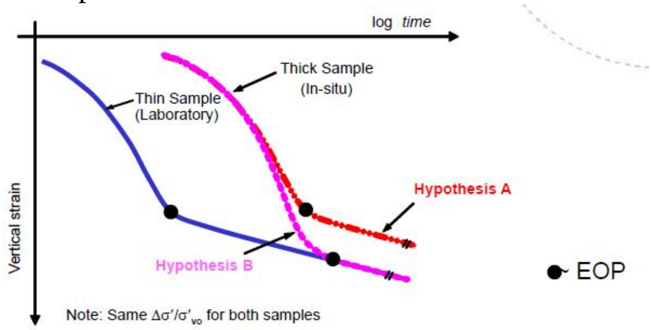
The 4th CREBS and 2nd IAPP-CREEP workshop

This workshop on the CREEP BEHAVIOUR OF SOFT SOILS is a combination of the CREBS series of workshops, this will be the fourth, and it is also the second workshop of the EU CREEP OF GEO-MATERIALS partnership. We are here to share knowledge with respect to creep of soft soils, and I'm happy to see that together, we are a healthy mix of practitioners and scientists, from Holland and abroad.

The list of CREBS workshops is like this.

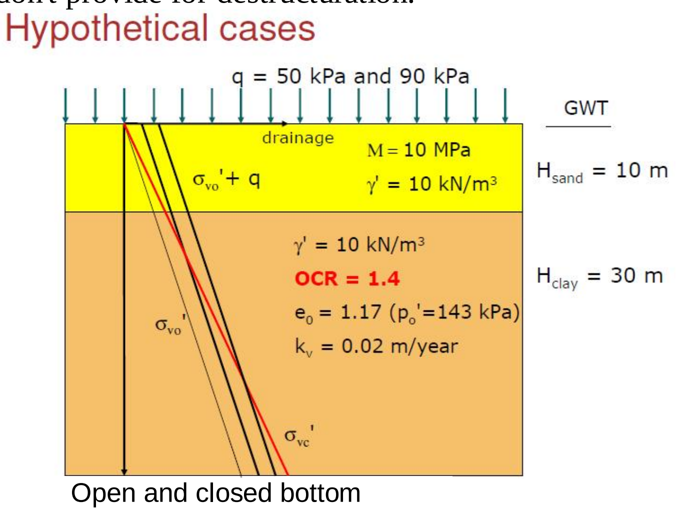
CREBS-I	Oslo	jan - 2006
CREBS-II	Pisa	sep - 2007
CREBS-III	Gothenburg	jun - 2009
CREBS-IV	Delft	jan - 2014

It started 8 years ago in Oslo, and there were follow-ups in Pisa and Gothenburg. I was not involved in the first two, so this information is not from first hand, but if I'm not mistaken, CREBS has helped the understanding of creep behaviour of soft soils forward immensely. The End of Primary controversy – is the strain at the end of primary consolidation independent of layer thickness – was taken into study as a result of discussions at CREBS I, and Samson Degago will take us through that subject again at this workshop.



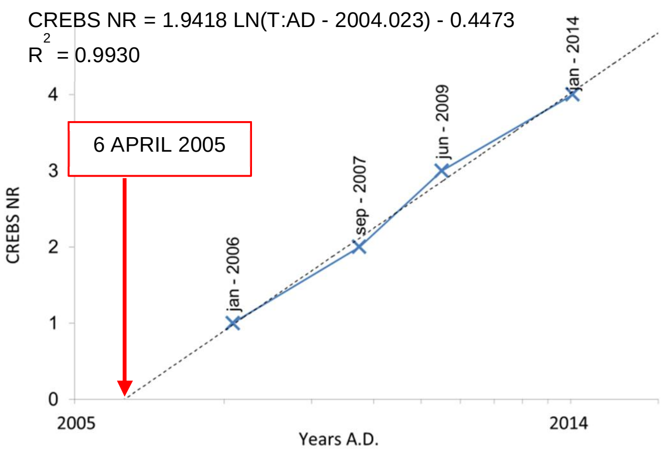
Again, if I'm not mistaken, CREBS II provided strong impulses to develop advanced computer models of behaviour, combining anisotropy, destructuration and time effects.

And a Case Prediction exercise started after CREBS II and was presented at CREBS III. The results were published in a NGI report, a Numge paper, and recently in a nice paper by David Nash. Destructuration around the yield stress was an important issue, and was treated very differently by the various models. Deltares didn't participate – our isotache models don't provide for destructuration.



