

Supplement to article “Questions offering opportunities to elaborate on soil mechanics concepts” by Emil Mejlhede Kinslev and Marina Pantazidou, submitted for review to Int. Conf. Advances and Innovations in Soft Soil Engineering, 24-26 August, 2026, Delft, NL.

Background to the isotache curves used to calculate total settlement in accordance with creep Hypothesis B

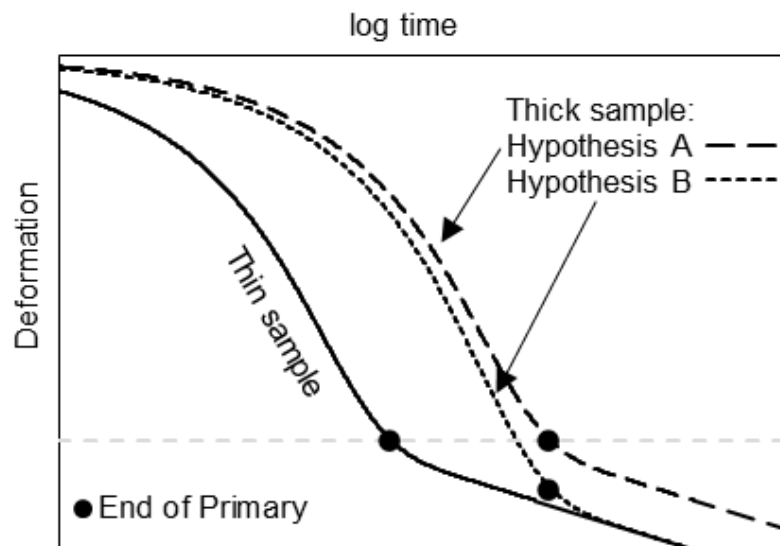


Figure S1. Copy of Figure 1. The origin of hypotheses A and B for extrapolating from the laboratory (thin sample) to the field (thick sample), as proposed by Ladd et al. (1977), modified from Degago et al. (2011), e.g., to also include deformation of the thick samples over the entire time interval.

Key difference between Hypotheses A and B (see Figure S1)

Regardless of creep hypothesis, there is agreement that the creep deformations (after end of primary consolidation) may be described by a linear line in the deformation versus log time plot; hence, with the creep index C_{α} . Differences between the two hypotheses are stated below.

Hypothesis A: The strain at the End of Primary (EOP) consolidation is the same for a thin sample (laboratory) and a thick sample (field).

Hypothesis B: In addition to creep being identified by the slope, C_{α} , the position of the line in the deformation versus log time plot is also unique and independent of sample thickness. Hence, both samples end up on the same line after consolidation has finished. This is a unique effective stress – void ratio – time relationship or, equivalently, a unique effective stress – void ratio – strain rate relationship.

Implications of the above difference for calculating total settlement

Hypothesis A: Because the End of Primary (EOP) consolidation happens at the same strain for thin and thick samples, the settlement resulting from primary consolidation of the thick

sample in the field can be extrapolated from the thin sample in the laboratory using Terzaghi's theory of consolidation. Settlement due to secondary compression is then added using the coefficient of secondary compression determined from C_α (for the test load increment that corresponds to the particular load in the field or best approximation of that load).

Hypothesis B: The dissipation of excess pore pressure is calculated with Terzaghi's theory of consolidation, which leads to a change in vertical effective stress at any given time after loading. To describe the deformation associated with this change in stress we construct a set of curves known as "isotache curves" (see Figure S2). These curves are equivalent to the "isochronous stress (or load)-strain curves" commonly reported in the creep literature and applied to a wide range of materials, including metals (Dowling 1998) and geosynthetics (McGown et al. 2004). With these curves and the change in stress, first an "immediate" deformation following the recompression (unloading-reloading) index (C_r) is calculated. Based on this, an updated position in the unique effective stress-void ratio-strain rate relationship is found, which thereby dictates the updated creep strain rate (see Figure S2). It is important to realize at this point that the rate of pore pressure dissipation affects the path in Figure S2. It is necessary to iterate in time through the plot to calculate the creep contribution during consolidation. For a thin sample, the consolidation is quick and not much creep will have time to accumulate, but for a thick sample, a longer time is spent at each effective stress between the initial and the full load increment, which causes additional creep deformations.



Figure S2. The relationship between void ratio and vertical effective stress during one load step of an incremental loading (IL) oedometer test with indication of intersection with isotaches (the dashed lines), modified from Degago et al. (2011).

