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Stress relaxation coefficient and formulation for soft soils

Z.-Y. YIN*†, Q.-Y. ZHU*†, J.-H. YIN‡ and Q. NI§

Current studies rarely investigate the stress relaxation behaviour of soft soils. This paper proposes a practically useful coefficient with a formulation based on the behaviour of stress relaxation under one-dimensional conditions. Firstly, the stress relaxation coefficient is proposed after summarising stress relaxation test results according to the linear relationship between the vertical stress and time in a double logarithmic plot. Secondly, from the newly developed rate-dependency based elasto-viscoplastic formulations, an analytical solution for stress relaxation is derived. A unique relationship connecting the stress relaxation coefficient, the secondary compression coefficient and the rate-dependency coefficient is then obtained. The applicability of the stress relaxation formulation with its key coefficient to determine time-dependent parameters is finally validated with published experimental results on reconstituted illite and Berthierville clay.

KEYWORDS: clays; laboratory tests; time dependence

NOTATION

b	experimental constant relating to stress relaxation
C_c	slope of the normal compression line in e–log(σ'_v) plane
C_s	slope of the swelling line in e–log(σ'_v) plane
$C_{\alpha e}$	secondary compression coefficient (based on e–log(t) curve)
CI	clay content
e	void ratio
e_0	initial void ratio
q	deviatoric stress
q_0	deviatoric stress at time t_0
$q(\varepsilon,t)$	deviatoric stress acting at a given axial strain ε at time t
t_0	time at the beginning of stress relaxation
t_{ie}	equivalent time
R_α	stress relaxation coefficient
w	water content
w_L	liquid limit
w_P	plastic limit
β	rate-dependency coefficient
ε_v^{vp}	viscoplastic volumetric strain
$\dot{\varepsilon}_v$	volumetric strain rate
$\dot{\varepsilon}_v^e$	elastic volumetric strain rate
$\dot{\varepsilon}_v^r$	reference volumetric strain rate
$\dot{\varepsilon}_v^{vp}$	viscoplastic volumetric strain rate
σ'_p	initial preconsolidation pressure corresponding to $\dot{\varepsilon}_v$
σ'_v	effective vertical stress
σ'_{vi}	initial effective vertical stress at the starting of stress relaxation

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INTRODUCTION

Natural soft clays exhibit significant time-dependency under laboratory and in situ conditions due to their viscosity. Typically, tests at different loading rates (e.g. Graham *et al.*, 1983; Leroueil *et al.*, 1985; Sheahan *et al.*, 1996; Kim & Leroueil, 2001; Karstunen & Yin, 2010; Yin & Karstunen, 2011; Yin *et al.*, 2010b, 2011) or creep tests (e.g. Yin & Graham, 1989; Kutter & Sathialingam, 1992; Sheahan, 1995; Vermeer & Neher, 1999; Yin *et al.*, 2010a; Wang & Yin, 2013, Yin *et al.*, 2013) are conducted to evaluate the time-dependent properties of soils. A few stress relaxation tests (e.g. Lacerda & Houston, 1973; Yin & Graham, 1989; Sheahan *et al.*, 1994; Fodil *et al.*, 1997; Kim & Leroueil, 2001; Yin & Hicher, 2008) have also been carried out and used to investigate the stress relaxation behaviour under different conditions. However, due to a lack of studies concerning the relationship between the key parameters of stress relaxation and strain-rate-dependency or creep parameters, the stress relaxation test is still not widely used to determine the time-dependency related parameters of soft soils.

This paper attempts to propose a stress relaxation coefficient with a formulation describing stress relaxation versus time, and investigates its relevance with the strain-rate-dependency parameter and the secondary compression coefficient. First, studies on stress relaxation are briefly summarised and discussed. A new stress relaxation coefficient based on the stress relaxation oedometer test – one of the simplest tests for soils – is then proposed. By deriving a newly developed rate-dependency based formulation, a stress relaxation formulation is proposed and relationships connecting the stress relaxation coefficient, the secondary compression coefficient and the rate-dependency coefficient are obtained. Published experimental results on reconstituted illite and Berthierville clay are used to validate the proposed formulation and coefficient, and the relationships between different time-dependency parameters.

