The initial water content in independent data ranged from 1.0 to 1.75 times liquid limits, and liquid limits varied from 42% to 128%. Yin and Miao, 2013 [7] introduced two relationships for calculating the intrinsic parameters:

$$e_{100}^* = 1.13w_L + 0.39\, w_0/w_L - 0.084 \tag{7}$$

$$C_c^* = 0.91w_L + 0.25\, w_0/w_L - 0.461 \tag{8}$$

Zeng et al., 2015 [5] performed multi-linear regression analyses on both published data and their recent work to develop new relationships (Eq. (9) and (10)) for predicting intrinsic parameters:

$$e_{100}^* = 0.223 + 0.261e_0 + 0.282e_L - 0.018e_0^2 - 0.05e_L^2 + 0.015e_L^3 \tag{9}$$

$$C_c^* = -0.064 + 0.153e_0 + 0.11e_L - 0.006e_0^2 \tag{10}$$

In this study, the compression behaviour of an expansive clay from Western Australia was investigated by performing 1-D consolidation tests on reconstituted samples. All tests began from a very low consolidation stress level of 1 kPa to consider the influence of low levels of stress, increasing to high stress levels to also test this influence. Two different methods of normalising inherent compression curves were used to determine the most suitable method for characterisation the compressibility of expansive clays. As a part of this study, clay mineralogy was investigated by X-ray diffraction tests to analyse the impact of clay mineralogy on the intrinsic parameters. An empirical relationship then was proposed for determining the remoulded yield stress of expansive soils with the dominant clay mineral of smectite.

Most research on inherent compressibility of clays, to the authors' knowledge, has focused on geotechnical invariants so far. This paper presents the influence of clay mineralogy as well as initial water content on the compressibility of expansive soils based on intrinsic framework. There is also a lack of information about the relationships for predicting the remoulded yield stress of clays with predominant mineral of smectite. Furthermore, existing experimental relationships underestimate the value of remoulded yield stress of such expansive soils. Overall, the following questions will be discussed in this study:

- Is it possible to use existing relationships for predicting intrinsic parameters (C_c^*, e_{100}^*) of an expansive soil with chief clay mineral of smectite?

- How susceptible is the expansive soils' structure to the initial water content?
- How much does clay mineralogy affect the value of remoulded yield stress?
- What is the best method of normalising inherent compression curves of expansive soils?

2. MATERIAL AND TEST PROCEDURE

Soil samples used in this research were collected from an under development residential site at Baldivis, a suburb 46 km south of Perth, the capital city of Western Australia. All disturbed samples were hand dug from a depth of 0.3 m to 0.5 m below ground surface after grass was removed. Basic soil index tests were performed in according to ASTM standards to identify the physical properties of the studied soil [8]. The liquid limit test was performed using a Casagrande device and the plastic limit was measured with thread rolling in accordance to ASTM D4318; a specific gravity test was carried out using a pycnometer (ASTM D854). The result of consistency limits for Baldivis clay is plotted on the plasticity chart in Fig. 1; the data lies slightly above the A-line in the plasticity chart. The high value of plasticity index indicates that the studied soil is highly expansive.

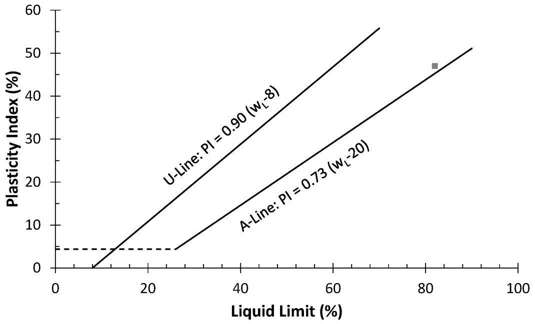


Fig. 1 Plasticity chart

Particle size distribution of the studied soil performed is shown in Fig. 2. It can be seen that Baldivis soil consists 20% sand, 12% silt and a considerable amount of clay (68%). Physical properties of the studied clay are also tabulated in Table 1. The organic content of Baldivis clay was measured by ignition method; the studied soil was burnt out at a furnace to 400±5°C for 24 hrs. The measured loss was approximately 5.3% to 6.6% for soil at the studied depth.

