SAGE
CRISP

CRISP NEWS

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Editorial

In this issue, we continue with our series of brief technical articles; Amir Rahim reports on some comparative analyses of footing collapse load in which the influence of flow rule is investigated. What is particularly interesting about this study is that it began as a technical query e-mailed to the "crisp-users" list, where it received considerable attention, and was then discussed in open session at the 11th CRISP User Group Meeting at Birmingham University (full report in next Issue). To me, this epitomizes what the User Group is all about, and underlines its inherent synergy. If you have not yet joined "crisp-users", then I urge you to subscribe today.

Also in this issue, Ian Pyrah describes some of the work currently being undertaken at Napier University with CRISP. Amir lists some of the new features in Sage-Crisp version 4. Finally, I am pleased to introduce the first in a new series of articles in which key people involved with CRISP will be profiled. Several users have suggested such a feature, and in this issue the spotlight is on Roger Chandler.

Finally, please let me have your suggestions on the content and format of CRISP NEWS, to help us ensure that it continues to fulfil a useful function.

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11th CRISP User Group Meeting

Andrew Chan reports on the meeting at the University of Birmingham

The CRISP User Group Meeting this year made its first ever appearance in the Midlands, and was held at the University of Birmingham on 18th September. Around 45 delegates came from industry and academia - with many familiar faces, but quiet a few new ones too.

If you have been to a User Group Meeting in the past, you will know that it's not so much about people trying to impress each other, but rather talking about the successes and failures they have had over the past year when attempting to apply CRISP to a wide range of practical and research-oriented problems.

For the benefit of those who were not able to attend, the contributions in each session (together with the discussion leaders) were as follows:

Session 1 : Tunnels
(Professor Chris Rogers)
Jun Xie
Stability analysis of tunnels
Tony Swain
Analysis of shafts with minimal reinforcement
Pierre van der Berg/James Scott
Numerical modelling of Heathrow T4 SCL tunnels

Session 2: Embankments & Walls
(Professor William Powrie)
Ian Pyrah
Non-uniformities induced by consolidation with vertical drains
Anu Naataanen
Haarajok test embankment - calculations with SAGE CRISP
Tadahiko Shiomi
Seismic induced liquefaction of an embankment dam
Rick Woods
Smoothing out the bumps in shear force diagrams

Session 3: Theoretical Developments
(Professor David Muir Wood)
Sarah Stallebrass
Some recent 3D analyses
David Naylor
3D tetrahedral mesh generation - a user perspective
Derek Styles
3D mesh generation
Mike Gunn / Amir Rahim
Non-associated flow

Session 4 : Recent Developments
(Professor Ian Pyrah)
Amir Rahim
Recent developments in SAGE CRISP leading up to Version 4
Geoff Watson
Recent developments in the graphical user interface for SAGE CRISP
Roger Chandler
Activities of the CRISP Consortium in 1997-98

Many thanks to Gurmel Ghataora and David Chapman for helping me with the organization. Anyone who would like copies of the papers presented at the Meeting should contact me directly.

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The significance of Non-associated Plasticity- Part I

Amir Rahim reports on the influence of flow rule on footing collapse load

The purpose of this study is to compare the drained collapse loads of footings using both dilatant and non-dilatant behaviour in the Mohr-Coulomb yield criteria. In a subsequent article, the influence of dilation on the consolidation behaviour of triaxial samples will be discussed.

Associated flow implies that the vector of plastic strain increment is normal to the yield or failure surface. This leads to mathematical simplifications and when applied to von Mises or Tresca failure criterion, correctly predicts zero plastic volume change during yield for fully cohesive materials, or undrained clays.

For frictional materials described by the Mohr Coulomb criterion, the use of associated flow leads to physically unrealistic volumetric change. For such cases non-associated flow is preferred in which the vector of plastic strain is not normal to the yield surface. Instead, this vector is normal to the 'plastic potential' which is geometrically similar to the failure function but with the friction angle ϕ replace by a dilation angle ψ.

The analyses presented here are for different angle of friction and with a varying angle of dilation. Only smooth rigid plane strain footings have been considered.

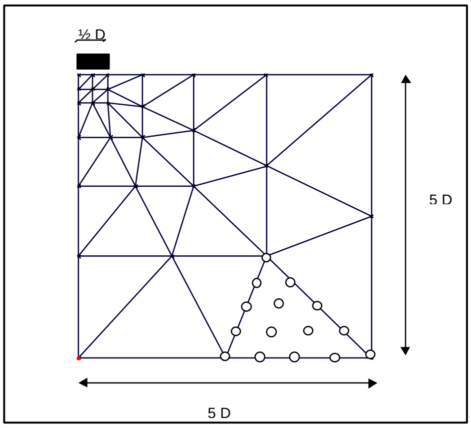
Analytical solutions for plane strain (strip) footings on soils with different angles of friction can be obtained from the equations of plastic equilibrium (bearing capacity) presented by Terzaghi & Peck (1948). These formulae assume a weightless soil and are based on the earlier work of Prandtl (1921).