We should give credit to Hans Petter Jostad of NGI as initiator of these CREBS workshops and the results they produced. He really is the Godfather of these events. And that is why you saw the NGI logo on the flyer.

You might have noticed that CREBS III was quite a while back. Perhaps CREBS IV could have been expected much earlier? Yes, if you apply a linear time law. No, if you apply a logartihmic time law, and as we are in Delft, the home of the log t law, CREBS IV comes at the appropriate time. I had to apply a time shift to get the best fit, and some of you will know that this equation is the basic isotache equation. It even allows to back-calculate when the CREBS workshops were conceived, 6 April 2005, if Hans Petter has forgotten.



You might think that the time shift equation was a Norwegian invention, by prof. Janbu in 1969. It wasn't. Keverling Buisman was already doing this in 1937, although he didn't seem to realize its connection to rate of strain.

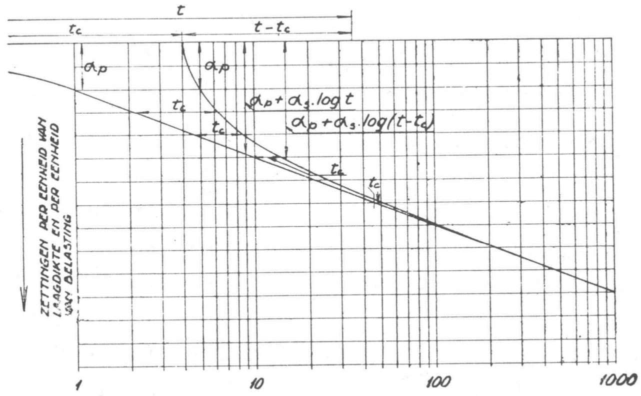


Fig. 71.
Deze figuur brengt in beeld den invloed van het kiezen van een ander nulpunt voor den tijd dan het belastingstijdstip zelf.

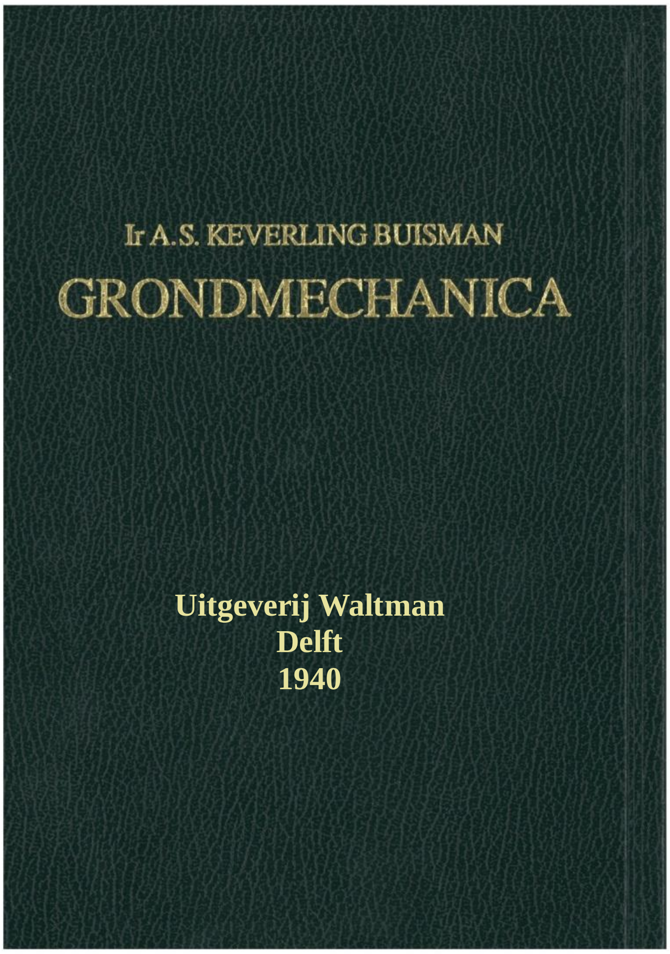
Keverling Buisman was the pioneer of soil mechanics in Holland. He is best known for his log t compression law. Secondary compression if you like, and he was aware that that word was being used in the USA. But he used the word secular in the sense of a period spanning approximately a human lifetime. And he used the word 'direct' in the sense of immediate compression.