Table 1 Physical properties of Baldivis clay

Liquid Limit (w_L)	Plastic Limit (w_P)	Plasticity Index (PI)	Specific Gravity (G_s)	Sand (%)	Silt (%)	Clay (%)
82	35	47	2.6	20	12	68

X-ray diffraction tests were conducted to analyse the mineralogical component of Baldivis clay. Air-dried samples were run on powder diffractometer D8 Advance (Bruker AXS, Germany) with a copper tube (K-alpha radiation, wavelength 1.54A) at 40kV and 40mA and with a LynxEye detector. The results, presented in Fig. 3, shows a considerable amount of smectite (montmorillonite) in the studied soil. However, smectite is the main clay mineral; kaolinite was also detected with a basal order reflection of 7.15 Å and 3.58 Å.

Reconstituted samples were prepared according to the sample preparation proposed originally by Burland, 1990 [2] and followed by Hong et al., 2010 [3]. First, samples obtained from the site were oven-dried at 105-110°C. The samples were then ground to a powder by using a pestle and mortar to pass a 2 mm sieve. The determined amount of distilled water was added to the measured oven-dried soil to achieve the prescribed initial water content (w_0); initial water content of sample preparation ranged from 0.67 to 1.33 times liquid limit (w_L) in this study. Prepared samples were kept in an air-tight container at a controlled room temperature (25 ± 2°C) for 24 hours to equilibrate before performing consolidation tests. The initial water content of each specimen was measured before the consolidation test to determine the precise value of initial water content.

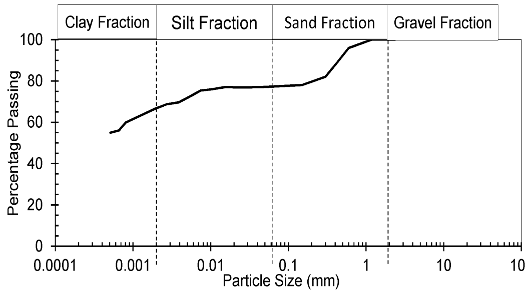


Fig. 2 Particle size distribution curve for the studied soil

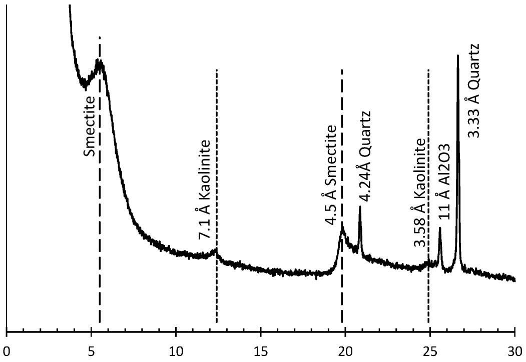


Fig. 3 XRD pattern for the studied soil

One-dimensional consolidation tests were conducted on specimens of 64 mm in diameter and 25.4 mm in height (i.e., area of the specimen was 3217 mm^2). Sample preparation techniques were chosen based on the relative value of initial water content of each specimen to the liquid limit. For specimens with an initial water content more than the liquid limit, the prepared soil was carefully spooned into the consolidation rim to avoid trapping any air bubbles in the specimen. However, the traditional method of sample preparation of a remoulded sample was chosen for those with an initial water content of less than the liquid limit [9]. The mixed soil was placed on a flat glass, and a consolidation ring was gently pushed into the soil. The specimen was then trimmed, and remaining trimmings were used for measuring its water content.

