STRAIN RATE BEHAVIOR OF SAINT - JEAN - VIANNEY CLAY

P.K. ROBERTSON

FURGO (HONG KONG) LIMITED, HONG KONG

AND

Y.P. VAID

DEPARTMENT OF CIVIL ENGINEERING AND ENGINEERING MECHANICS
McMASTER UNIVERSITY, HAMILTON, ONTARIO

AND

R.G. CAMPANELLA

DEPARTMENT OF CIVIL ENGINEERING
THE UNIVERSITY OF BRITISH COLUMBIA, VANCOUVER, B.C.

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ABSTRACT

Rate effects on one-dimensional compressibility and undrained shear strength of a heavily overconsolidated naturally cemented clay have been studied. It is shown that in constant rate of strain consolidation tests, the compressibility increases and the apparent preconsolidation pressure decreases with progressive decrease in rate of strain. Also a decrease in undrained strength is shown to occur with slower rates of strain in constant rate of strain shear and with increased time of sustained loading in creep tests. Undrained strength from the two types of shear tests have been correlated.

INTRODUCTION

Deposits of sensitive marine clays, known as "Leda clays" are found in Eastern Canada in the valleys and tributaries of the St. Lawrence and Ottawa Rivers. These soils are known to possess extreme compressibility when loaded beyond their apparent preconsolidation pressure, and the stress-compressibility relationships have been found to be strongly dependent on the rate of loading (Crawford 1964, Jarret 1967). This poses considerable problems in field estimates of settlements. The more rapid rates of loading in laboratory consolidation tests result in magnitudes of apparent preconsolidation pressure which are higher than that applicable under the slow rate of loading of the natural clay deposit. When loaded in shear, Leda clays generally show a brittle behaviour at stress levels below the apparent preconsolidation pressure. The strength envelope in this range of stresses is believed to be governed by the strength of interparticle cementation bonds (Sangrey 1972, Lo and Morin 1972, Townsend et al 1969, Conlon 1966). Lo and Morin have suggested that this bonded structure strength envelope is a function of the rate of loading. Time effects on shear strength were also noted by Conlon (1966) and Crawford (1959, 1961, 1963) in tests on overconsolidated Leda clays.

Slopes in Leda clays have been susceptible to many landslides. The last major slide occurred at Saint-Jean-Vianney in 1971 (Tavenas et al 1971). Consequently many studies have been made on the geotechnical properties of Leda clays. However, research in the area of time effects on shear strength and compressibility of highly overconsolidated deposits of Leda clays is rather limited.

The purpose of the investigations reported in this paper was to study the influence of time on stress-compressibility and stress-strain and strength relationships of Leda clay from the site of the Saint-Jean-Vianney slide in 1971. Stress-compressibility behaviour was studied in one dimensional consolidation tests carried out at various constant rates of strain. Isotropically consolidated triaxial test specimens were loaded undrained under constant rate of strain and under constant stress creep in order to study the effect of time on stress-strain-strength behaviour.

DESCRIPTION OF THE SOIL TESTED

The clay used in this testing programme was block sampled from the site of the Saint-Jean-Vianney slide in Québec in June, 1971 by the Ministère des Richesses Naturelles du Quebec and the samples were provided by the courtesy of Laval University. Leda clays are believed to have been deposited in a brackish or marine environment during a brief postglacial period of isostatic depression and marine invasion. Subsequent leaching by percolating fresh ground water has been one of the reasons for the clay's large sensitivity. Cementation at particle contacts has also been postulated as a major cause for the large sensitivity (Crawford 1968 and Kenney, Moum and Berre 1967). Table 1 shows typical physical properties of the clay tested, which will be referred to as S.J.V. clay in this paper.

EXPERIMENTATION

Constant rate of strain consolidation tests were carried out in a larger sample version of the K_o - Triaxial cell (Campanella and Vaid, 1972). The sample was 6.1 cm in diameter and 2.5 cm high. During loading, the drainage was permitted from the top of the sample and excess pore water pressures were measured at the bottom. All consolidation tests were run under a back pressure of approximately 200 kPa in order to ensure complete saturation and freedom from compliance effects in pore pressure measurements, which are invariably associated with tests using no back pressure. In addition, an incremental loading consolidation test was performed using a 5 cm diameter polished stainless steel ring consolidometer and 2.5 cm high

TABLE 1

PHYSICAL PROPERTIES OF UNDISBURBED SAINT-JEAN-VIANNEY (S.J.V.) CLAY*

Liquid Limit	36%
Plastic Limit	20%
Plasticity Index	16%
Natural Water Content	42% ± 1%
Degree of Saturation	100%
Specific Gravity of Solids	2.75
Percent Finer than 2μm	50%
Unconfined Compressive Strength (test duration approx. 3 min.)	640 kPa
Sensitivity	Approx. 100
Activity $\frac{\text{P.I.}}{\% < 2\ \mu\text{m}}$	0.32
Maximum Past Pressure	Approx. 940 kPa

* The block sample was taken from an elevation of approximately 40 m in a trench dug in the lowest part of the crater left by the slide.

sample. The standard load increment ratio of one was not adhered to in the neighbourhood of the apparent pre consolidation pressure in order to obtain a more accurate pressure void ratio curve by this incremental test. Each load increment, however, was maintained for 24 hours before adding the next.

Constant rate of strain undrained shear and constant stress undrained creep tests were carried out on samples isotropically consolidated to an effective confining pressure of approximately 4o kPa. This low consolidation pressure was chosen in order that the behaviour of this clay could be studied in a highly overconsolidated range, where the shear strength is considered to be governed by the strength of the natural cementation bonds. The samples were 3.5 cm in diameter and 7.5 cm long and were consolidated under a back pressure of 300 kPa.

Two thin rubber membranes, separated by a thin layer of silicone grease, were used to seal the triaxial samples. This manner of sealing was found to result in no noticeable rise in pore water pressure (an absence of leakage) even in saturated metal samples when left undrained for up to 3 weeks under a consolidation pressure of 100 kPa. Thus, the measured pore water pressures in creep tests were not affected by possible leakage into the samples.

The clay was very stiff in the undisturbed state. Extreme care was required in sample trimming. A sharp knife was used to remove extremely small shavings while trimming. Special care was taken to cut the ends of samples square in order to avoid premature failure due to eccentric loading on account of possible non-parallel ends.

All the test variables were electronically monitored using transducers and test data was automatically recorded by a digital data aquisition system.

