Artificial neural networks models for rate of penetration prediction in rock drilling

Prediction of the rate of penetration (ROP) is an important task in drilling economical assessments of mining and construction projects. In this paper, the predictability of the ROP for percussive drills was investigated using the artificial neural networks (ANNs) and the linear multivariate regression analysis. The “power pack” frequency, the revolution per minute (RPM), the feed pressure, the hammer frequency, and the impact energy were considered as input parameters. The results indicate that the ANN with the regression model predicts the ROP under different conditions with high accuracy. It also demonstrates that the ANN approach is a beneficial tool that can reduce cost, time and enhance structure reliability.

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Organisations: Civil Engineering
Authors: Fathipour Azar, H., Saksala, T., Jalali, S. E.
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Research output: Scientific - peer-review › Article

Numerical modelling of rock materials with polygonal finite elements

This article presents some preliminary results on numerical modeling of rock materials with polygonal finite elements. A method to describe the rock microstructure based on Voronoi diagrams, representing the rock grain texture, is sketched. In this method, the minerals constituting the rock are represented as Voronoi cells which themselves are polygonal finite elements. A three-point bending problem under plane stress linear elasticity condition is solved in order to compare the performance of polygonal elements to ordinary finite elements. Moreover, it is demonstrated by solving the stress state in uni-axial compression that the heterogeneity described with the present method results in short-range tensile stresses which could initiate mode-I cracks.

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**Numerical modelling of dynamic spalling test on rock with an emphasis on the influence of pre-existing cracks**

This article deals with numerical modeling of rock fracture under dynamic tensile loading and the related prediction of dynamic tensile strength. A special emphasis is laid on the influence of pre-existing natural microcrack populations as well as structural (artificial) cracks. For this end, a previously developed 3D continuum viscodamage-embedded discontinuity model is employed in the explicit dynamic finite element simulations of the spalling test. This model is capable of modelling the effect of natural microcracks populations always present in rocks as well as to capture the strain rate hardening effect of quasi-brittle materials. In the numerical simulations of spalling test on Bohus granite, it is shown that the model can predict the pull-pack velocity of the free end of the intact rock sample and the effect of structural cracks with a good accuracy. According to the simulations, the effect of microcrack populations, modeled here as pre-embedded discontinuity populations, is weaker than the corresponding effect under quasi-static loading.

**General information**

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Organisations: Civil Engineering
Authors: Saksala, T.
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**Numerical 3D modelling of the effects of strain rate and confining pressure on the compressive behavior of Kuru granite**

This paper deals with numerical modeling of the compressive behavior of granite rock under high strain rate dynamic loading and wide range of confining pressure. For this end, a constitutive model based on damage mechanics and viscoplasticity for rock is formulated and implemented in explicit dynamics FEM. The viscoplastic part is based on a simple power law type yield criterion that incorporates the rate-dependency with a linear viscosity term. Moreover, a Rankine type of tensile cut-off is employed. The damage part of the model is formulated with separate scalar damage variables in tension and compression. The model is calibrated for Kuru granite and validated with the experimental data from dynamic compression tests at the strain rate of 600 1/s up to 225 MPa of confining pressure. The numerical simulations demonstrate that, despite the underlying continuum modeling approach, the model captures the correct experimental failure modes, including the transition from single-to-multiple fragmentation, as well as the dynamic compressive strengths at different confining pressures.

**General information**

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Ministry of Education publication type: A1 Journal article-refereed
Organisations: Civil Engineering, Research area: Applied Mechanics, Materials Science, Research group: Materials Characterization
Authors: Saksala, T., Hokka, M., Kuokkala, V.
Number of pages: 8
Pages: 1-8
Publication date: 11 Mar 2017
Peer-reviewed: Yes

**Publication information**

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Volume: 88
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Failure in anisotropic sensitive clays: a finite element study of the Perniö failure test