EXPERIMENTAL EVIDENCE AND CURRENT APPROACHES FOR STRESS RELAXATION

Experimental investigations

Stress relaxation tests on different soft clays under different conditions have been carried out. These include tests on

- undisturbed soft San Francisco Bay Mud (w_L = 88%, w_P = 36%) under triaxial undrained conditions by Lacerda & Houston (1973) (Fig. 1(a))
- reconstituted Hong Kong marine deposit (w_L = 60%, w_P = 28%) under triaxial undrained conditions by Zhu *et al.* (1999) (Fig. 1(b))
- natural Le Flumet clay (w_L = 38%, w_P = 24%) under triaxial drained conditions by Fodil *et al.* (1997) (Fig. 1(c))
- natural Saint-Herblain clay (w_L = 96%, w_P = 54%) under pressuremeter conditions by Yin & Hicher (2008) (Fig. 1(d))
- reconstituted illite (w_L = 61%, w_P = 26%) under one-dimensional (1D) conditions by Yin & Graham (1989) (Fig. 1(e))
- Berthierville clay (w_L = 43%, w_P = 22%) by Kim & Leroueil (2001) (Fig. 1(f))
- reconstituted Boston blue clay (w_L = 42%, w_P = 23%) by Sheahan *et al.* (1994) under triaxial undrained conditions (Fig. 1(g)).

Based on these results, different expressions for the relationship between stresses and time were assumed, as follows.

Current approaches and limitations

Based on stress relaxation tests on various materials under triaxial stress conditions, Lacerda & Houston (1973) proposed a formulation of stress relaxation expressed as

$$\frac{q}{q_0} = 1 - s\log\left(\frac{t}{t_0}\right) \quad \text{for } t > t_0 \tag{1}$$

where s represents the slope of the relaxation curve in a q–log(t) diagram and relates to the deviatoric stress level. It is noted that one of the problems with equation (1) is that it predicts a negative stress because of the semi-logarithmic function with a large value of time t.

Later, Prevost (1976) developed a phenomenological approach to describe the stress relaxation behaviour of soils, expressed as

$$\begin{aligned} &q(\varepsilon_{1\cdot 0},\ t) = q(\varepsilon_{1\cdot 0},\ t) - \\ &[q(\varepsilon_{1\cdot 0},\ t) - q(\varepsilon_{1\cdot 0},\ 0)]\tanh\left[b\ln\left(\frac{t}{t_0}\right)\right] \quad \text{for } t > t_0 \end{aligned} \tag{2}$$

Equation (2) is capable of describing non-linear stress relaxation in q–log(t) space and operates with a final relaxed state of deviator stress when the time tends toward infinity. However, this approach needs six input parameters, which is inconvenient.

Yin & Graham (1989) proposed a formulation for the stress decay with time in stress relaxation under 1D conditions as

$$\sigma'_{\mathrm{v}} = \sigma'_{\mathrm{vi}}\left(\frac{t_{\mathrm{ie}} + t_0}{(C_{\mathrm{c}}/C_{\mathrm{s}})t + t_{\mathrm{ie}} + t_0}\right)^{C_{\alpha\mathrm{e}}/C_{\mathrm{c}}} \tag{3}$$

with

$$t_{\mathrm{ie}} = -t_0 + t_0\exp\left((\varepsilon_{\mathrm{v}} - \varepsilon^{\mathrm{ep}}_{\mathrm{v0}})\frac{1+e_0}{C_{\alpha\mathrm{e}}}\ln 10\right)\left(\frac{\sigma'_{\mathrm{v}}}{\sigma'_{\mathrm{v0}}}\right)^{-C_{\mathrm{c}}/C_{\alpha\mathrm{e}}} \tag{4}$$

where t_0 is the reference time, t_{ie} is the equivalent time and $\varepsilon^{\mathrm{ep}}_{\mathrm{v0}}$ is the strain at $\sigma'_{\mathrm{v}} = \sigma'_{\mathrm{v0}}$. The formulation implies a non-linear stress evolution with time followed by a linear stress relation with time in log–log space, which in general agrees with experimental observations. The stress relaxation was described directly by using the secondary compression coefficient $C_{\alpha\mathrm{e}}$. However, this expression does not relate stress relaxation behaviour to either a relaxation coefficient or a constant rate-dependent parameter (Leroueil *et al.*, 1985; Leroueil & Marques, 1996).