Eight series of 1-D consolidation tests were conducted on reconstituted samples in an auto consolidation apparatus in fully saturated conditions. The initial vertical consolidation stress was kept as low as possible to investigate the effect of low stresses on the compression behaviour. The stress increments used in this study were 1, 3, 6, 12.5, 25, 50, 100, 200, 400, 800, 1600 kPa in the loading phase. The deformation curves versus time were employed to define the end of primary consolidation of each stage by using the log-time method introduced by Casagrande [9]. The maximum and minimum time for primary consolidation of each stage were 24 hours and 8 hours respectively. Two porous stones were used at top and bottom of the specimen. Thus, drainage was allowed at both surfaces of the specimen during the test. Room temperature during all tests was kept constant at 25 ± 2°C.

3. RESULTS AND DISCUSSION

3.1 Inherent Compressibility and Remoulded Yield Stress

To investigate a complete intrinsic compression line (ICL) of Baldivis clay, one-dimensional tests began at a very low stress of 1 kPa and ended at 1600 kPa in the loading phase. Compression curves of Baldivis clay for various initial water content, $0.67w_L$ to $1.33w_L$, are presented in Fig. 4 in a semi-logarithmic space of $e - \log \sigma'_v$. It is clear from this figure that all compression curves are an inverse S-shape and slightly concave upwards, similar to those of natural clays. The same shape of ICL was reported by other researchers with different degrees of plasticity for reconstituted clays as well [3], [5]. Moreover, Fig. 4 depicts that the compression behaviour of Baldivis clay is highly sensitive to its initial water content. It is evident from this figure that samples with higher initial water content have relatively greater values of void ratio at the same vertical consolidation stress. However the gap between curves decreases gradually when vertical stress increases. It indicates that even reconstituted clays have a definite structure which withstands the external force. However this bonding is destroyed with increasing the vertical stress.

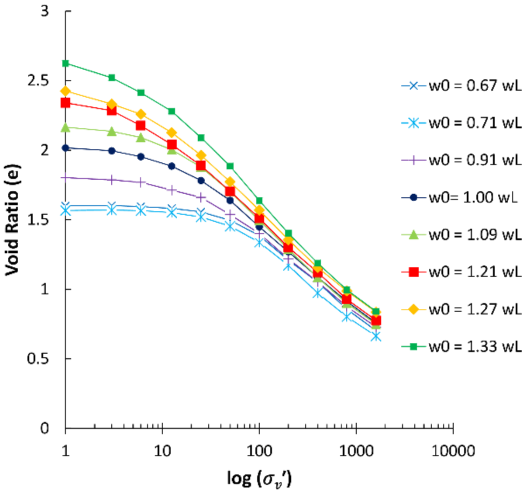


Fig. 4 Inherent compression curves of Baldivis clay

The term *structure* in this study is used as the combination of inter-particle bonding of clay particles and fabric (clay particle arrangement) following Mitchell and Soga, 1976 [10]. After applying a certain amount of external force (i.e. vertical consolidation stress) to specimen, soils cannot keep their original structures and the gap between compression curves will reduce.

ICLs of either natural or reconstituted clays are an inverse S-shape, and for consolidation stresses greater than a particular stress, become marginally concave upwards. This particular stress, which is very comparable to pre-consolidation stress for natural clays, has been named differently by earlier researchers: pore-water suction, suction pressure, apparent consolidation stress, and remoulded yield stress [3], [11]. In the interest of not being confused with unsaturated definitions, as well as natural clay pre-consolidation stress, it seems *remoulded yield stress* (σ'_{yr}) employed by Hong et al., 2012 [11] is the appropriate term to describe this definite stress. As the ICL of a reconstituted clay is similar to the compression curve of a natural clay, the remoulded yield stress can be defined by methods such as those presented for preconsolidation stress of sedimentary clays. Butterfield, 1979 [12] firstly used bilogarithmic space to present 1-D consolidation results of natural clays. He proposed the inverse S-shape of $e - log\,\sigma'_v$ compression curves can be simply presented by two straight lines in the bi-logarithmic plane. In fact, this method is highly useful when the compression curves of those clays with ambiguous yield stress are being investigated.