The railway network on coastal areas of Finland is predominantly located in soft clay areas. The undrained shear strength of such clays is generally low, highly anisotropic, rate dependent and it exhibits post-peak strain softening under undrained conditions. A full-scale failure test was performed by Tampere University of Technology in Perniö, Western Finland, in 2009. A shallow railway embankment built on a soft clay deposit was equipped with a loading structure and loaded to failure in about 30 hours. The embankment collapsed two hours after the last loading step. In this study, data collected from the experiment is used, together with laboratory test results on high quality samples, to conduct advanced finite element analysis of the Perniö failure test. The NGI-ADPSoft model is used for this purpose, which is capable of simulating the strain-softening behavior of the clay. Even though the observed rate effect is not taken into account in the analyses, the failure load can be predicted reasonably well. Good agreement is also observed for calculated displacements and failure mechanism with experimental observations.

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Ministry of Education publication type: A1 Journal article-refereed
Organisations: Research group: Foundation Structures, Civil Engineering, Norwegian Geotechnical Institute (NGI)
Authors: D'Ignazio, M., Länsivaara, T., Jostad, H. P.
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Scopus rating (2013): SJR 2.158 SNIP 2.959 CiteScore 2.51
Scopus rating (2012): SJR 2.149 SNIP 2.974 CiteScore 1.99
Scopus rating (2011): SJR 1.751 SNIP 3.384 CiteScore 2.2
Scopus rating (2010): SJR 1.691 SNIP 2.522
Scopus rating (2009): SJR 1.167 SNIP 2.07
Scopus rating (2008): SJR 0.935 SNIP 1.659
Scopus rating (2007): SJR 0.892 SNIP 1.673
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Scopus rating (2005): SJR 0.683 SNIP 2.912
Scopus rating (2004): SJR 0.65 SNIP 1.462
Scopus rating (2003): SJR 0.507 SNIP 0.815
Scopus rating (2002): SJR 0.873 SNIP 1.309
Scopus rating (2001): SJR 0.751 SNIP 0.792
Scopus rating (2000): SJR 0.519 SNIP 1.268
Scopus rating (1999): SJR 0.598 SNIP 1.342
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DOIs: 10.1016/j.compgeo.2017.03.004
Research output: Scientific - peer-review » Article
Chasing measurements for real-world emissions of city buses

General information
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Organisations: Physics, Research area: Aerosol Physics, Research group: The Instrumentation, Emissions, and Atmospheric Aerosols Group
Authors: Järvinen, A., Karjalainen, P., Bloss, M., Potila, O., Simonen, P., Kuuluvainen, H., Timonen, H., Saarikoski, S., Niemi, J. V., Keskinen, J., Rönkkö, T.
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ASJC Scopus subject areas: Automotive Engineering, Pollution, Energy (miscellaneous)
Research output: Scientific › Paper, poster or abstract

Continuum modelling of dynamic rock fracture under triaxial confinement
This paper deals with numerical modelling of compressive fracture behavior of granite rock under high strain rate and wide range of confining pressure. For this end, a constitutive model based on damage mechanics and viscoplasticity is formulated and implemented in explicit dynamics FEM. Rock heterogeneity is characterized with the Weibull distribution. In the numerical examples, triaxial compression tests on Kuru granite at the strain rate of 600 1/s up to 225 MPa of confining pressure were simulated. Simulations show that the model captures the correct experimental failure modes, including the transition from single-to-multiple fragmentation, as well as the dynamic compressive strengths at different confining pressures.

General information
State: Published
Ministry of Education publication type: A4 Article in a conference publication
Organisations: Civil Engineering, Research area: Applied Mechanics, Materials Science, Research group: Materials Characterization
Authors: Saksala, T., Hokka, M., Kuokkala, V.
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Bibliographical note
Research output: Scientific › Conference contribution

Determination of remoulding energy of sensitive clays
Energy involved in disintegrating of sensitive clays from an intact to a fully remoulded state is one of the key aspects in assessing the post failure movements of sensitive clay landslides. This energy is referred to as remoulding energy. In this paper, the energy approach is conceptualised using an analytical approach. A comprehensive review of the empirical, laboratory and field techniques to estimate remoulding energy are presented and discussed in detail.
Effects of sample disturbance in the determination of soil parameters for advanced finite element modelling of sensitive clays