While the prior works evolved towards a mathematical characterisation of relaxation behaviour, there is no unifying expression that ties together the three time-dependent behaviours (i.e. stress relaxation, secondary compression and constant rate). The present work focuses on the stress relaxation coefficient and a formulation relating to behaviours of creep and rate-dependency under 1D conditions.

PROPOSED STRESS RELAXATION COEFFICIENT AND FORMULATION

Proposed stress relaxation coefficient

According to experimental results (Fig. 1), a linear relationship between the vertical stress and time in ln(σ'_{v})–ln(t) space during stress relation can be generally assumed. The slope of ln(σ'_{v}) versus ln(t) can then be defined as the stress relaxation coefficient R_α

$$R_\alpha = -\frac{\Delta\ln(\sigma'_{\mathrm{v}})}{\Delta\ln(t)} \tag{5}$$

Analytical solution of 1D stress relaxation

The authors have proposed a rate-dependency based elasto-viscoplastic model (Yin *et al.*, 2010b, 2011, 2013) similar to those proposed by Yin & Graham (1989), Kutter & Sathialingam (1992) and Leoni *et al.* (2008) based on the creep behaviour of clay. The total strain rate under 1D conditions can be expressed as

$$\dot{\varepsilon}_{\mathrm{v}} = \dot{\varepsilon}^{\mathrm{e}}_{\mathrm{v}} + \dot{\varepsilon}^{\mathrm{vp}}_{\mathrm{v}} = \frac{C_{\mathrm{s}}}{(1+e_0)\ln 10}\frac{\dot{\sigma}'_{\mathrm{v}}}{\sigma'_{\mathrm{v}}} + \dot{\varepsilon}^{\mathrm{r}}_{\mathrm{v}}\frac{C_{\mathrm{c}} - C_{\mathrm{s}}}{C_{\mathrm{c}}}\left(\frac{\sigma'_{\mathrm{v}}}{\sigma'^{\mathrm{r}}_{\mathrm{p}}}\right)^{\beta} \tag{6}$$

where β is the rate-dependency coefficient representing the slope of the linear relationship log(σ'_{p})–log(dε_{v}/dt), which was first proposed by Leroueil & Marques (1996), $\dot{\varepsilon}^{\mathrm{r}}_{\mathrm{v}}$ is the reference volumetric strain rate and the reference yield stress $\sigma'^{\mathrm{r}}_{\mathrm{p}}$ corresponds to $\dot{\varepsilon}^{\mathrm{r}}_{\mathrm{v}}$.

When the soil is under a stress relaxation condition, the total strain rate is zero. Thus, equation (6) can be rewritten as

$$\begin{aligned} &\frac{C_{\mathrm{s}}}{(1+e_0)\ln 10}\frac{\dot{\sigma}'_{\mathrm{v}}}{\sigma'_{\mathrm{v}}} = -\ \dot{\varepsilon}^{\mathrm{r}}_{\mathrm{v}}\frac{C_{\mathrm{c}} - C_{\mathrm{s}}}{C_{\mathrm{c}}} \\ &\left(\frac{\sigma'_{\mathrm{v}}}{\sigma'^{\mathrm{r}}_{\mathrm{pi}}\exp(\{[(1+e_0)\ln 10]/(C_{\mathrm{c}} - C_{\mathrm{s}})\}\varepsilon^{\mathrm{vp}}_{\mathrm{v}})}\right)^{\beta} \end{aligned} \tag{7}$$

where $\sigma'^{\mathrm{r}}_{\mathrm{pi}}$ is the initial value of the current reference stress corresponding to the start of stress relaxation. During stress relaxation, the viscoplastic strain is equal to the negative value of elastic strain

$$\varepsilon^{\mathrm{vp}}_{\mathrm{v}} = -\int\frac{C_{\mathrm{s}}}{(1+e_0)\ln 10}\frac{\dot{\sigma}'_{\mathrm{v}}}{\sigma'_{\mathrm{v}}}\mathrm{d}t \tag{8}$$