In this method, the intersection point of pre-yield and post-yield states can be defined as the yield stress. This technique has been successfully used by several researchers [3], [4].

Intrinsic compression curves of Baldivis clay are replotted in Fig. 5 in the bi-logarithmic plane of ln(1+e) vs. log (σ_v'). All compression curves can be well characterised by two individual lines which intersect at the remoulded yield stress. For different values of initial water content, the reconstituted clay has low compressibility for stresses less than σ_{yr}' , while its compressibility increases abruptly when the vertical consolidation stress is greater than σ_{yr}' . The slope of compression line in ln(1+e)-log (σ_v') plane increased from about 0.01-0.04 for pre-yield state to 0.13 for post-yield state. There is a sharp escalation of compressibility at σ_{yr}', 3.2 to 13 times its initial value, because the bond of clay inter-particles is destroyed and the original structure is lost. Oedometer test results presented in Fig. 5 depicts a clear value of remoulded yield stress for the studied range of water contents for the studied soil. The remoulded yield stress of Baldivis clay varies between 19 kPa to 70 kPa.

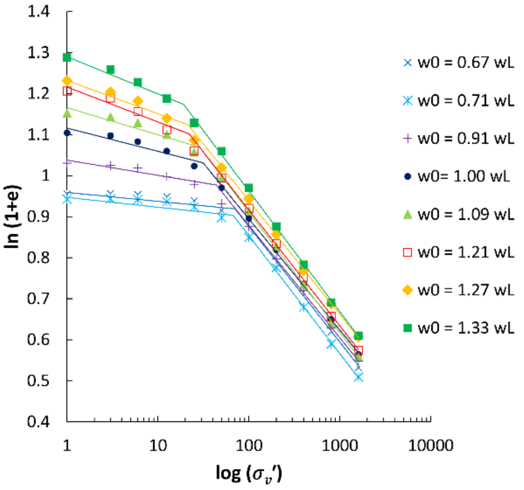


Fig. 5 Inherent compression curves of Baldivis clay in bi-logarithmic plane

It is well established that the remoulded yield stress (σ_{yr}') of clays reduces with the growth in initial moisture content [3], [13]. Remoulded yield stress for various values of initial water content have been normalised against the normalised initial water content (w_0/w_L) as seen in Fig. 6. It can been seen in this figure that the remoulded yield stress decreases non-linearly with an increase of normalised initial water content (w_0/w_L). The relationship between σ_{yr}' and normalised initial water content can be presented by the following power equation:

$$\sigma_{yr}' = 33.5/(w_0/w_L)^{-1.96} \tag{11}$$

where σ_{yr}' is in kPa. Hong, 2007 [13] extrapolated compression curves to calculate the remoulded yield stress (σ_{yr}') in a bi-logarithmic plane. He also used e_L to normalise the relationship between σ_{yr}' and initial void ratio (e_0). He suggested that there is a unique relationship between σ_{yr}' and normalised initial void ratio e_0/e_L using an extrapolation method to find e_0:

$$e_0/e_L = \left(2.14/\sigma_{yr}'\right)^{0.22} \tag{12}$$

Hong et al., 2010 [3] correlated the ICL for a wider range of initial water contents (25% to 160%) using a normalising invariant of I_v. Hong et al., 2010 [3] also developed an equation to determine the remoulded yield stress by knowing the normalised initial void ratio:

$$\sigma_{yr}' = 5.66/(e_0/e_L)^2 \tag{13}$$

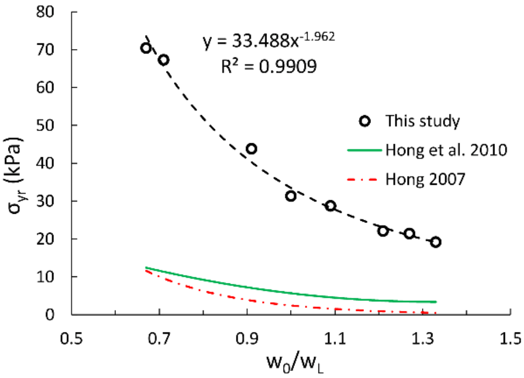


Fig. 6 Remoulded yield stress against normalized water content

A comparison of the remoulded yield stress derived from the aforementioned relationships and the results of this study are also given in Fig. 6. As all samples were saturated and the specific gravity was the same, the value of (w_0/w_L) is equal to (e_0/e_L) for each clay and the graph can be drawn against normalised initial water content. Figure 6 shows that the remoulded yield stress for Baldivis clay is far greater than the values calculated by Eq. (12) and (13). Although the tendency of decreasing σ_{yr}' with w_0/w_L is almost the same for all test results, the disparity between the results of this study and the other data is enormous. Fortunately, this gap can be explained by studying clay mineral composition of studied soils. Recent studies show that the predominant clay mineral of past research were mostly illite and the amount of smectite mineral was noticeably low [14]. However, the main clay mineral of Baldivis clay which has been studied herein was known to be smectite. This indicates that the principal clay minerals of reconstituted clays has a crucial impact on the value of σ'_{yr}. According to Fig. 6, the remoulded yield stress of Baldivis clay plummets rapidly with the increase of initial water content, and almost levelled off for w_0/w_L greater than 1.21. This sharp plunge in the value of remoulded yield stress indicates that expansive clay with the main clay mineral of smectite is more susceptible to initial water content rather than other minerals. Furthermore, the structure of expansive clay becomes weak so rapidly with an increase of initial water content that σ'_{yr} drops more suddenly than for other clay minerals reported in the literature. Thus, the variation of the remoulded yield stress of clays with different predominant clay varies considerably when the initial water content changes. In fact, most of the relationships for estimating the remoulded yield stress of reconstituted clays presented in the literature have been derived from a limited range of clay mineralogy. However, while these relationships can effectively predict σ'_{yr} of clays with a principal clay of either kaolinite or illite, they underestimate the value of the remoulded yield stress for clays with a considerable amount of smectite.

3.2 Normalising Inherent Compression Curves

In this study, two of the most popular frameworks for normalising inherent compression curves have been used. First, void ratio at liquid limit (e_L) was used as a normalising parameter following Nagaraj and Murthy, 1983 [15]. Second, void index – introduced originally by Burland, 1990 [2] – was employed for standardisation. Then the effectiveness of each method was investigated in characterising the compressibility behaviour of reconstituted Baldivis clay.

Nagaraj and Murthy, 1983 [15] introduced a unique relationship between the effective consolidation stress (σ'_v) and the normalised void ratio (e/e_L) as follows:

$$e/e_L = a - b(\log \sigma'_v) \tag{14}$$

where *a* and *b* are constants. They suggested the values of *a* and *b* to be 1.099 and 0.223 [15]. Then they revised *a* and *b* invariants to 1.122 and 0.2343 respectively [16].

The inherent compression curves of Baldivis clay normalised by e_L is presented in Fig. 7. For comparison, the normalised compression lines proposed by Nagaraj and Murthy 1983, 1986 [15], [16] are also plotted in this figure. As can been seen in Fig. 7, the results are highly dependent on the value of initial water content. However, the results approach the values estimated by above relationships when vertical stress increases. This consistency at high levels of stress is due to loss of the original structure of clay. Thus, the normalised void ratio approached the value determined by Eq.(14).