The stress-strain response of sensitive clays tested in a laboratory setting can be significantly affected by disturbance effects caused by sampling, transport, storage and specimen preparation. Soil models for finite element analyses are commonly calibrated using the results from laboratory tests and, consequently, calibrated model parameters are likely to be affected by sample disturbance. For sensitive clays subjected to constant volume shearing, the stress-strain behavior is dependent on the direction of loading and, due to build-up of shear induced pore pressure, effective stresses will reduce with increasing strain in the post-peak regime. According to previous studies, peak strengths, strains at failure and postpeak behavior of sensitive clays are all significantly influenced by sample quality. Therefore, the relative quality of model predictions generated using a sensitive clay finite element model can also be expected to be notably affected by sample disturbance. In this study, the impact of sample disturbance on the determination of model input parameters for advanced finite element modelling of sensitive clays is addressed and critically discussed. Two advanced soil models are used for this purpose: the total stress based NGI-ADPSoft model, which is able to predict the anisotropic strain-softening behavior of saturated sensitive clays, and the effective stress based S-CLAY1S model, which is characterized by an anisotropic yield surface and is able to simulate soil destructuration. The practical implications of a thoughtful selection of the input parameters are evaluated through FE stability analyses of a sensitive clay slope.
Features of water co-operatives: A comparative study on Finland and Kenya

There are several ways of arranging rural water supply. One of these is through water cooperatives that have been established to provide water supply, irrigation, and/or sewerage services. Water cooperatives are found in developed countries such as Finland, Denmark, Austria, Canada, and United States, and in developing countries in South America, such as Bolivia and Chile. Water cooperatives or their equivalent organizations that exist in Kenya are called self-help water projects. Yet, surprisingly little attention has been paid to this option even in countries with rich tradition of cooperatives in other sectors. In this study, Finland and Kenya were selected for a comparative analysis of the identified features of water cooperatives. Best practices observed in the features with differences could be shared between the two countries.

Problems related to field vane testing in soft soil conditions and improved reliability of measurements using an innovative field vane device

In Finland, undrained shear strength is commonly measured using the field vane shear test (FV). Currently, the most commonly used field vane testers are the Nilcon vane and the electrical vane with shear rotation and measuring systems
located above the ground level. Vane testing is normally carried out using vanes equipped with slip coupling, while the use of casing for protecting the vane is not very common. Recent studies from Finland have shown that the undrained shear strength of clays can be significantly underestimated when casing is not used. Experimental observations suggest that the slip coupling might not always be sufficient to remove all of the rod friction effects that occur during testing. Tampere University of Technology has recently purchased an innovative field vane apparatus with a vane tester unit, where torque and rotations are measured right above the vane. In this way, the effect of rod friction is minimized and the measured stress rotation behavior is less biased. In this study, issues related to practical applications, testing devices and interpretation methods are discussed. Then, a critical comparison between test results in soft clays from both the traditional and new field vane testers is performed.

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Organisations: Civil Engineering, Norwegian Geotechnical Institute (NGI)
Authors: Selänpää, J., Buò, B. D., Länsivaara, T., D'Ignazio, M.
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Research output: Scientific - peer-review » Chapter

Reply to the discussion by Mesri and Wang on "Correlations for undrained shear strength of Finnish soft clays"

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Organisations: Civil Engineering, Research group: Foundation Structures, Norwegian Geotechnical Institute (NGI), National University of Singapore
Authors: D'Ignazio, M., Phoon, K., Tan, S. A., Länsivaara, T., Lacasse, S.
Number of pages: 5
Publication date: 2017
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Scopus rating (2015): SJR 1.979 SNIP 1.915 CiteScore 1.89
Scopus rating (2014): SJR 1.739 SNIP 1.929 CiteScore 1.66
Scopus rating (2013): SJR 2.189 SNIP 2.075 CiteScore 1.62
Scopus rating (2012): SJR 1.497 SNIP 2.053 CiteScore 1.1
Scopus rating (2011): SJR 1.721 SNIP 2.149 CiteScore 1.43
Scopus rating (2010): SJR 1.346 SNIP 1.593
Scopus rating (2009): SJR 1.566 SNIP 1.574
Scopus rating (2008): SJR 1.337 SNIP 1.811
Valkea kaupunki, mustat vedet