Since

$$\int\frac{\dot{\sigma}'_{\mathrm{v}}}{\sigma'_{\mathrm{v}}}\mathrm{d}t = \ln(\sigma'_{\mathrm{v}}) - \ln(\sigma'_{\mathrm{vi}})$$

(σ'_{vi} is the initial vertical stress at the starting of stress relaxation), substituting equation (8), equation (7) can be further transformed to

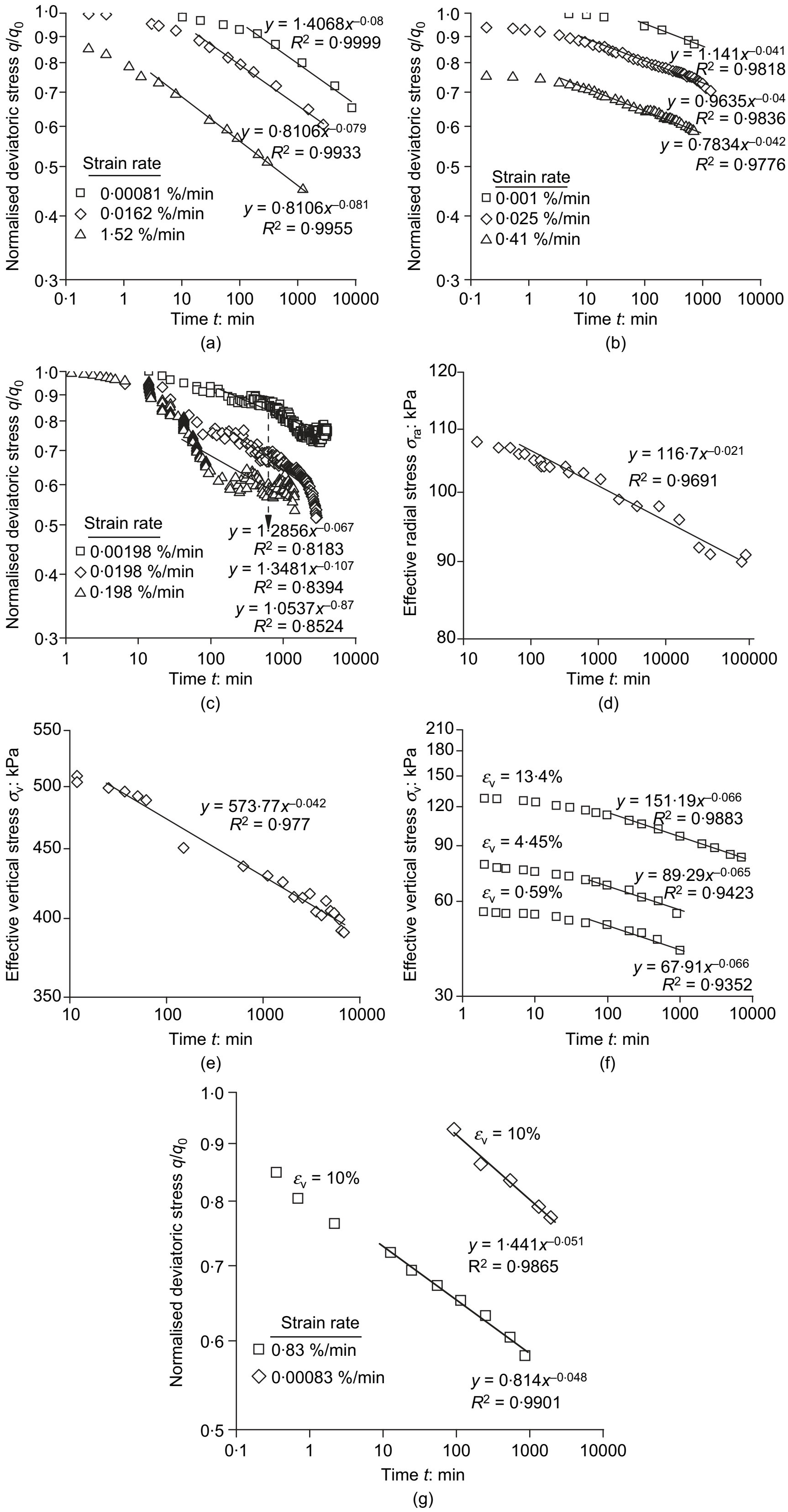

Fig. 1. Results of stress relaxation tests on different clays under different conditions: (a) undisturbed soft San Francisco Bay mud, triaxial undrained conditions; (b) reconstituted Hong Kong marine deposit, triaxial undrained conditions; (c) natural Le Flumet clay, triaxial drained conditions; (d) natural Saint-Herblain clay, pressuremeter conditions; (e) reconstituted illite, 1D conditions, strain rate $3{\cdot}7 \times 10^{-6}$/s; (f) Berthierville clay, 1D conditions, strain rate $6{\cdot}35 \times 10^{-6}$/s; (g) reconstituted Boston blue clay, triaxial undrained conditions

$$\frac{C_s}{(1+e_0)\ln 10}\frac{\dot{\sigma}'_v}{\sigma'_v} = -\dot{\varepsilon}_v^r \frac{C_c - C_s}{C_c}\left(\frac{\sigma'_v}{\sigma'^{r}_{pi}(\dot{\sigma}'_v/\dot{\sigma}'_{vi})^{-C_s/(C_c - C_s)}}\right)^{\beta} \tag{9}$$

In general form, the equation can be written as

$$\dot{\sigma}'_v = A(\sigma'_v)^m \tag{10}$$

with

$$A = -\dot{\varepsilon}_v^r \frac{\ln 10(1+e_0)(C_c - C_s)}{C_c C_s}\left(\frac{1}{\sigma'^{r}_{pi}\cdot\sigma'^{\,C_s/(C_c - C_s)}_{vi}}\right)^{\beta} \tag{11a}$$

and

$$m = \frac{C_c\beta}{C_c - C_s} + 1 \tag{11b}$$

where A and m are both constant values during stress relaxation. Solving this first-order differential equation with the initial condition σ'_{vi} for $t = 0$, the analytical solution for stress relaxation is