CONSOLIDATION CHARACTERISTICS

Figure 1a shows the results of constant rate of strain consolidation

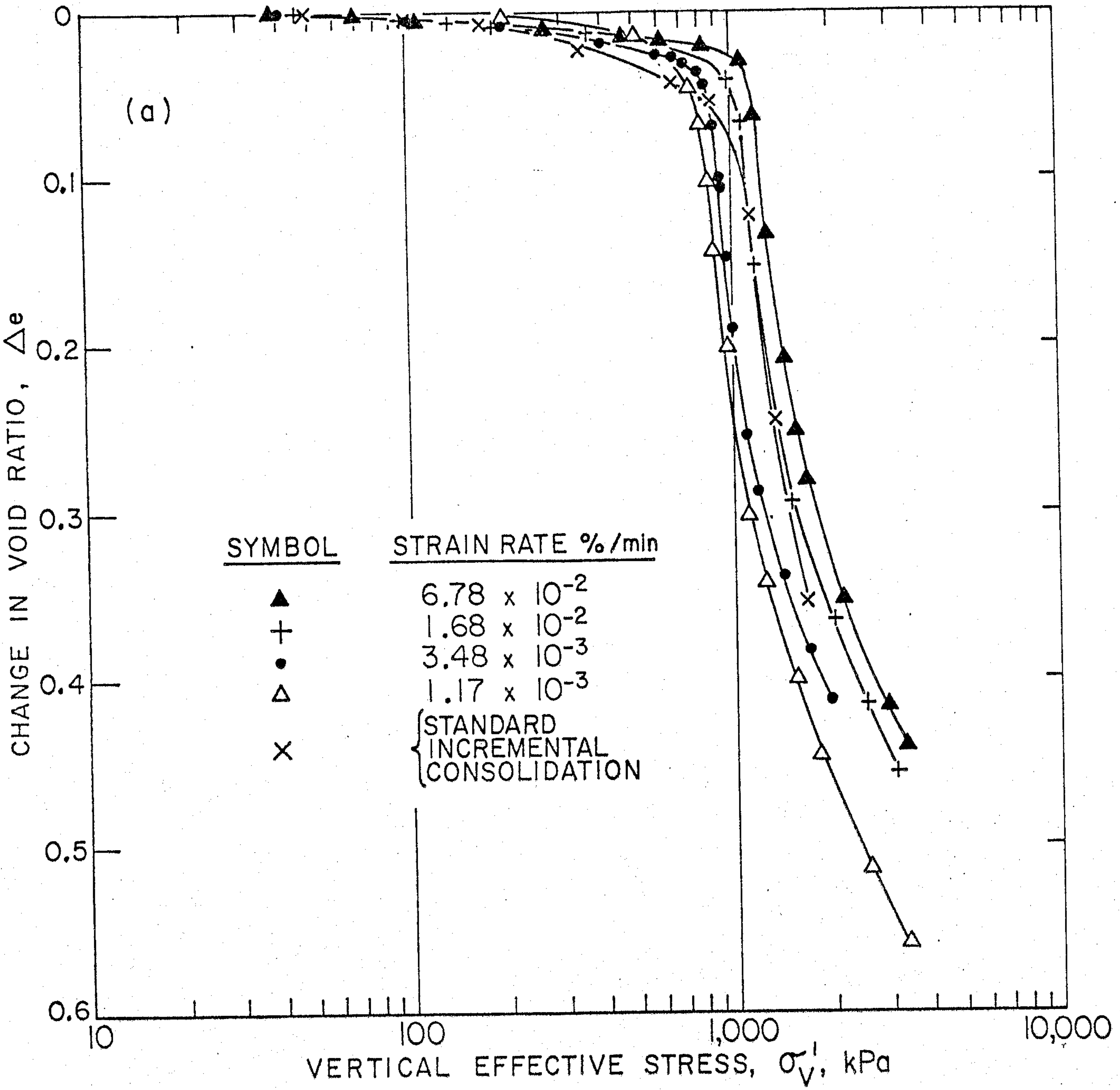

FIG. 1(a) ONE-DIMENSIONAL CONSOLIDATION CHARACTERISTICS OF S.J.V. CLAY.

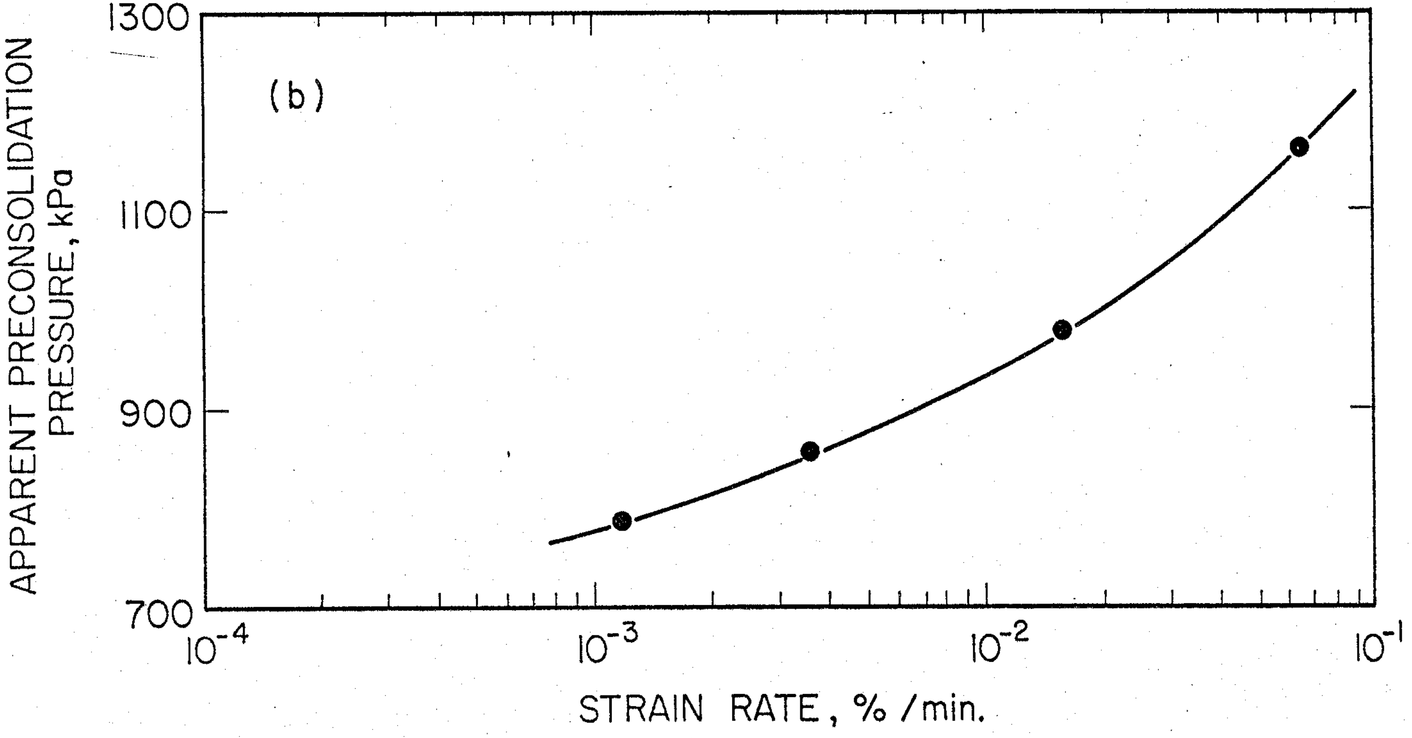

FIG. 1(b) ONE-DIMENSIONAL CONSOLIDATION CHARACTERISTICS OF S.J.V. CLAY tests expressing change in void ratio, Δe, against log-vertical effective stress, σ_v'. The rates of strain were selected so as to apply to the clay a given effective stress over widely different times, and also not to generate large excess pore water pressures. The maximum excess pore water pressure in the fastest test was 7 per cent of the applied stress for stresses in excess of 600 kPa. In the two slow tests, no measurable excess pore water pressures were generated. The average excess pore water pressure was taken as two thirds the excess pore water pressure at the base, if any, while computing σ_v'.

It may be seen in Figure 1a that the Δe vs. log σ_v' relationship of S.J.V. clay is a function of the rate of strain. At each strain rate an extremely well defined Δe vs. log σ_v' relationship was obtained with an abrupt change in the clay compressibility near the apparent preconsolidation pressure, which is typical of sensitive clays. The apparent preconsolidation pressure, p_c, however, was found to be a function of the rate of strain (Fig. 1b), varying between a high of 1160 kPa for the fastest to a low of 780 kPa for the slowest strain rate used. Similar variations in preconsolidation load of Leda clays have been reported by Crawford (1964) in variable time duration incremental loading and by Jarret (1967) in constant rate of loading consolidation tests. A sharp downward break in the Δe vs. log σ_v' curve in the vicinity of the apparent preconsolidation pressure has been attributed to the abrupt break up of natural cementation bonds in Leda clays (Conlon, 1966, Sangrey 1972, Townsend et al 1969). Changes in apparent preconsolidation pressure due to change in rate of strain is thus an indication of the rate sensitivity of the strength of cementation bonds. In the constant rates of strain consolidation tests shown in Figure 1, the rate of loading was essentially linear with time, until the apparent preconsolidation load was reached. This indicates that the clay behaved elastically in the recompression range. Loading rates became much slower when the apparent preconsolidation pressure was exceeded, which was further followed by an increase in rate of loading as the compressibility of the clay progressively decreased under increasing effective stresses.

Time effects on stress-compressibility relationships of S.J.V. clay are shown more clearly in Figure 2. The change in void ratio, Δe, is plotted against elapsed time since loading for given constant values of applied σ_v'. As can be seen, significant time effects on compressibility are not apparent until the clay is loaded to beyond $\sigma_v' = 700$ kPa. For example, under an effective stress of $\sigma_v' = 1100$ kPa ten times larger compression occurred when this pressure was reached in 15,000 minutes instead of 30 minutes.

Although the effect of duration of loading on compressibility was significant for all σ_v' beyond about 700 kPa, more dramatic effects seemed to be confined to a range of σ_v' values between 800-1300 kPa. This range of stresses is the same as the range of apparent preconsolidation pressures observed for the strain rates used in the testing program. Jarret (1967) noted similar results on a less heavily overconsolidated Leda clay when consolidated under constant rate of loading. In field loading of thick deposits of clay, the rate of effective stress increase is several orders of magnitude slower than that in the laboratory samples, particularly at locations remote from the drainage boundaries. A rational assessment of field settlement in sensitive bonded clays, for loading in the range straddling the apparent preconsolidation pressure, should take due account of loading duration on the magnitude of apparent preconsolidation pressure.