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Authors: Juuti, P., Rajala, R.
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Original language: English
Links: http://www.vesitalous.fi/vesitalous-lehdet/vesien-historia/
Research output: Scientific - peer-review > Review Article

Älypölkky, radan monitorointi, kreosoottipölkyn korvaavat vaihtoehdot

General information
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Organisations: Civil Engineering, Research group: Track Structures
Authors: Luomala, H.
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Year: 2016
Original language: Finnish
Research output: Scientific > Other contribution

Ballast bed

General information
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Organisations: Civil Engineering, Research group: Track Structures
Authors: Luomala, H.
Publication date: 24 Nov 2016

Publication information
Mechanical properties of recovered municipal solid waste incineration bottom ash: the influence of aging and changes in moisture content

The scarcity of non-renewable natural resources and the demand for waste recycling and utilization are steering towards increasing use of waste-derived materials in civil engineering structures. However, as the quality of different waste-derived materials can vary depending on input materials and processes in which they are generated, the utilization of these materials in civil engineering may be risky and cumbersome unless their properties are well-known. In Finland, due to the recently increased number of waste incineration plants, nearly 300 000 t of municipal solid waste incineration bottom ash (MSWI BA) is generated annually in the country. As the material is mainly landfilled or used in landfill site structures at the moment, the utilization of MSWI BA in different civil engineering applications could be increased, if the essential properties of the material were properly understood. In this study, the mechanical properties of recovered MSWI BA were investigated with cyclic load and static triaxial tests. The study focused especially on the influence of changes in moisture content and its relation to the development of recovered MSWI BA stiffness and strength properties over time. The obtained results showed that the stiffness of recovered MSWI BA was highly affected by the changes in moisture content over time but also the material aging had an influence. The resilient modulus, Mr, was at least doubled during the two months storage of test specimens. Furthermore, when the MSWI BA material dried out and the moisture content
decreased 5-7%, the resilient modulus, Mr, of the material was even quadrupled.

Spatial variability of reed bed spectra in Olkiluoto Island

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Authors: Tuominen, J., Lipping, T.
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Name: IEEE International Geoscience and Remote Sensing Symposium Proceedings
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10.1109/IGARSS.2016.7730875
Research output: Scientific - peer-review › Conference contribution
Comparison of community managed projects and conventional approaches in rural water supply of Ethiopia

This study aimed to compare Community Managed Projects (CMP) approach with the conventional approaches (Non-CMP) in the case of Ethiopia. The data collection methods include a household survey (n=1806), community representative interviews (n=49), focus group discussions with district water experts (n=48) and observations of water systems (n=49). The data were collected from seven districts of two regions of Ethiopia. The study shows that CMP have a better platform to involve the community than non-CMP. In terms of reducing distances to water points, all approaches succeeded. However, the intended amount of water supplied is not achieved in all the cases: only 25% of CMP users and 18% of non-CMP users are able to get water according to the national standard, 15 L per capita per day. Fee collection in the approaches has a high disparity in favour of CMP. To keep long-lasting services, three requirements need to be particularly fulfilled: quantity, quality and accessibility.
Undrained shear strength of Finnish clays for stability analyses of embankments

The thesis deals with the undrained shear strength (su) of Finnish clays. The research study focuses on the evaluation and modelling of undrained shear strength for total stress stability analyses of embankments and it studies some special features of sensitive clays.

Firstly, a multivariate database of Finnish clay data points is compiled in order to derive correlations for undrained shear strength specific to Finnish clays. For each data point, information on su from field vane, consolidation stresses and other physical properties is available. The dependency of su on overconsolidation ratio (OCR) and index parameters is studied. The new correlations are derived through regression analyses. Results show that the dependency of su on index parameters is more marked when the uncorrected field vane measurements are considered. On the other hand, when measured su is corrected for strain rate and converted into mobilized su, such dependency becomes negligible. The new correlations are validated through comparison with existing correlations from the literature. Bias and uncertainties of the new transformation models are evaluated through an independent database consisting of clay data points from Sweden and Norway. The main result is that the new correlations are characterized by lower uncertainty than the other commonly used correlation models.