The drained collapse load is given by $q_d = N_c.c$

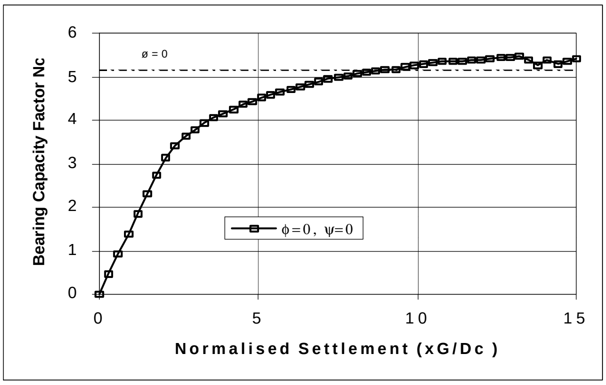
where $N_c = \cot\phi(N_q-1)$, $N_q = K_p.e^{(\pi\tan\phi)}$, and $K_p = (1+\sin\phi)/(1-\sin\phi)$

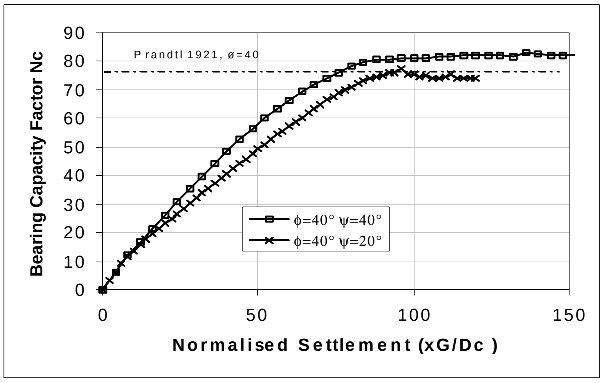
For $\phi = 0°$, $N_c = (2+\pi) = 5.1416$

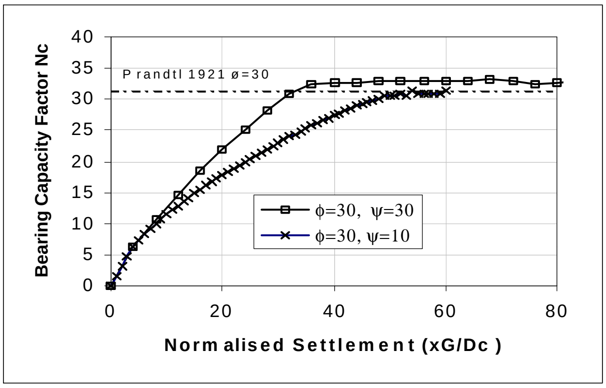
For $\phi = 20°$, $N_c = 14.83$
For $\phi = 30°$, $N_c = 30.14$
For $\phi = 40°$, $N_c = 75.31$

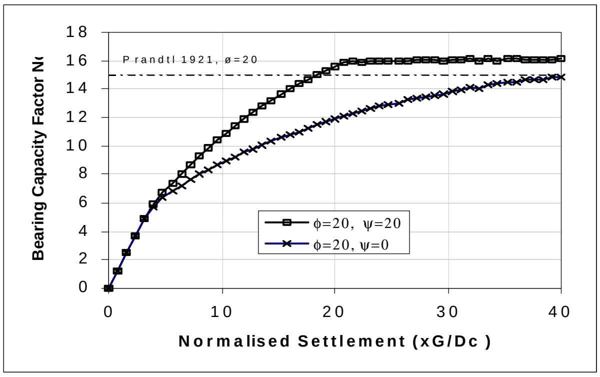


The finite element mesh for the strip footing (plane strain) is shown on right. Normalised plots of collapse load against settlement are shown below.









The 15-noded cubic strain triangle was used throughout. This element uses 12-point Gaussian integration scheme and was found to be superior to other elements. A weightless material without initial stresses is assumed. The same analyses were repeated using 8-noded linear strain quadrilaterals (3x3 Gauss rule), but convergence to the limit load was not achieved, particularly with non-associated flow. The displacement convergence criterion was used with a tolerance of 0.5%. This criterion tates that convergence is achieved when the square root of the sum of displacements in the current iteration over the square root of the sum of total displacements up to the current iteration is equal or less than a user specified tolerance, or

$$\frac{\left\| \{\Delta u_i\} \right\|_2}{\left\| \{{}^{t+\Delta t}u\} \right\|_2} \leq Tolerance$$

The results obtained show that, for a smooth footing, numerical solutions for $\psi = \phi$ and $\psi < \phi$ are very similar, and bracket the analytical solution quite closely. Footing settlements required to mobilise the collapse load are higher if $\psi < \phi$ - especially with low ϕ. Numerical difficulties were encountered where the degree of non-associativity was high. For example, solutions could not be obtained for ϕ=40° with ψ=0°, and for ϕ=30° with ψ=0°.