$$\sigma'_v = [A(1-m)t + \sigma'^{\,1-m}_{vi}]^{1/(1-m)} \tag{12}$$

Substituting the constants A and m into equation (12), the evolution of vertical stress is expressed as

$$\sigma'_v = \left(-\dot{\varepsilon}_v^r \frac{\ln 10(1+e_0)(C_c - C_s)}{C_c C_s}\left(\frac{1}{\sigma'^{r}_{pi}\cdot\sigma'^{\,C_s/(C_c - C_s)}_{vi}}\right)^{\beta}\left(-\frac{C_c\beta}{C_c - C_s}\right)t + \sigma'^{\,-\frac{C_c\beta}{C_c - C_s}}_{vi}\right)^{-\frac{C_c - C_s}{C_c\beta}} \tag{13}$$

Deriving stress relaxation coefficient with other time-dependency parameters

Based on the analytical solution of stress relaxation (equation (12)), R_α can be derived as follows. In the stage of stress relaxation, after a certain time, $\sigma'^{\,1-m}_{vi}$ become insignificant compared to $A(1-m)t$. Hence, the differential of $\ln(\sigma'_v)/\ln(t)$ is expressed as

$$\frac{\partial \ln(\sigma'_v)}{\partial \ln(t)} = \frac{1}{1-m} = -\frac{C_c - C_s}{C_c\beta} \tag{14}$$

Comparing equation (5) with equation (14), the stress relaxation coefficient R_α can be expressed in terms of compression parameters C_c, C_s and the rate-dependency coefficient β

$$R_\alpha = \frac{C_c - C_s}{C_c\beta} \text{ or } \beta = \frac{C_c - C_s}{C_c R_\alpha} \tag{15}$$

For natural soft clays, C_c/C_s varies generally from 5 to 15. According to this relationship, β can be expressed by R_α directly as described by equation (15). Figure 2 shows that the relationship between β and R_α is confined to a narrow range for a reasonable range of C_c/C_s.