In order to study some of the special characteristics of soft sensitive clays, the Perniö failure test is analyzed through the finite element method (FEM) using the advanced NGIADPSOFT model, which includes anisotropy and strain-softening behavior of sensitive clays. A series of laboratory and in-situ tests are used to determine the anisotropic shear strength of Perniö clay and Perniö dry crust. Stability analyses are performed using the software PLAXIS 2D and the influence of stress path dependency and post-peak strength reduction on the failure load is evaluated. Calculated displacements are compared to field measurements from the experiment. A good agreement is observed between field observations and calculation results. The study indicates that both su anisotropy and strain-softening have a notable impact on the undrained behavior of the Perniö embankment. Furthermore, it was shown how the modelling of post-peak properties influences the computed failure mechanism.

The issue of undrained shear strength increase in clayey layers under old embankments due to consolidation is studied through CPTU and field vane test results from Murro test embankment. Previous test results suggested a decrease of shear strength under the embankment after a few years of consolidation. The new test results show that the strength has increased and the soil has reached its normally consolidated state. Undrained shear strength and preconsolidation pressure are assessed using existing as well as calibrated transformation models. Data from the Murro test site shows that su has increased by over 50% in the uppermost part of the deposit.

Engineering aspects related to the topics object of study are discussed and some complex issues are addressed from a practical point of view. Firstly, some indications on the use of the new correlations for su of Finnish clays are provided. Secondly, suggestions about how to derive soil parameters for FE total stress soil models are given. Finally, a simplified methodology is proposed to model strength increase in total stress analyses.
Combining mineral fractions of recovered MSWI bottom ash: improvement for utilization in civil engineering structures

In real-life construction projects, the utilization of different types of waste derived aggregates can often be falsely considered as utilization, but in fact, it is merely dumping the potentially high value material from one site to another. For example, building highway noise barriers with waste derived aggregates cannot be considered as utilization. In this study, a more advanced approach was chosen in order to create aggregate like products from recovered municipal solid waste incineration (MSWI) bottom ash (BA) and thus potentially increase their value and image in civil engineering applications. MSWI BA from one waste incineration plant in Finland was first treated with a Dutch dry treatment technology called ADR (Advanced Dry Recovery). This process separates non-ferrous and ferrous metals from MSWI BA and generates mineral fractions of different grain sizes. These mineral fractions may not be used separately, for example, in the unbound structural layers of roads due to the strict grain size distribution requirements of these civil engineering structures. Hence, different combinations were designed from these BA mineral fractions using the mathematical proportioning of aggregates. The aim was to create aggregate like products from this waste material for different structural layers (filtration, sub-base and base) of, for example, road and field structures. Three mixtures were chosen based on their correspondence to the grain size distribution requirements of natural aggregates and further analyzed in the laboratory from their technical, mechanical and environmental point of view. The leaching of chrome (Cr) and chloride (Cl-) exceeded the Finnish emission boundary values for utilization of certain types of ashes in civil engineering. On the other hand, the technical and mechanical properties of these mixed bottom ash products were considered suitable to be used, for example, in the unbound structural layers of the interim storage field in a waste treatment center. In such location, also the leaching potential of harmful substances can be further studied and verified in a larger scale.
A laboratory listening experiment on subjective and objective rating of impact sound insulation of concrete floors

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Authors: Kylliäinen, M., Hongisto, V., Oliva, D., Rekola, L.
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http://www.internoise2016.org/
Research output: Scientific > Conference contribution

A method for design of sound insulation of glazed balconies against traffic noise

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Organisations: Department of Civil Engineering, Research group: Building Acoustics, A-Insinöörit Suunnittelu Oy
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http://www.internoise2016.org/
Research output: Scientific > Conference contribution

Problems with Railway Track Drainage in Finland
Several studies have shown that water plays a significant role in phenomena that weaken track geometry. For instance, water may cause frost heave, thaw softening, attrition of ballast, and weakening of the load bearing capacity of a track. Functioning drainage can prevent water damage, but no researched data on the magnitude of the impacts exist.