In part two, we will show the effect of associated flow on pore pressure behaviour in consolidation analyses.

Amir Rahim
The CRISP Consortium

Trench reinstatements - soft clays and unsaturated soils

Ian Pyrah profiles the use of CRISP at Napier University, Edinburgh

The Geotechnics Group in the Department of Civil & Transportation Engineering at Napier University, Edinburgh is currently using CRISP on a number of research projects. SAGE CRISP is being used on two (soil-pipe interaction and consolidation of soft ground around vertical drains) whilst the third (the simulation of unsaturated soil behaviour) involves development work on a version of CRISP which does not have the pre- and post-processing capabilities of the commercial software.

Soil-pipe interaction in shallow trench reinstatements

Dr Charles Fairfield and his co-workers are using CRISP for modelling the behaviour of buried flexible cable TV and telecommunications ducts in trench reinstatements. The study focuses on a variety of parameters including; pipe configuration (1-way, 2-way, and 4-way), reinstatement width (200mm to 450mm), backfill cover depth (100mm to 450mm), and associated pipe and soil stiffness combinations. The soil model simulates a typical Specification for Highway Works Type 1 fill at bulk unit weights ranging from 17kN/m^3 to 22kN/m^3 (elastic moduli ranging from 15MPa to 40MPa). Pipe stiffnesses have been varied to simulate the least stiff Class-O telecommunications ducts to stiffer uPVC products (elastic moduli ranging from 300MPa to 3200MPa). Slip elements governed by a Mohr-Coulomb frictional law are used at the pipe-soil interface.

Deformation predictions have been made for the various combinations of pipe and soil; reinstatements suffering less than 5% vertical diametral duct strain under 40kN applied surface load are deemed suitable. The research has led to the production and adoption of design charts for the cable TV industry's duct installation contractors and specifiers. Good correlation has been observed between FE predictions and *in situ* duct deformation trials. For example, a typical 1-way uPVC duct at a depth of 300mm underwent 1.2% vertical diametral strain in the FE simulation compared to 1% ± 0.1% as measured *in situ*. Further CRISP based research is underway to examine the effects of failing to compact the sidefill, subsequent removal of sidefill due to a parallel excavation, and failure to fill the gap(s) between pipes in multiple duct configurations.

Non-uniform consolidation around vertical drains

The rapid expansion of many cities, and the rise in demand for travel facilities, has led to an increased reliance on land reclamation for providing suitable development areas. Sand fills and other suitable materials may not be readily available and increasing use is being made of soft silty clays dredged from the seabed or taken from other parts of the site. The use of these materials usually leads to difficulties as such materials are usually highly compressible with large variations in their properties. Consolidation of these materials is usually accelerated by installing vertical drains, such as sand drains or prefabricated geotextile drains, and whilst this is beneficial in bringing forward the time when the land can be used, there are uncertainties in predicting the subsequent behaviour of the reclaimed ground. This is due to non-uniformities introduced during the consolidation process. These may be due to the redistribution of stress caused by the mechanical properties of the drain and/or as a result of the three-dimensional nature of the consolidation process even though the loading is one-dimensional. Due to the nature of soil behaviour e.g. two-phase material involving an elasto-plastic soil skeleton, conventional techniques based on Barron's solution, which rely simply on the rate of dissipation of excess pore water pressure, cannot predict this pattern of behaviour.

SAGE CRISP is being used to numerically simulate the problem and the results compared to those from physical models performed in the Research Center for Urban Safety and Security, Kobe University. The model tests involve plane strain consolidation of a soft clay with vertical drains at the sides and the analyses confirm the final non-uniform water content distributions observed in the model studies. The numerical study is helping to understand the observed patterns of behaviour in the laboratory and the type of non-uniformities that might be induced in the ground. The effects of soil fabric on this process are also being examined.