Results of an incremental consolidation test on S.J.V. clay are also shown in figure 1a. Expect in the recompression range, these results fall essentially within the range of results obtained from constant rate of strain consolidation tests. Crawford (1968) pointed out that a reduced load increment ratio could define more accurately the magnitude of p_c for sensitive clay.

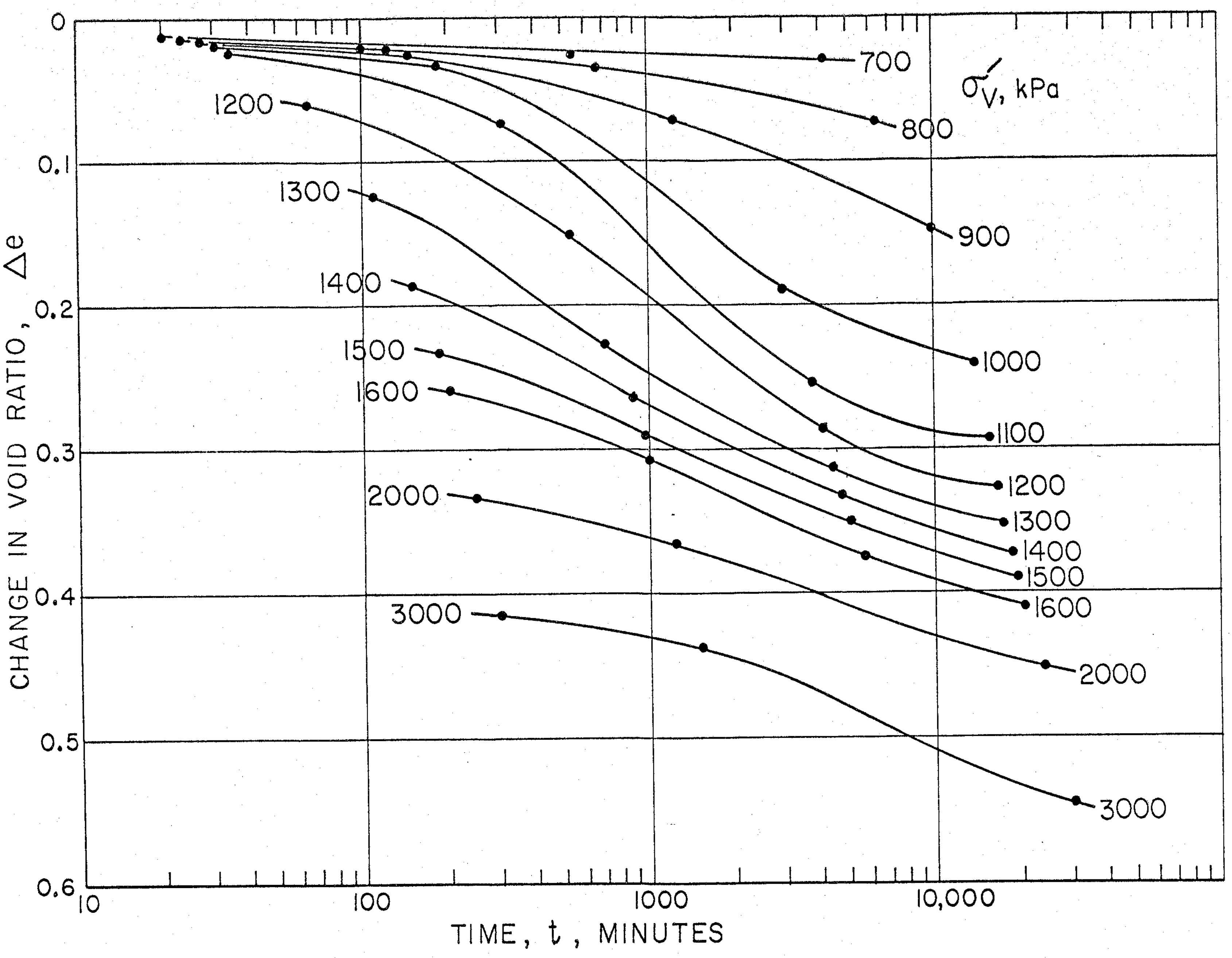

FIG. 2. EFFECT OF TIME ON STRESS-COMPRESSIBILITY BEHAVIOUR OF S.J.V. CLAY.

However, even though a reduced load increment ratio was used arount the apparent preconsolidation pressure, incremental consolidation did not yield as well defined p_c and Δe - log σ_v' relationship as was obtained by constant rate of strain consolidation tests. The standard incremental consolidation test is generally not suitable for an accurate determination of the apparent preconsolidation pressure of sensitive bonded clays.

The incremental consolidation test was carried out with single drainage and pore water pressure measurements at the base. It was observed that a significant part of the total compression during load increments approaching p_c and beyond was due to secondary effects, since no measurable pore water pressures were recorded during this phase of compression. For example, during the load increment $\sigma_v' = 840 - 1130$ kPa, which straddled the apparent preconsolidation pressure, almost half of the total compression was of a secondary nature.

SHEAR STRENGTH CHARACTERISTICS

Behaviour in Constant Rate of Strain Shear

Figure 3a shows the results of a set of three undrained constant rate of strain compression tests at different strain rates. The results clearly demonstrate that there was a 25 per cent increase in peak deviator stress with about a 100 times increase in strain rate. The prepeak part of the curves show that the distortion was of a linear nature. The effect of strain rate in this linear range before peak deviator stress was quite small in comparison to the point at which peak occurred. It would appear that any bonding that exists within the clay is not very strain rate dependent, except in relation to the point at which the bonds actually break. This point of failure, or peak deviator stress, was reached at between 0.58 and 0.70 per cent strain, which is an extremely small strain. This small strain level at peak deviator