Most of the Finnish rail network has been built in times when earthworks were kept to a minimum. Drainage generally functions well along new and renovated rail sections, but the situation is quite different with old tracks. If unevenness problems can be dealt with adequately by improving drainage, it is considerably more advantageous compared to massive renovation. The aim is to find out whether systematic improvement of drainage can produce significant savings in rail network maintenance.
The study examines the unevenness problems discovered along the Finnish rail network where the functioning of drainage is thought to be a major factor, while seeking solutions to the problems. This article presents the technical and administrative problems related to drainage in the Finnish rail network. Based on observations made so far, even basic drainage solutions are beset with problems since e.g. ditches are not cleaned with sufficient regularity.

The on-going study aimed to determine the impact of drainage on track unevenness at monitored sites. However, the method did not work as expected since no suitable sites, where other significant measures had not been carried out in connection with drainage renovation, could be found along the rail network. Moreover, it was difficult to get information about earlier renovation measures.

It can be said already at this phase of the study that drainage maintenance should be improved. There are also problems with drainage assessment methods which consist mainly of visual inspection instead of more sophisticated methods. Subjective assessment methods and maintenance contracts that call for maintenance 'as required' easily lead to postponement of maintenance measures.

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Scopus rating (2012): SJR 0.191 SNIP 0.396 CiteScore 0.28
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Research output: Scientific - peer-review › Article

The effect of climate change on freeze-thaw durability of concrete structures in Finland
Lahdensivu presented in his Doctoral Thesis (Durability Properties and Actual Deterioration of Finnish Concrete Facades and Balconies, 2012) that without proper air-entrainment outdoor concrete structures have needed average of 307 freeze-thaw cycles (threshold value: t ≤ -5 °C) after a rain event in southern Finland and 388 cycles in inland for incipient freeze-thaw damage to occur. The difference between figures can be explained by the greater amount of wind-driven rain (WDR) before the freeze-thaw cycle on coastal areas.

As a consequence of climate change it has been shown that by the end of the century, the amount of WDR is going to increase 30 % at southern Finland and 40 % at inland. At the same time the amount of freeze-thaw cycles after a rain event are decreasing significantly at both locations which indicates freeze-thaw durability-wise longer service life for outdoor concrete structures. However, the latest studies show that while the amount of freeze-thaw cycles is decreasing, the amount of WDR before the cycles is also increasing significantly.

The WDR at winter time in Finland is highly orientated on west to south-east directions which can be seen also by the degradation rate observations of concrete facades and balconies based on condition assessments. In this study, the changes at WDR before the freeze-thaw events and the effect of climate change on them depending on the structure orientation are calculated to estimate the changes of climatic stress level on outdoor concrete structures.
Deterioration mechanisms and life cycle of concrete monoblock railway sleepers in Finnish conditions

Thirty eight sleepers aged 30 to 40 years old were removed from Finnish railway lines and were loaded. Twelve new sleepers were also tested. The old sleepers fulfilled most of the requirements specified for the new ones. The old sleepers were also much more resistant to loading than predicted by structural calculations. The purpose of field tests was to establish the role of traffic loads in the life-cycle of sleepers: the actual stresses and moments in sleepers due to traffic loads; the distribution of the load through the underside of the sleeper to the ballast; and the variation in ballast-sleeper reaction on different sections of track in different seasons. Strain changes at the top surfaces of sleepers were measured on tracks while the rail was loaded by passing trains. Ballast-sleeper reactions tended to be concentrated under the rail along a length of sleeper of approximately 350 mm towards the centre of the track. The mean bending moments determined at the rail seat and centre of sleepers were about ± 2.5 kNm, and the maximum moments were up to ±10 kNm. The purpose of fatigue loading tests was to analyse the long term properties of the sleepers and the effect of fatigue on the stiffness of sleepers. Several load levels were chosen in order to estimate the significance of the fatigue in a real operating situation. The fatigue limit determined based on the loading tests and the computational limit state of crack formation were clearly higher than the bending moments measured in the field tests.
Preliminary results from a study aiming to improve ground investigation data