Intrinsic compression curves for Baldivis clay which have been normalised using Burland's concept are presented in Fig. 8 at different initial water contents, from 0.67 to 1.33 times liquid limit. It can be seen that the results conform well with both Burland, 1990 [2] and Hong et al., 2010 [3] at post-yield state, i.e. when the vertical stress is greater than the remoulded yield stress. However, the void index is less than the calculated value of aforementioned relationships at pre-yield phase. On the other hand, compression curves cannot be normalised at pre-yield states by using the intrinsic framework. Moreover, the value of the void index is completely affected by the initial water content for the studied soil. It shows that there is a certain structure at the pre-yield state, i.e. the vertical stress is less than the remoulded yield stress, which bears the deformation, and this structure depends on the value of initial water content.

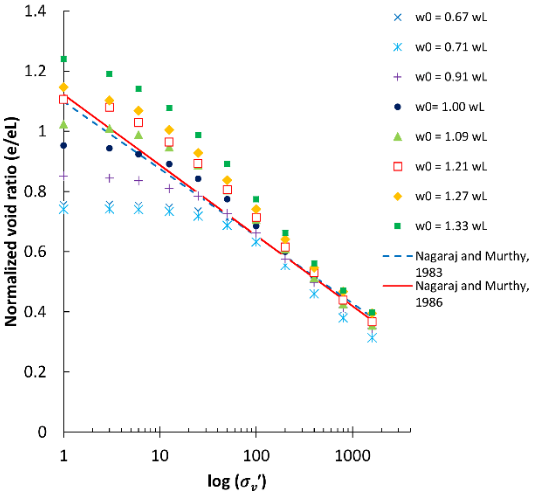


Fig. 7 Normalized void ratio graphs for Baldivis clay

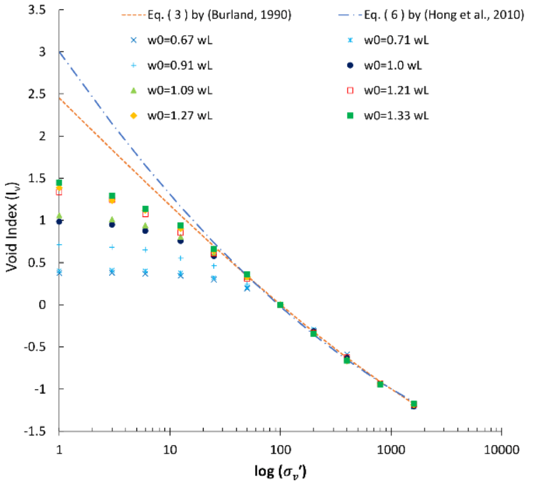


Fig. 8 Intrinsic compression curves for Baldivis clay

Figure 9 shows the measured values of intrinsic parameters of e^*_{100} and C^*_c for various initial states (i.e. w_0/w_L =0.67 to 1.33) and those calculated from Eq. (4) and (5). As can been seen in this graph, e^*_{100} increases gradually with an increase of water content. Moreover, for all ranges of initial water content, e^*_{100} is higher than the values calculated by the empirical relationship. On the other hand, the rate of variation of C^*_c against normalised water content is less than the rate of e^*_{100}. However, C^*_c has an almost positive correlation with the normalised water content to a lesser degree. C^*_c is approximately uniform for the range of the normalised water content of 1.0 to 1.33, which is in good agreement with Burland, 1990 [2]. Overall, the empirical relationships proposed by Burland, 1990 [2] underestimated intrinsic parameters for the studied range of initial water content for the studied soil.