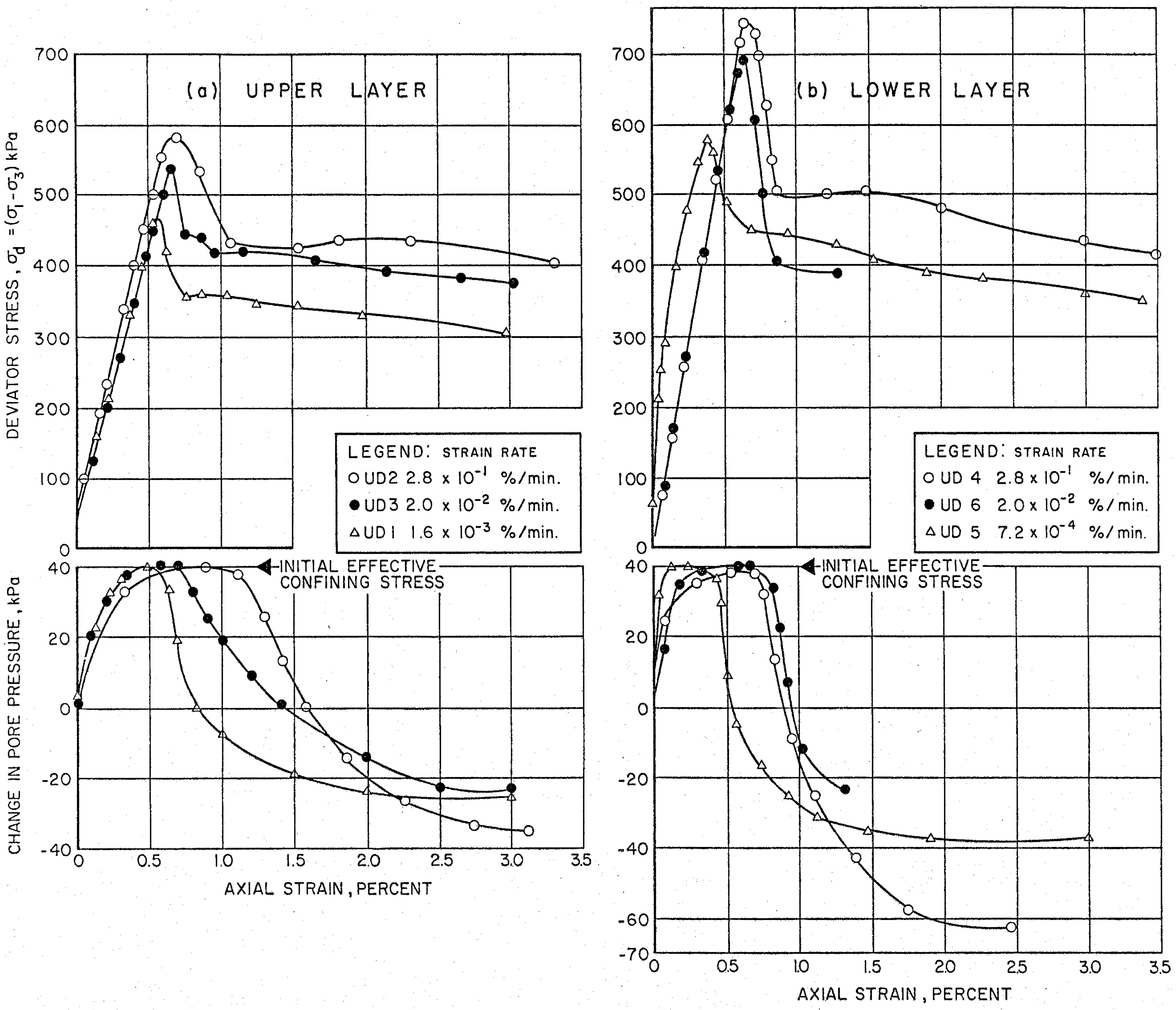

FIG. 3. STRESS-STRAIN AND PORE WATER PRESSURE BEHAVIOUR OF S.J.V. CLAY IN CONSTANT RATE OF STRAIN UNDRAINED COMPRESSION.

stress is typical for such a stiff, overconsolidated and bonded clay. Figure 3a also shows how the pore water pressure quickly rose to almost equal the consolidation pressure, then rapidly decreased to a negative value. This rise in pore water pressure meant that, at peak deviator stress, the samples were essentially under zero effective confining stress. This resulted in some of the samples showing signs of vertical splitting due to tensile failure caused apparently by the presence of rigid end caps. This also suggests that just about all of the compressive strength of these samples was due to some form of cementation bonding.

The block from which the samples came was so shaped that the samples used for the first three undrained strain controlled compression tests and the first three creep tests were from the top half of the block whilst the remaining samples were from the lower half. Figure 3b shows the results of the undrained constant rate of strain compression tests on the clay from the lower layer of the block. It may be noted that at corresponding rates of strain, there was approximately 28 per cent increase in undrained strength of this second layer in comparison to the first layer, even though the samples were only inches apart vertically. No complete explanation can be given for this, except that the concentration of silt lenses did appear to be higher in the top layer. However, the results in Figure 3b still show that there was a 25 per cent increase in undrained strength with a 100 times increase in strain rate. Figure 3b also shows how the pore water pressure rose quickly to equal the consolidation pressure and then after peak, dropped rapidly to a negative value. Again this suggests that just about all the strength of these samples was due to cementation bonding and that the *bond strength appears to be a function of strain rate.*

Rate dependence of undrained strength in conventional constant rate of strain tests on overconsolidated Leda clays has also been reported by other researchers (Crawford 1959, 1961, 1963, Coates and McRostie 1963, Conlon 1966), who noted an increase of about 6 to 12 per cent in undrained strength for a ten fold increase in rate of strain. S.J.V. clay tested in these investigations showed a similar level of strength increase.

It has been suggested (Conlon 1966) that during shear tests on a naturally cemented clay, bonds break in response to both increase in consolidation stresses and deviator stress. A vivid demonstration of bonds breakdown due to large consolidation stresses was noted when an undisturbed sample of S.J.V. clay was first air dried and then submerged in water. The sample started to flake immediately and completely disintegrated within 10 minutes. An identical sample when submerged in water in its natural state did not show any signs of disintegration for several days and maintained its original consistency. Air drying obviously caused large shrinkage stresses, thereby resulting in a complete breakdown of natural cementation bonds.

Figure 4 shows the effective stress path on a modified Mohr plot for one of the undrained constant rate of strain compression tests (UD2). The stress path shows how the effective stresses within the sample quickly rise and climb up closely to the limit of triaxial testing ($\sigma'_3 = 0$). The average normal effective stresses continue to rise following this limitation until peak deviator stress, whereupon they drop back sharply. Further straining moves the state of stress toward an ultimate strength condition. All the undrained constant rate of strain compression tests followed this same pattern except for the point at which peak deviator stress was reached.

Figure 5 shows the results of all constant rate of strain compression tests on the modified Mohr plot corresponding to both peak and ultimate (axial strain $\geqslant$ 3%) conditions. It may be seen that irrespective of the rate of strain or the location of samples within the block, the peaks of deviator stress lie on or very close to the limit of triaxial testing. Figure 5 also shows that

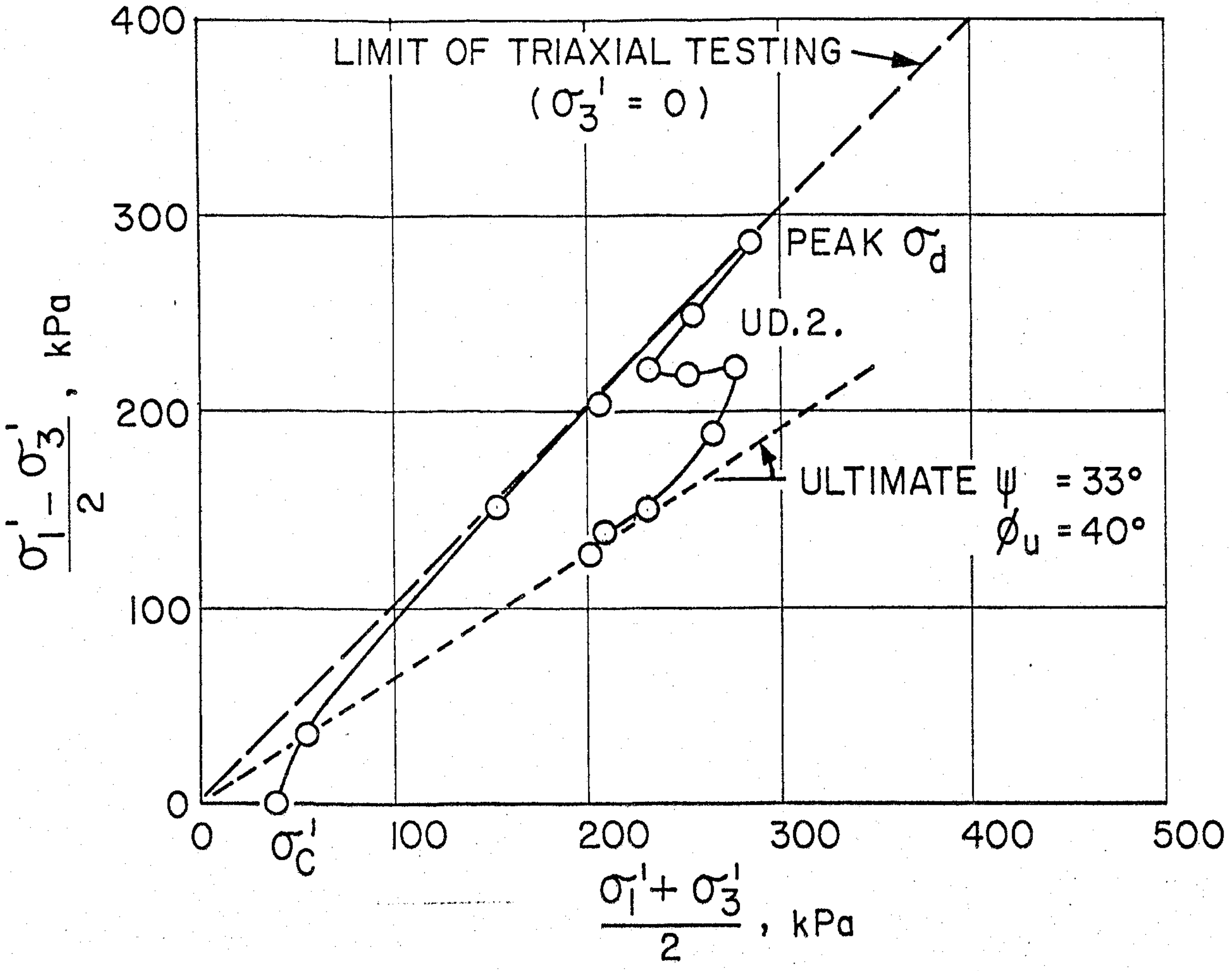

FIG. 4. TYPICAL STRESS PATH IN CONSTANT RATE OF STRAIN, UNDRAINED COMPRESSION TESTS FOR S.J.V. CLAY.