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Organisations: Department of Civil Engineering, Research group: Foundation Structures, Research area: Earth and Foundation Structures
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Links:
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Research output: Scientific - peer-review » Conference contribution

Strength increase below an old test embankment in Finland

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Organisations: Department of Civil Engineering, Research group: Foundation Structures
Authors: D'Ignazio, M., Länsivaara, T.
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http://britishgeotech.org/the-17th-nordic-geotechnical-meeting/
Research output: Scientific - peer-review » Conference contribution

3D Finite Element Model as a Tool for Analyzing the Structural Behavior of a Railway Track
The rising public and commercial demands on railway network increases the need to improve systems that comprise the railway network. Especially in case of mixed corridors, the demands for track smoothness and load carrying capacity increase simultaneously. From this perspective, the optimization of track design creates efficiency and reduction of life-cycle costs. Hence, there is a great need for a tool which enables designing the load-carrying capacity of a railway track structure as a whole and simultaneously evaluates the stress and/or strain levels of each track component such that the life cycle of the track structure is optimized. The main focus of this study was to create a three dimensional structural model in which the stress-strain behavior of different railway track components could be evaluated realistically. The created model is based on finite element method using PLAXIS 3D software which is specialized in geotechnical problems. Differing from most of the traditional methods, which are based on a theory of linear elasticity, Finite Element Method-based approach with the chosen tool provides a non-linear solution and a three dimensional stress state. As features, the created structural model enables variation in structural layer thickness, rail size, sleeper type (wood/concrete) and material properties of rail pad, ballast, subballast layers and subgrade.
Back-calculation of the Saint-Alban A test embankment with a new modelling approach in LEM
To facilitate the continued use of limit equilibrium method (LEM) in stability design of embankments on soft clays, the new calculation method “Hybrid su” (HSU) has been developed. It is used to derive undrained shear strength from effective strength parameters, or to predict the excess pore pressure at failure. The HSU method uses an anisotropic effective stress soil model with volumetric hardening, from which a closed form solution for the effective mean stress at failure $p'_f$ is derived. This in turn is used to derive the anisotropic undrained shear strength (for use in total stress analyses), or excess pore pressure (for use in undrained effective stress analyses). The model accounts for factors such as anisotropy, consolidation state, volumetric hardening and to some extent, rate effects. An advantage of the model over traditional undrained effective stress calculations is that the overestimation of shear strength at $F > 1$ is avoided.
Characterization of fine fraction mined from two Finnish landfills

A fine fraction (FF) was mined from two Finnish municipal solid waste (MSW) landfills in Kuopio (1- to 10-year-old, referred as new landfill) and Lohja (24- to 40-year-old, referred as old landfill) in order to characterize FF. In Kuopio the FF (<20mm) was on average 45±7% of the content of landfill and in Lohja 58±11%. Sieving showed that 86.5±5.7% of the FF was smaller than 11.2mm and the fraction resembled soil. The total solids (TS) content was 46-82%, being lower in the bottom layers compared to the middle layers. The organic matter content (measured as volatile solids, VS) and the biochemical methane potential (BMP) of FF were lower in the old landfill (VS/TS 12.8±7.1% and BMP 5.8±3.4m³ CH₄/t TS) than in the new landfill (VS/TS 21.3±4.3% and BMP 14.4±9.9m³ CH₄/t TS), and both were lower compared with fresh MSW. In the Kuopio landfill materials were also mechanically sieved in the full scale plant in two size fraction <30mm (VS/TS 31.1% and 32.9m³ CH₄/t TS) and 30-70mm (VS/TS 50.8% and BMP 78.5m³ CH₄/t TS). The nitrogen (3.5±2.0g/kg TS), phosphorus (<1.0-1.5g/kg TS) and soluble chemical oxygen demand (COD) (2.77±1.77kg/t TS) contents were low in all samples. Since FF is major fraction of the content of landfill, the characterization of FF is important to find possible methods for using or disposing FF mined from landfills.