Furthermore, Kutter & Sathialingam (1992) presented the quantity $(C_c - C_s)/C_{\alpha e}$ and Yin *et al.* (2010b, 2011) related it to the rate-dependency coefficient β (Leoni *et al.*, 2008) as

$$\beta = \frac{C_c - C_s}{C_{\alpha e}} \text{ or } C_{\alpha e} = \frac{C_c - C_s}{\beta} \tag{16}$$

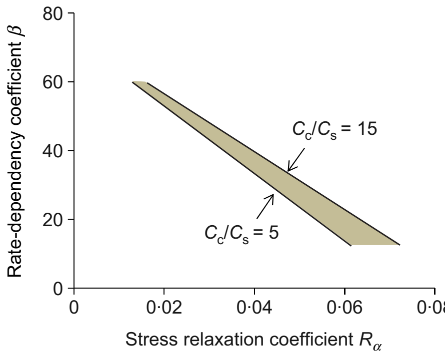

Fig. 2. Relationship between β and R_α for a reasonable range of ratio C_c/C_s for soft clays

Hence, substituting β from equation (16) into equation (15), R_α can also be expressed by $C_{\alpha e}$ or the inverse

$$R_\alpha = \frac{C_{\alpha e}}{C_c} \text{ or } C_{\alpha e} = R_\alpha C_c \tag{17}$$

Mesri & Castro (1987) showed that $C_{\alpha e}$ is related to C_c of the soil and, more precisely, that the ratio $C_{\alpha e}/C_c$ is constant for a given soil. Moreover, they summarised a range of values for a number of clays published in the literature and found that $C_{\alpha e}/C_c$ is 0·04 ± 0·01 for most inorganic soft clays and 0·05 ± 0·01 for highly organic plastic clays. Based on equation (17), it is interesting to note that this classification is also related to the stress relaxation coefficient. Consequently, previous studies on the properties of $C_{\alpha e}/C_c$ can be used for R_α.

According to Mesri & Castro (1987), C_c can be different for different loading increments. For soils with a constant C_c, many investigators have studied the relationship between C_c and clay physical properties and proposed correlation equations. The generally accepted correlation is the one proposed by Terzaghi & Peck (1967) as $C_c = 0{\cdot}009(w_L - 10)$. According to this, the ratio of $C_{\alpha e}/R_\alpha$ varies significantly with the liquid limit of soils.

Overall, based on the derived expressions between R_α, β and $C_{\alpha e}$, a unique relationship among the three time-dependency related parameters was obtained, which suggests that once R_α is measured, β and $C_{\alpha e}$ can be subsequently obtained. Therefore, the relaxation test can be used to determine the time-dependency related parameters. Note that the stress relaxation test can be a test stage during a constant rate of strain (CRS) test: a CRS test up to ε_v = 20% at $d\varepsilon_v/dt = 10^{-6}$/s (the order used by Yin & Graham (1989) and Kim & Leroueil (2001)) followed by a 1 day stress relaxation stage needs a total of 3·3 days, which is more beneficial than conventional oedometer testing in terms of time cost.

EXPERIMENTAL VALIDATION

In order to evaluate the applicability of the proposed stress relaxation formulation and its coefficient in studies of the time-dependent behaviour of soft clay, experimental validations were performed using test results on reconstituted illite by Yin & Graham (1989) and on Berthierville clay by Kim & Leroueil (2001).

Experimental description

Yin & Graham (1989) conducted a stress relaxation test following stepped CRS tests on reconstituted illite. The physical properties of the clay are summarised in Table 1.

Table 1. Physical properties of selected clays

	e_0	w: %	w_P: %	w_L: %	CI: %
Reconstituted illite	—	51	26	61	61
Berthierville clay	1·73	80	22	43	81

The stepped-loading portion of the test produced $C_c/(1+e_0) = 0{\cdot}23$, $C_s/(1+e_0) = 0{\cdot}057$ and $C_{\alpha e}/(1+e_0) = 0{\cdot}009$. Moreover, $R_\alpha = 0{\cdot}042$ was obtained in the $\ln(\sigma'_v)$–$\ln(t)$ plot (Fig. 1(e)).

Kim & Leroueil (2001) conducted a stress relaxation test with three stress relaxation stages on Berthierville clay at different strain levels during one CRS test (see Fig. 3). The physical properties of the Berthierville clay are summarised in Table 1. The specimen was loaded by displacement control at a constant strain rate of $6{\cdot}35 \times 10^{-6}$/s. Three relaxation stages were conducted when the vertical strain was equal to 0·59, 4·45 and 13·40%. From Fig. 3, $C_c = 1{\cdot}133$ and $C_s = 0{\cdot}074$ were measured. Based on the three stages of stress relaxation tests (Fig. 1(f)), an average $R_\alpha = 0{\cdot}0657$ was measured.