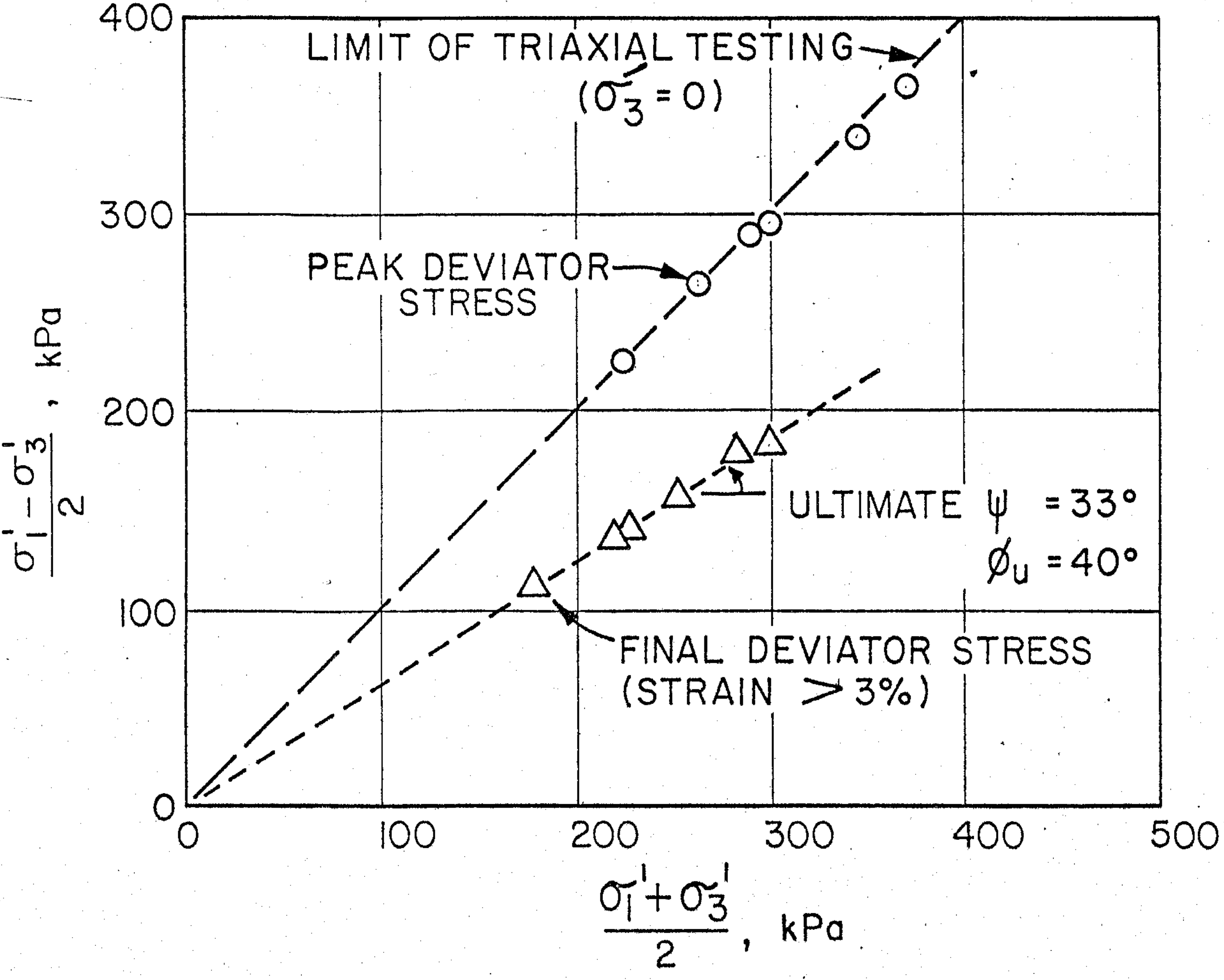

FIG. 5. EFFECTIVE STRESS CONDITIONS AT FAILURE FOR S.J.V. CLAY.

the final deviator stress condition lies on a linear envelope passing through the origin that rises at around 33 degrees to the abscissa for a value of ϕ_u = 40 degrees. This value appears to agree well with the "residual friction envelope" as it was called by Lo and Morin (1972), ϕ_r = 44 degrees, for Leda clays from St. Louis and St. Vallier when sheared starting from effective consolidation stresses well below the apparent preconsolidation pressure.

A summary of the results for the constant rate of strain compression tests is given in Table 2.

BEHAVIOUR UNDER CREEP LOADING

Time - dependent deformation and creep rupture under constant stress is another manifestation of time effects on shear behaviour. Figure 6 shows the accumulation of axial strain and change in pore water pressure, Δu with time at various levels of constant deviator stress, σ_d, in a series of samples of S.J.V. clay. For the stress level σ_d = 550 kPa and larger the samples from the lower layer of the block progressively strained with time until eventual rupture. However, the sample under σ_d = 515 kPa showed continuously decreasing rate of strain until an elapsed time of about one week when the test was terminated. In samples which eventually ruptured, the pore water pressure increased with time to a value close to the consolidation pressure (Fig. 6b). Thereafter the pore water pressure decreased rapidly to negative values as the samples strained towards rupture with increasing time. Samples from the upper layer of the block demonstrated similar behaviour and are also included in Figure 6.

Figure 7 shows the strain rate - time histories under creep loading. The regions of initially decreasing, leading to a minimum and ultimately increasing strain rate, may be noted for samples which finally ruptured.

TABLE 2

RESULTS OF CONSTANT RATE OF STRAIN UNDRAINED TRIAXIAL TESTS

Sample Location	Test No.	Strain Rate $\dot{\varepsilon}$ %/min	Effective Consol. Stress σ'_3 kPa	Peak σ_d kPa	Percent Strain at Peak σ_d	Final σ_d kPa ($\varepsilon \geqslant 3\%$)
Upper Layer	UD2	2.8×10^{-1}	40	580	0.70	420
	UD3	2.0×10^{-2}	40	535	0.68	375
	UD1	1.6×10^{-3}	40	470	0.58	310
Lower Layer	UD4	2.8×10^{-1}	40	745	0.68	440
	UD6	2.0×10^{-2}	40	690	0.65	N/A
	UD5	7.2×10^{-4}	40	580	0.40	360