The idea behind the isochronous stress-strain curves is of a practical nature: we replot creep data, i.e., deformation-time data obtained for specific loads (or stresses), in the form of

synthetic (i.e., not measured) load (or stress)-strain curves for a given time (e.g., see Dowling 1998: p. 714, Fig. 15.11). This concept already appeared in textbooks on creep in the 1950s; Finnie & Heller (1959) report that this method of replotting data was first suggested by McVetty (1934). The approach is equivalent to assuming that total strain is a function of stress and time. An equivalent assumption is that total strain is a function of stress and strain rate, which is the version proposed for soils by Šuklje (1957), bypassing thus the problem of determining the origin of time ($t=0$) in a clay deposit in the field.

Constructing the isotaches

The isotaches represent creep deformations and hence are only constructed when effective stress is known. This is the case either in a constant rate of strain (CRS) oedometer test, since pore pressure is measured, or in an incremental loading (IL) oedometer test, after the end of primary for each load step. From a CRS test, the strain rate may be changed during the test to then map the change in position in the strain (or void ratio) versus effective stress plane, as shown in Figure S3.

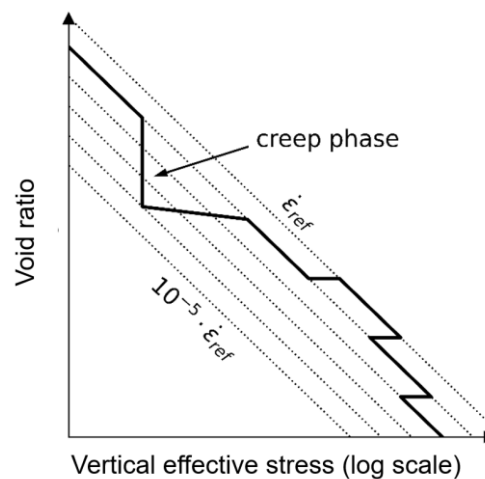


Figure S3. Conceptual behavior of a CRS test with a creep phase and three changes to the strain rate during the subsequent compression (first going from $10^{-1} \cdot \dot{\epsilon}_{ref}$, to $\dot{\epsilon}_{ref}$, second back to $10^{-1} \cdot \dot{\epsilon}_{ref}$ and third to $10^{-2} \cdot \dot{\epsilon}_{ref}$). Modified from Kinslev (2021).

For each load step of an IL test, the creep deformation (when consolidation is not present) is described by equation S1:

$$\epsilon_{creep} = C_{\alpha} \cdot \log(t) + c \quad (S1)$$

This forms a straight line in the strain versus log-time plot with inclination equal to C_{α} , the coefficient of secondary compression. To derive the strain rate (hence $d\epsilon/dt$) from this straight-line equation S1 is differentiated with respect to linear time, which results in equation S2:

$$\frac{d\epsilon_{creep}}{dt} = \frac{C_{\alpha}}{t} \quad (S2)$$

Based on this derivative, the strain rate may be calculated for any time (once on the creep line), and since the effective stress is constant at this point (i.e. after dissipation of excess pore pressures) and the void ratio is a direct outcome of the time-curve, points for the isotaches can be drawn at each load step (where sufficient creep was allowed). From equation S2 it is shown that the isotaches are equally vertically spaced by C_α for one order of magnitude change of time and thereby strain rate, assuming that C_α remains constant over the range of the effective stresses of interest.

References

Degago, S. A., Grimstad, G., Jostad, H. P., Nordal, S. and Olsson, M. (2011). Use and misuse of the isotache concept with respect to creep hypotheses A and B. *Géotechnique*, 61(10):897-908.

Dowling, N.E. (1998). *Mechanical behavior of materials, Engineering methods for deformation, fracture and fatigue*, 2nd Ed., Prentice Hall, Upper Saddle River, NJ.

Finnie, I. and Heller, W.R. (1959). *Creep of engineering materials*, McGraw-Hill, New York, NY.

Kinslev, E. M. (2021). *Efficient performance of large infrastructure : a geomechanical approach towards sustainable design*. PhD thesis at the Technical University of Denmark.

Ladd, C. C., Foott, R., Ishihara, K., Schlosser, F., Poulos, H. G. (1977). *Stress-Deformation and Strength Characteristics, State-of-the-Art Report*, Proceedings of the 9th International Conference on Soil Mechanics and Foundation Engineering, Tokyo, Japan.

McGown, A., Khan, A. J. and Kupec, J. (2004). The isochronous strain energy approach applied to the load–strain–time–temperature behaviour of geosynthetics, *Geosynthetics International*, 11(2):114-130.

McVetty, P.G. (1934). Working stresses for high temperature service, *Mech. Eng.*, 56:149.

Šuklje, L. (1957). The analysis of the consolidation process by the isotache method, Proceedings of the 4th International Conference on Soil Mechanics and Foundation Engineering, London, United Kingdom.