Stress relaxation behaviour

As discussed earlier, the time-dependency related parameters R_α, β and $C_{\alpha e}$ can each be obtained from the other two. Consequently, the analytical solution of 1D stress relaxation (equation (13)) using β can also be expressed directly by R_α. Thus, substituting equation (15) into equation (13), the stress relaxation can be expressed as follows by using R_α as a key parameter

$$\sigma'_v = \left(\left(\dot{\varepsilon}_v^r \frac{\ln 10(1+e_0)(C_c - C_s)}{C_c C_s} \frac{1}{\sigma'^r_{pi} \cdot \sigma'^{C_s/(C_c-C_s)}_{vi}}\right)^{\frac{C_c - C_s}{C_c R_\alpha}} \frac{1}{R_\alpha} t + \sigma'^{-1/R_\alpha}_{vi}\right)^{-R_\alpha} \quad (18)$$

Then, equation (18) is used to simulate the stress relaxation behaviour of both reconstituted illite and Berthierville clay. As shown in Fig. 4, the theoretical curves produced by the analytical solution can not only capture well the constant slope of stress relaxation in log–log space, but can also adequately describe the initial evolution of stress at the beginning portion of relaxation.

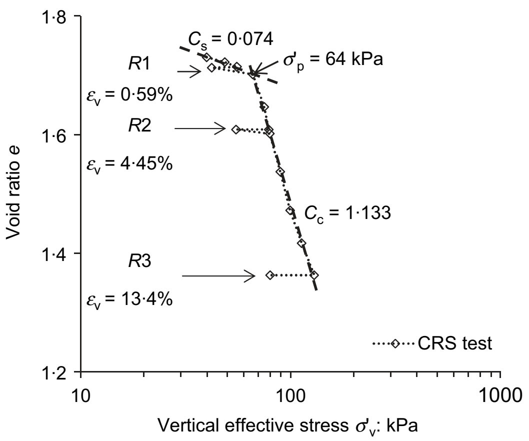

Fig. 3. Test stages of stress relaxation during a CRS test on Berthierville clay

Validation for strain-rate-dependent behaviour

As shown by equation (15), β can also be obtained by the stress relaxation coefficient R_α. In this way, $\beta = 17{\cdot}9$ and $\beta = 14{\cdot}2$ were obtained for reconstituted illite and Berthierville clay, respectively. To identify the difference between the experimental and derived values of β, adopting the preconsolidation pressure corresponding to the constant strain rate after which the stress relaxation stage was performed, $\log(\sigma'_{p0})$–$\log(d\varepsilon_v/dt)$ curves were plotted with β derived from R_α and compared with measurements for reconstituted illite and Berthierville clay. As shown in Fig. 5, the differences between measurements and theoretical curves are rather small and the predictions agree well with the experimental results.

Validation for creep behaviour

From 1D oedometer creep tests, $C_{\alpha e}/(1+e_0) = 0{\cdot}009$ was measured by Yin & Graham (1989) for reconstituted illite and an average $C_{\alpha e} = 0{\cdot}062$ was obtained for Berthierville clay by Leroueil *et al.* (1988). As shown in equation (16), $C_{\alpha e}$ can also be calculated by the stress relaxation coefficient R_α. In this way, $C_{\alpha e}/(1+e_0) = 0{\cdot}0097$ and $C_{\alpha e} = 0{\cdot}074$ were obtained for reconstituted illite and Berthierville clay, respectively. Comparing $C_{\alpha e}$ measured from creep tests and that derived by R_α, the differences are acceptable, which demonstrates the applicability of R_α in predicting $C_{\alpha e}$. Note that, currently, only data for two clays are available for the validation.

Overall, all the validations showed that the stress relaxation coefficient R_α can be used to predict the other two parameters (β and $C_{\alpha e}$), which reveals the unique stress–strain–strain rate law assumed by equation (6).