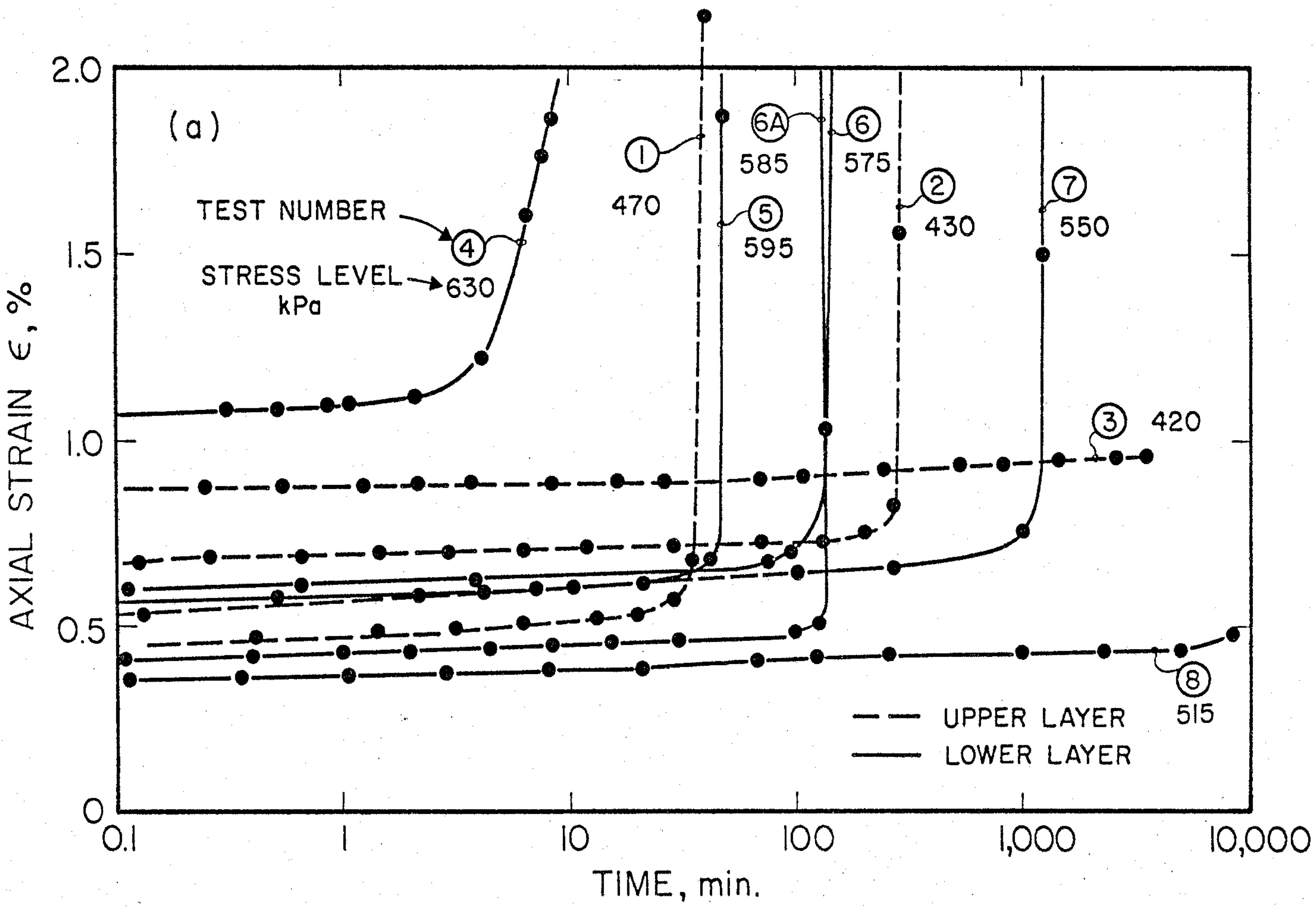

FIG. 6(a) VARIATION OF AXIAL STRAIN AND PORE WATER PRESSURE WITH TIME IN CONSTANT STRESS CREEP TESTS ON S.J.V. CLAY.

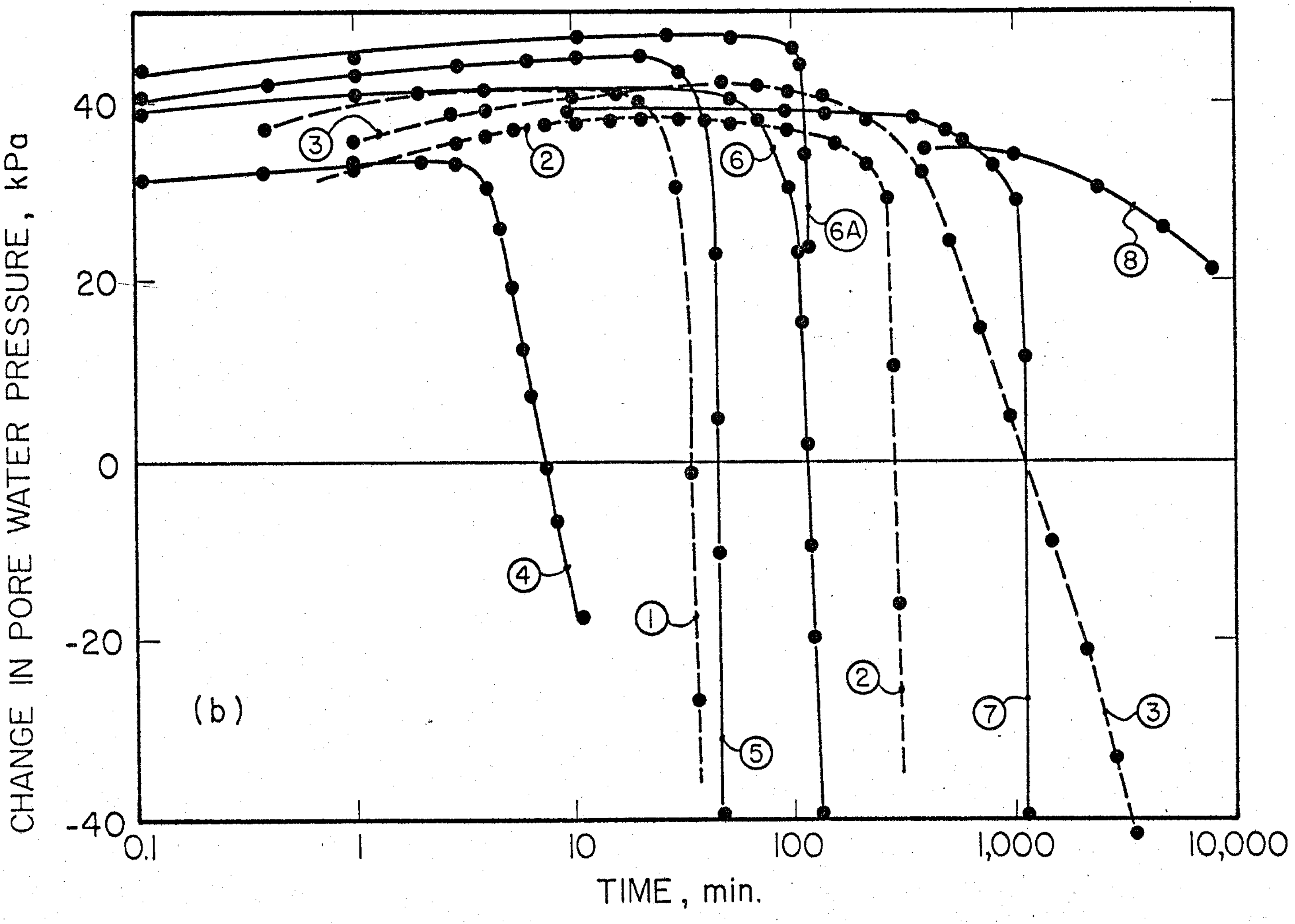

FIG. 6(b) VARIATION OF AXIAL STRAIN AND PORE WATER PRESSURE WITH TIME IN CONSTANT STRESS CREEP TESTS ON S.J.V. CLAY.