Implementation of a critical state model to simulate the behaviour of unsaturated soil

The first stage of this research involved the modification of CRISP to model drained behaviour and was carried out at the University of Sheffield. The modified version of CRISP, incorporating the "Barcelona" model for unsaturated soil, was verified for a wide range of stress-paths and then used to perform numerical simulations of a variety of geotechnical problems. These included the simulation of the deposition and partial erosion of a soil deposit, the lowering of the water table, the application of a strip load and the subsequent behaviour of the strip load, and the surrounding ground, as the water table rises. The predicted differential movements between the foundation and the adjacent ground are significantly greater than those predicted for a fully saturated soil. This work will be presented at the BGS/Ground Engineering meeting in London in October which will also include a presentation by Professor Wheeler (University of Glasgow) on the theoretical model used in the simulations and the experimental work required to obtain the appropriate parameters.

This work has been extended by Dr Nesnas at Napier with the introduction of undrained conditions and, more recently, consolidation behaviour into the program. It is now possible to simulate drained behaviour, undrained behaviour and time-dependent consolidation of an unsaturated soil using a critical state model although further verification is required for the consolidation version of the program

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Who's Who in the CRISP world

Roger Chandler - MD of the CRISP Consortium

Roger Chandler started his involvement with CRISP in 1991 when he spent 3 years using CRISP90 (the old DOS version) as part of his PhD at Queen Mary and Westfield College, University of London. His research, which was supervised by Professor William Powrie, was primarily aimed at investigating retaining walls propped at formation level, but also included the implementation of the Simpson Brick model into his version of the program.

During his PhD, Roger was a demonstrator on the "Advanced Geotechnical Analysis using CRISP" course held at Cambridge University, and it was whilst talking to delegates on this course, and through his own personal experiences with the program, that he started to gather support for a Windows version of the program. In 1993 he proposed this idea to Cambridge University.

In 1994 SAGE Engineering was awarded the contract to develop the windows interface, and soon after Roger was offered the opportunity to be the project manager for the first release. His background as a user was invaluable at the time and enabled him to see things as the users would want them. The first windows version of the program was released at the end of 1995 and proved an immediate success with the CRISP users of the day.

As the program became increasingly popular (due mainly to its increased user friendliness) there was a demand to improve and update the engine. At the time, the engine was still owned, and therefore maintained, by Cambridge University and many of the requested alterations could not be classified as research and so were not easily fundable by the University. This provided the impetus behind the formation of the CRISP Consortium, which Roger founded in July 1996.

The CRISP Consortium has given CRISP a very powerful development team, both with the fully time programmer, Amir Rahim, and with the network of associates and members that are involved with its development. Roger is still the Managing Director of the CRISP Consortium and is very much involved with the company's activities and daily running.

At Easter this year Roger left SAGE Engineering to take up the position of technical director at a geotechnical software company called Key Systems Geotechnical. He is now working with many geotechnical consultancies assisting them with their site investigation interpretation.

Roger still works as a consultant to SAGE when they require his assistance and still promotes, supports and teaches SAGE CRISP in numerous countries. When asked recently whether leaving SAGE meant leaving CRISP he replied "Once you become involved with CRISP and are considered part of the family, you will never be able to turn your back on program or its users. I hope SAGE will still let me play an active part."

Roger Chandler can be contacted by Email on roger.chandler@key-systems.com

WHAT?! NOT YET JOINED THE CRISP-USERS DISCUSSION LIST?

To join, send an e-mail message to “mailbase@mailbase.ac.uk” which contains only the following lines:

join crisp-users *YourFirstname YourLastname*
stop

Latest on Sage-Crisp Version 4

Sage Engineering would like to offer its sincere apologies for the delay in the completion of version 4. This is due to exceptional circumstances; departure of Project Manager, departure of the original VB programmer. Sage is now working more closely with the Crisp Consortium on both the Windows interface and the FE engine. A beta release will be available from the first week of 1999. Please contact Sage if you wish to receive the version 4 Beta release.

New feature in the Windows interface:

- 32bit compatible for Win95 and NT
- Introducing Layers for easy meshing and selection of superimposed elements.
- Introducing the Find feature for searching for elements and nodes in a mesh.
- Animated display of deformed mesh
- Improved display of stress contours.
- Improved display of stress state codes

New Features in the FE engine are:

- 3-Surface Kinematic Hardening model allowing simulation of stiffness of soils which exhibit low stiffness at small strain by tracing the soil stress history.
- New Mohr-Coloumb model with associated plasticity allowing better prediction of deformation for soils with varying or zero dilatancy. This elasto-plastic model also includes hardening which is based on cohesion or friction angle or both.
- Duncan and Chang's Hyperbolic model for hard soils such as sand and highly overconsolidated clays.
- Introducing large deformation formulation based on the Updated Lagrangian method. This now accounts fully for large deformation and may be used in solving problems such as embankments on soft clay.
- Introducing iterative solution which help eliminate force residuals within each increment before going to the next increment, thus improving the quality of solution.

There are also improvements to the slip element, a new 3D slip element, and bar and beam elements in 3D space.

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