CONCLUSIONS

Previous studies on stress relaxation were briefly summarised and discussed. The experimental results suggest a linear relationship between vertical stress and time in the graph of $\ln(\sigma'_v)$–$\ln(t)$. Based on that, the stress relaxation coefficient R_α was proposed.

After developing the new rate-dependency based elasto-viscoplastic model, the stress relaxation formulation under 1D conditions was derived. Then, a unique relationship between the stress relaxation coefficient R_α, the secondary compression coefficient $C_{\alpha e}$ and the rate-dependency coefficient β was determined. This relationship indicates that β increases with decreasing R_α and $C_{\alpha e}$ increases with increasing R_α. Moreover, the relationship between β and R_α is confined in a narrow area for a reasonable range of C_c/C_s. The ratio of $C_{\alpha e}/R_\alpha$ varies significantly with the liquid limit of soils, taking into account the correlation between C_c and the liquid limit.

Test results on reconstituted illite and Berthierville clay were adopted to evaluate the applicability of the proposed stress relaxation coefficient and formulation. The stress relaxation coefficient was measured based on stress relaxation tests for both clays. The stress relaxation formulation was used and simulated well the experimental stress relaxation behaviours of the two clays. The measured

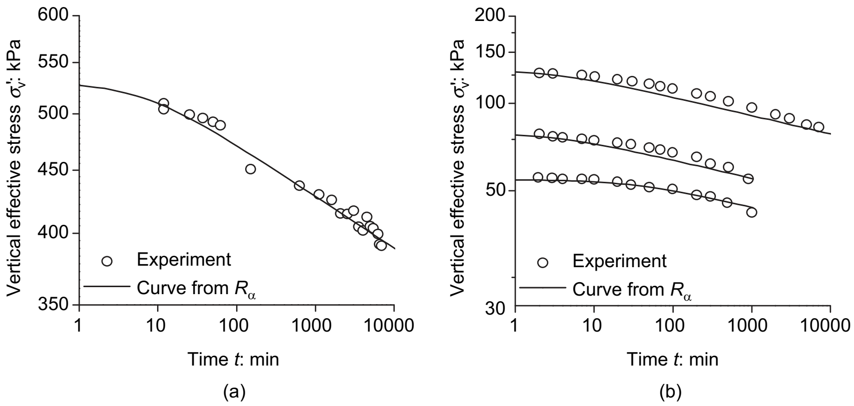

Fig. 4. Comparison of experimental and theoretical results for stress relaxation on (a) reconstituted illite and (b) Berthierville clay

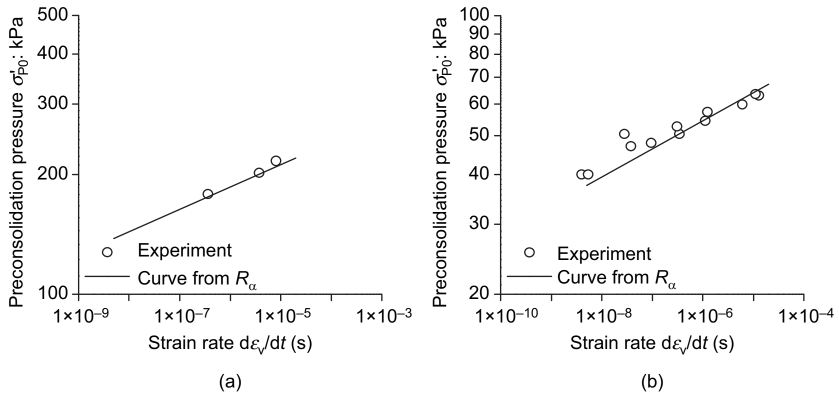

Fig. 5. Comparison of theoretical curves using β derived from R_α and measurements on the strain-rate-dependency of preconsolidation pressure for (a) reconstituted illite and (b) Berthierville clay

R_α was then used to derive the rate-dependency parameter β and the secondary compression coefficient $C_{\alpha e}$ to compare with experimental measurements. This demonstrated the applicability of the stress relaxation coefficient in determining other time-dependency parameters.

Further work will be carried out on stress relaxation tests for different clays under more complicated conditions (e.g. structured clays and triaxial conditions).

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