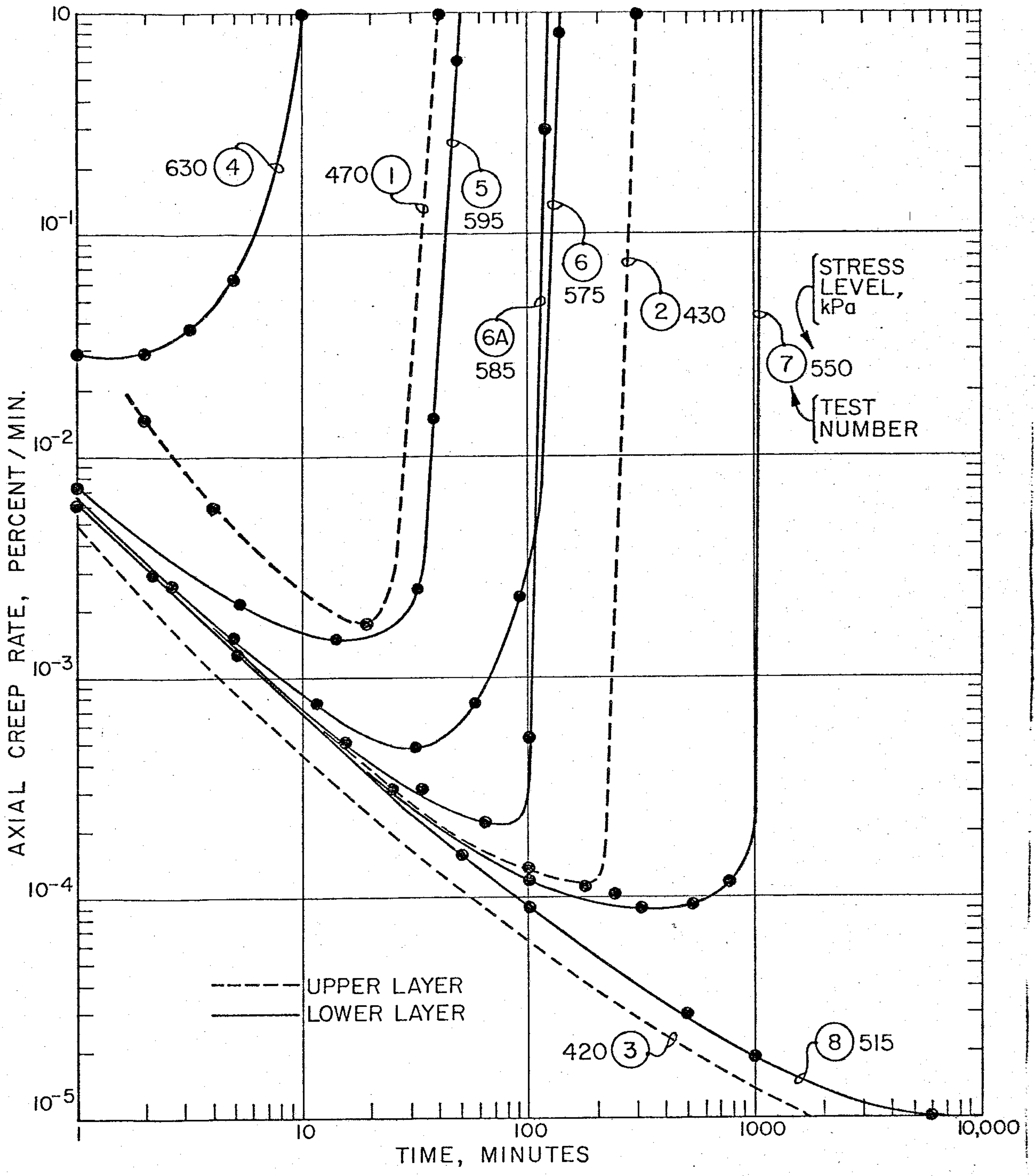

FIG. 7. VARIATION OF CREEP RATE WITH TIME IN CONSTANT STRESS CREEP TESTS ON S.J.V. CLAY.

During the region of increasing strain rate, the pore water pressure was rapidly decreasing (Fig. 6b) and hence the effective stresses were increasing with time. Accelerating creep rate at constant σ_d despite increasing effective stresses cannot therefore be explained in terms of effective stresses within the samples. Samples CRT3 and CRT8, which did not rupture, show a continuously decreasing strain rate with time. The creep rate behaviour of S.J.V. clay is similar to that reported earlier by Vaid and Campanella (1977) for an uncemented normally consolidated natural clay.

Strength reduction with time under sustained loading expressed by a relationship between σ_d and log rupture life, t_f (total elapsed time since initiation of creep) is shown in Figure 8. There was a marked reduction in rupture life as the creep stress increased. The shape of the stress - rupture life curve, however, is seen flattening off with decrease in creep stress level and seems to indicate the existence of an upper yield strength below which creep rupture will not occur. If it is assumed that the sample CRT8, which did not rupture under a sustained stress of 515 kPa for about one week, would never fail, the upper yield strength of the clay will lie between the limits 550 kPa and 515 kPa. Reduction in creep strength of Leda clays from other localities has also been reported by Crawford (1963) and Coates, Burn and McRostie (1963).

It was shown by Vaid and Campanella (1977), that the creep strength and strength under constant rate of strain of a clay could be correlated using the hypothesis that a unique stress - strain - strain rate relationship exists for the clay. The hypothesis postulated that the stress at a given strain during the deformation process is a function only of the current strain rate and is independent of the past strain rate history. An important consequence of the hypothesis was that the relationship between undrained strength and

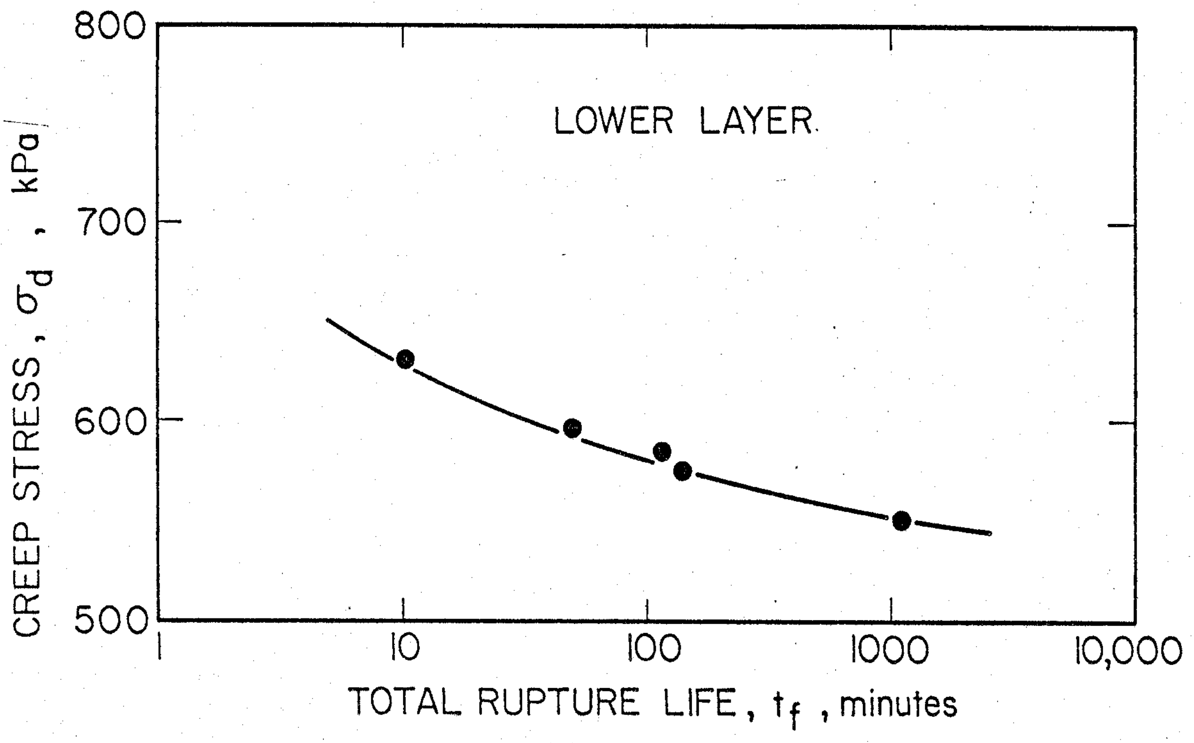

FIG. 8. TIME DEPENDENCE OF UNDRAINED STRENGTH IN CONSTANT STRESS CREEP TESTS ON S.J.V. CLAY.

strain rate observed in the constant rate of strain shear will be identical to the relationship between creep stress and the minimum strain rate in creep rupture tests. Figure 9 shows the experimental data for these two types of shear tests on S.J.V. clay, and it may be seen that the results provide a good correlation of strength under constant rate of strain and sustained loading conditions. The existence of a minimum strain rate in creep tests is a positive indication of impending failure. Minimum strain rate is thus the critical parameter which controls the creep strength of a clay.

The axial strain at the instant of minimum strain rate in creep rupture tests varied between 0.42 to 0.49 (Table 3). The corresponding values of strain at peak deviator stress in constant rate of strain tests were in the range of 0.40 - 0.68% (Table 2). Similarity in the magnitude of these strains in the two types of tests suggests that the failure of the clay tested seems to be controlled by a critical level of shear strain. Such a possibility was suggested by Coates and McRostie (1963). This critical strain would be required in order to mobilize the full strength of the cementation bonds, which exclusively control the strength of the soil in the range of stresses below the apparent preconsolidation pressure.