This is the famous equation from his 1936 paper to the 1st ICSMFE

$$z_t = \alpha_p + \alpha_s \log_{10} t$$

The p signifies the direct influence of effective stress, and p was the symbol for effective stress at that time. So direct and secular, not primary and secondary. The Americans continued along the primary and secondary path and got stuck in the EoP hypothesis. The choice of terminology may have influenced thinking. What is only a consecutive separation, primary followed by secondary, mutated in this thinking into constitutive separation. Direct and secular is much closer to the isotache principle.

Keverling Buisman left us with a book with a wealth of solutions and concepts.



One of those was the hyperbola which was later readopted by Kondner.

$$\gamma = a_\gamma \cdot \left(\frac{\frac{\tau}{\sigma}}{\frac{\tau_{kr}}{\sigma} - \frac{\tau}{\sigma}} \right)^n$$

Another was the effect of unloading on subsequent creep in the oedometer test. He found that there is a lasting detrimental influence of the preloading, and only recently is this beginning to be investigated in the context of isotache models. The presentation by Yixing Yuan tomorrow may touch on this.

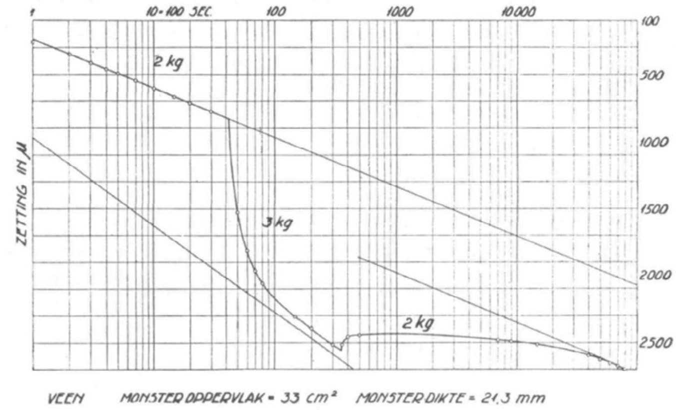


Fig. 72.
Invloed van een tijdelijke overbelasting op het zettingsdiagram.

The book contains a lot of concepts. Keverling Buisman lacked the time and means for all the experimental research he needed, so he necessarily made assumptions. One of these was the superposition of incremental loadings in the oedemeter. It results in the slope of the strain - log t asymptotes increasing with stress, and strain - log sigma slopes increasing with time. Engineers in Holland were brought up with this concept, but it turned out to be wrong, and it was a huge obstacle to further development in Holland. It took to De Rijk 1977 before it was refuted, and another 30 years before this was generally recognized. But Keverling Buisman had written that it needed to be verified.

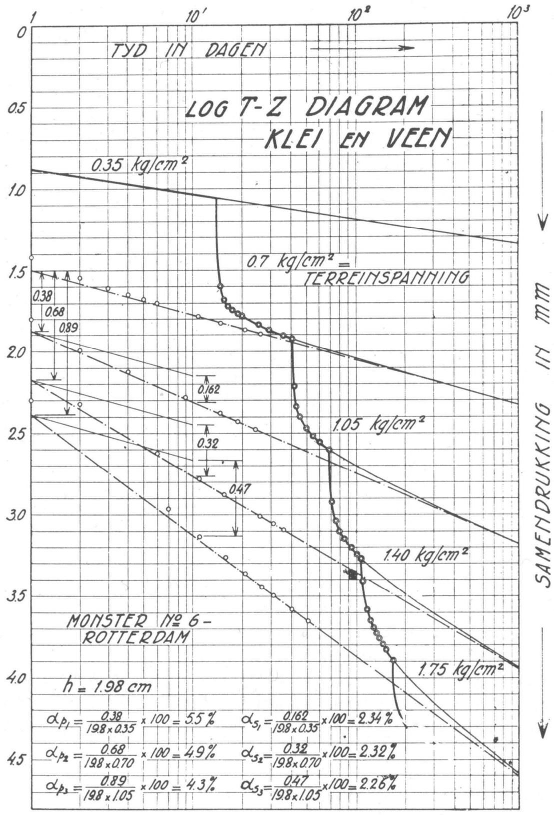
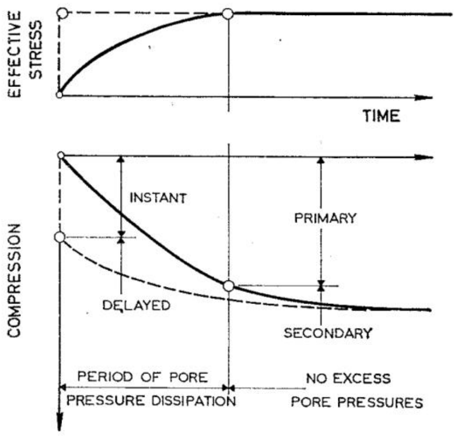


Fig. 70.
Waargenomen zettingsverloop van een grondmonster onder toenemende belastingen; de gevonden a_p- en a_s-waarden zijn in de figuur aangegeven.