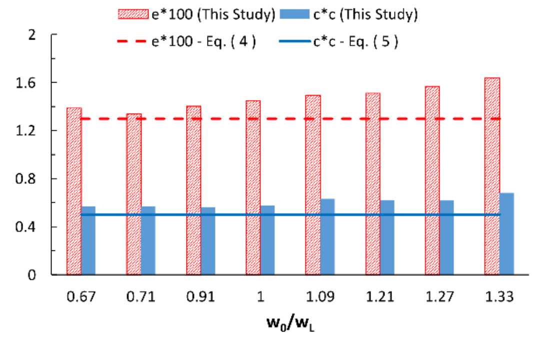
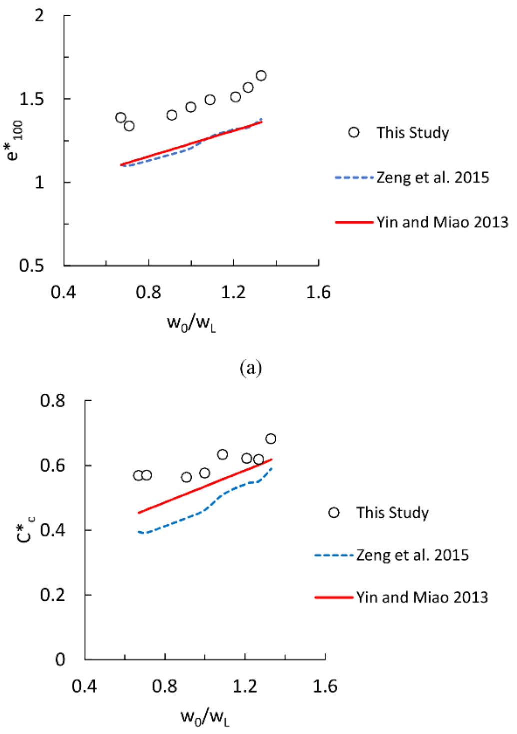


Fig. 9 Comparison of intrinsic parameters against initial water content

Figure 10 shows the measured values of intrinsic parameters for Baldivis clay as well as derived value for this soil using some more recent empirical relationships. The graph depicts that the measured values of both intrinsic parameters are higher than the derived ones through relationships proposed by Zeng et al., 2015 [5] and Yin and Miao, 2013 [7]. However, the increasing trend is almost the same for all these relationships and measured values. These results show how important the impact of clay minerals is on the values of intrinsic parameters, such as with Baldivis clay, with the chief clay of smectite, having unique values for intrinsic parameters regarding average values derived from empirical relationships. Therefore, the intrinsic framework can be used to properly characterise the inherent compression curves for various clays including expansive clays, yet the empirical relationships should be used cautiously as they underestimate the intrinsic parameters for clays with a considerable amount of smectite.



(a)

(b)

Fig. 10 Relationship of intrinsic parameters plot against initial water content: (a) e^*_{100} graph. (b) C^*_c graph

4. CONCLUSIONS

Intrinsic compression behaviour of Baldivis clay from Western Australia was investigated in this paper using two different methods of normalisation (i.e. normalised void ratio and void index). The following results were observed for the studied soil based on XRD and 1-D consolidation tests:

All compression curves of reconstituted Baldivis clay were an inverse S-shape similar to those of natural clays. The intrinsic concept can explain well the compression behaviour of reconstituted Baldivis clay beyond the remoulded yield stress. However, the behaviour is completely affected by the initial water content at stresses lower than the remoulded yield stress.

Inherent compression curves of an expansive clay can be well defined by two straight lines in a bi-logarithmic plane with a definite remoulded yield stress. However, the gap between normalised void ratios for different initial states decreases when the vertical stress increases and the original structure is destroyed. The remoulded yield stress has a negative non-linear correlation with normalised initial water content.

Intrinsic compression curves of the studied soil cannot be effectively standardised using normalised void ratio. However, the disparity decreases when the vertical stress increases. Nevertheless, the inherent compression curves can be normalised satisfactory for the post-yield phase by using the intrinsic concept and void index.

Most experimental relationships for estimating the remoulded yield stress of reconstituted clays in literature are based on consolidation tests on clays with the principal clay of illite. These relationships underestimate the value of remoulded yield stress. A new relationship has been presented in this study for predicting the remoulded yield stress, especially for expansive soils in which the predominant clay is smectite.

However, while the intrinsic frame of reference can be used to satisfactorily explain the compressibility of reconstituted clays, the experimental relationships developed for estimating the void index can underestimate the intrinsic compression parameters of expansive clays.

5. ACKNOWLEDGEMENTS

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