CONCLUSIONS

Both the compressibility and the undrained shear strength of a naturally cemented heavily overconsolidated clay were found to be profoundly influenced by the time effects. Slow rates of strain in constant rate of strain consolidation tests resulted in large reductions in apparent preconsolidation pressure and increased compressibility. A decrease in the rate of strain in constant rate of strain shear tests was associated with significant loss in undrained strength. Similar reductions in strength were noted in creep tests. Creep stress at a given minimum strain rate was found

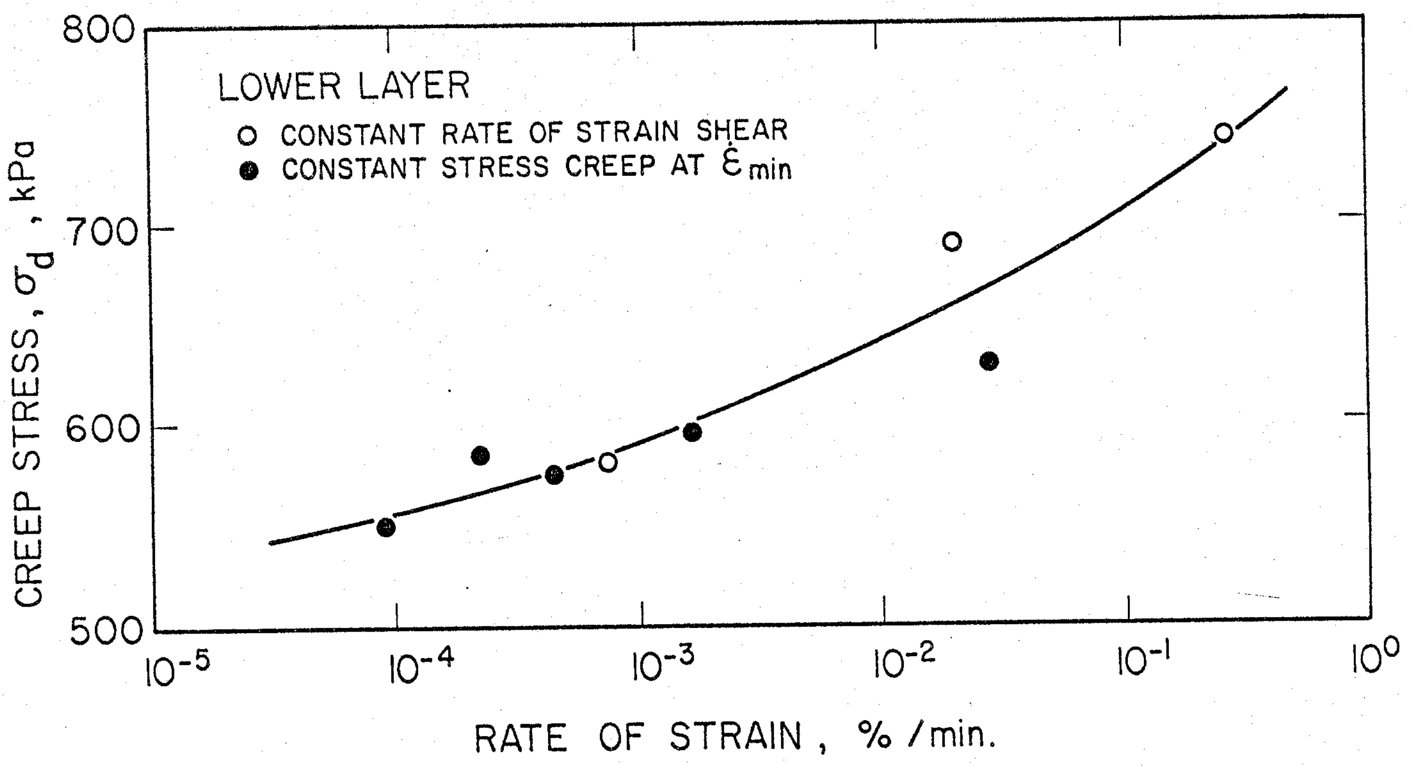

FIG. 9. STRAIN RATE DEPENDENCE OF UNDRAINED STRENGTH IN CONSTANT RATE OF STRAIN SHEAR AND CONSTANT STRESS CREEP OF S.J.V. CLAY.

TABLE 3

SUMMARY OF RESULTS OF CREEP TESTS

Sample Location	Undrained Test No.	Creep Stress σ_d kPa	Mean Effective Consol. Stress σ'_2 kPa	Minimum Strain Rate $\dot{\varepsilon}_{min}$ (%/min)	Strain at $\dot{\varepsilon}_{min}$ %	Rupture Life t_f min
Upper Layer	CR.T1	470	45	1.8×10^{-3}	0.40	40
	CR.T2	430	42	1.2×10^{-4}	0.42	300
	CR.T3	420	42	1.0×10^{-6}	0.95	3426 No Failure
Lower Layer	CR.T4	630	43	2.7×10^{-2}	0.42	10
	CR.T5	595	47	1.5×10^{-3}	0.46	50
	CR.T6A	585	49	2.1×10^{-4}	0.47	120
	CR.T6	575	46	4.6×10^{-4}	0.46	135
	CR.T7	550	43	8.9×10^{-5}	0.49	1050
	CR.T8	515	45	1.0×10^{-5}	0.50	8586 No Failure

to be identical to the peak deviator stress in constant rate of strain tests carried out at the minimum strain rate of the creep test. Failure of the clay under both creep and strain controlled loading was associated with approximately constant level of shear strain.

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APPENDIX - NOTATION

σ'_1, σ'_3	Major and minor principal effective stresses
σ'_m	Mean effective consolidation stress = $\frac{1}{3}(\sigma'_1 + 2\sigma'_3)$
σ'_v	Vertical effective stress
σ_d	Deviator stress
Δe	Change in void ratio
Δu	Change in pore water pressure
p_c	Apparent preconsolidation pressure
ϕ_u	Ultimate angle of internal friction
t_f	Rupture life
ε	Axial strain
$\dot{\varepsilon}_{min}$	Minimum strain rate in creep rupture test

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STRAIN RATE BEHAVIOR OF SAINT-JEAN-VIANNEY CLAY

by

Y.P. Vaid[1], P.K. Robertson[2] and R.G. Campanella[3]

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Reply to Discussions
by

S. Leroueil and F. Tavenas
G. Mesri and Y.K. Choi and
G.A. Leonards

The authors wish to thank Leroueil and Tavenas, Mesri and Choi and Leonards for their discussions along with additional analyses and interpretations of the data in the paper.

Leroueil and Tavenas object to Saint-Jean-Vianney clay being referred to as cemented on the grounds that both its compressibility and shear behavior are similar to clays with no cementation bonds. The authors did not do any tests in order to seek a direct evidence for cementations. Existence of cementation was simply assumed based on the research work on other Leda clays by many investigators (referenced in the paper). In those studies, the proof of the presence of cementation bonds was either directly obtained or was based indirectly on the section of the failure envelope, along which the shear strength of clay was unaffected by the magnitude of effective stresses. Complete disintegration of an air dried sample of the clay studied in a very short time on submergence in water in comparison to no effect on a natural sample, pointed out to another indirect evidence of cementation bonding.

It will be a gross oversimplification to suggest that $\log \dot{\varepsilon} - \log f(t)$ relationship in creep loading is identical for all clays. Considering the data in Fig. 2 of Leroueil and Tavenas, such as a suggestion along with the assumption of $\dot{\varepsilon}_1 = 10^{-2}\%/\text{min}$ at $t = 1$, the predicted

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[1],[3] Department of Civil Engineering, University of British Columbia, Vancouver, B.C. V6T 1W5

[2] Geotechnical Engineer, Fugro (Hong Kong) Ltd., Hong Kong.

and actual strain rates at any time could vary by a factor of 10. Furthermore, Singh and Mitchell's equation was developed for time dependent deformation under those loading conditions only which do not lead to creep rupture. Consequently it predicts deformation at a continuously decreasing rate with time. The existence of a minimum creep rate before its acceleration leading to rupture cannot be considered by Singh and Mitchell's strain time function. Also under creep rupture stresses 'm' is not constant; it increases gradually as the creep stress level decreases (Vaid and Campanella, 1977).

The values of Δe for the incremental loading consolidation test in Fig. 1 corresponds to 24 hours, although the authors agree with Mesri and Choi in the arbitrary nature of this loading duration. This time duration was adhered to simply because it is the standard practice. It is true that if Δe is taken as that corresponding to the instant of "no measurable pore water pressures", Δe - log $\bar{\sigma}_v$ relationship will get slightly modified, but only in the range of stresses which straddle apparent preconsolidation pressure where the greatest manifestation of secondary compression effects was noted.

Mesri and Choi make an interesting separation of total compressibility into time-independent and time-dependent components (Eqn. [1]). They observe that the compressibility data of Saint-Jean-Vianney clay tends to verify the validity of their Eqn. [1]. It may, however, be pointed out that constant $\bar{\sigma}_v$ contours in Fig. (2) of the paper may not be unique for the clay. They will, in all likelihood depend on the time history of loading by which a given $\bar{\sigma}_v$ is arrived at. For example, if a series of consolidation tests was carried out at constant rate of loading, the resulting constant $\bar{\sigma}_v$ contours will be different from those in Fig. 2. Consequently, relationships such as C_α - log $\bar{\sigma}$ in Fig. 1 of Mesri and Choi can be considered applicable only under the time loading history imposed by the constant rate of strain consolidation tests.

Leonard's analysis of the data, which clearly demonstrates that compressibility of SJV clay shows major time-dependence only within stress range which straddles the apparent preconsolidation pressure, is much appreciated.