So a lot of Keverling Buisman's work was rediscovered much later. E.g. Bjerrum later reintroduced the terms direct and secular as immediate and delayed, but the meaning is precisely the same.



Bjerrum's 1967 SoA paper shows he understood the isotache principle completely, and Šuklje already had it worked out in 1957, but it took decades more before it became common knowledge. But eventually the isotache principle has become accepted. The first consistent mathematical description of the principle, as far as I can see, is due to

Christie and Tonks (1985): Developments in the time lines theory of consolidation.

and

Leroueil, S., Kabbaj, M., Tavenas, F. & Bouchard, R. (1985): Stress-strain-strain rate relation for the compressibility of sensitive natural clays.

and the numerical implementation together with pore water dissipation came a little later:

Kabbaj, M., Oka, F., Leroueil, S. & Tavenas, F. (1986). Consolidation of natural clays and laboratory testing.

The next major breakthrough was to combine Modified Camclay with the isotache principle, which led to the Soft Soil Creep model. Prof. Kutter of Univ of California and Pieter Vermeer take credit for that developement. From then on, theoretical developments have accelerated, although at the last CREBS in Gothenburg, Pieter Vermeer stated that the recent models (SClay1 and its variations, nSAC, EVP models etc) were not yet sufficiently developed to be included in Plaxis. 4½ years later the situation is the same. None have yet been canonised.

So development is slow, about as slow as getting rid of erroneous concepts. It's humbling really. Perhaps it's just a given fact that soil behaviour and it's numerical modelling is complicated.

The further developments of Soft Soil Creep are very theoretical, and a few of the presentations we will be listening to reflect that. At present, we appear to be in a phase of trying to come to grips with the strengths and weaknesses of the advanced models. This is reflected in the presentations of applications of theory to cases, and lastly we have a few presentations which look purely at soil creep behaviour. We look at 1D and 2D creep, during loading and after unloading, of a variety of soils: clay, peat and frozen soil. So all angles are covered. At the end of tomorrow morning, Thomas Benz will present the EU CREEP OF GEOMATERIALS project.

Finally, David Muir-Wood will lead a discussion on what we need to research and develop in the coming years.

Presentations at CREBS-IV Workshop, Deltares, the Netherlands

Wednesday 8 january 2014

0 Introduction
Evert den Haan, Deltares

1 Modelling rate dependency of Gothenburg clay
Mats Olsson, NCC Construction AB and Chalmers University of Technology, Gothenburg

2 Time and rate effects on the ultimate resistance of foundations on clays
Teresa Bodas Freitas, Instituto Superior Técnico, Portugal

3 Back calculation of embankments with OCR determined from prediction of initial strain rate rather than from OCR determined from disturbed samples in oedometer tests under unknown (different than the in-situ) stress condition, with a simple creep model
Gustav Grimstad, NTNU Trondheim

4 Primary consolidation and creep of clays
Samson Degago, Statens Vegvesen Norway

5 Modelling peat behaviour with an elasto-viscoplastic model for clay
Djamalddine Boumezerane, Deltares

6 Creep of frozen soils
Qi Jilin, State Key Laboratory of Frozen Soil Engineering, Lanzhou

7 Strength of embankments on peat
Cor Zwanenburg, Deltares

8 Overview of suitable case studies for benchmarking of time-dependent constitutive models
Jelke Dijkstra, Chalmers University of Technology, Gothenburg

Thursday 9 january 2014

9 FEA of the Zelazny Most tailing dam - time dependent displacements due to horizontal creep?
Hans Petter Jostad, NGI Oslo

10 Post surcharge creep rate
Yixing Yuan, MIT Cambridge USA

11 Long term behaviour of retaining walls in Dublin boulder clay
Mike Long, University College Dublin

12 Settlements: a consultancy case
Jaap Bijnagte, Deltares

13 The Marie Curie "CREEP" project: goals, progress, future
Thomas Benz, NTNU Trondheim

14 Needs and directions for future research of creep of geomaterials: Discussion, led by David Muir Wood, Chalmers University of Technology, Gothenburg