General information

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Authors: Mönkäre, T. J., Palmroth, M. R. T., Rintala, J. A.
Number of pages: 6
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Scopus rating (2013): SJR 1.822 SNIP 2.435 CiteScore 3.39
Scopus rating (2012): SJR 1.611 SNIP 2.184 CiteScore 2.91
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Scopus rating (2006): SJR 1.046 SNIP 1.749
Scopus rating (2005): SJR 1.059 SNIP 1.65
Scopus rating (2004): SJR 1.289 SNIP 1.939
Scopus rating (2003): SJR 0.847 SNIP 1.269
Scopus rating (2002): SJR 0.581 SNIP 0.874
Commercialising reclaimed materials in earthworks – guidelines for productization and the process of appending these materials in the Finnish national code of practice

To decrease the use of non-renewable natural resources as well as environmental effects of earth-works, natural aggregate materials can be replaced with recycled materials acquired from surplus soil, industrial by-products and waste, etc. When wishing to increase the usage of these reclaimed materials (=“UUMA”-material), the usage must be straightforward for developers, designers and constructors alike. To make this possible, the materials must have design guidelines for their appropriate applications. They must be productized and CE marked or otherwise authorized, and the construction guidelines for the materials must be included in the Finnish general specifications for infrastructural construction works (InfraRYL). As productization is especially important in increasing the usage of UUMA materials, guidelines for vendors are being drawn that present information on commercializing reclaimed materials to be used in earthworks. The guidelines for productization are being prepared in the Finnish national UUMA2 programme (2013-2017, www.uuma2.fi), which was created to promote the use of recycled materials in earthworks.

General information
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Ministry of Education publication type: A4 Article in a conference publication
Organisations: Department of Civil Engineering, Research area: Earth and Foundation Structures, Research group: Earth Constructions, Research group: Track Structures, Ramboll Finland Ltd.
Authors: Koivisto, K., Forsman, J., Ronkainen, M., Lahtinen, P., Kolisoja, P., Kuula, P.
Number of pages: 10
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Correlations for undrained shear strength of Finnish soft clays
The study focuses on the derivation of transformation models for undrained shear strength ($s_u$) of Finnish soft sensitive clays. Specific correlation equations for $s_u$ of Finnish clays are presented in this work for the first time. Field and laboratory measurements from 24 test sites in Finland are exploited for this purpose and a multivariate database is constructed. The multivariate data consists of $s_u$ from field vane, preconsolidation stress, vertical effective stress, liquid limit, plastic limit, natural water content and sensitivity. The main objective is to evaluate the interdependence of $s_u$, consolidation stresses and index parameters and provide a consistent framework for practical use. The new correlations are established through regression analyses. The constructed framework is further validated by another independent multivariate database of clays from Sweden and Norway as well as by empirical equations for Swedish and Norwegian clays. Existing correlations are evaluated for Finnish and Scandinavian clays. Finally, bias and uncertainties of the new correlations are presented.

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Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Civil Engineering, Research group: Foundation Structures, National University of Singapore
Authors: D'Ignazio, M., Phoon, K. K., Tan, S. A., Länsivaara, T.
Pages: 1628-1645
Publication date: 2016
Peer-reviewed: Yes
Modelling of plastic culvert and road embankment interaction in 3D

A series of 3D Finite Element simulations was performed to investigate the effect of different factors influencing the distortions undergone by a plastic culvert tube while subject to external loading from a heavy truck. The applied simulation model was verified by full-scale loading tests carried out on a number of actual culvert installation sites. Based on the results of the study, it can be concluded that both installation depth and quality of the material surrounding the culvert have a dominant effect on culvert distortions while the effects of material quality above the culvert and the type of tyre configuration transmitting the wheel load are much less pronounced.
Teräsrumpujen uudet korjausmenetelmät: Halkaistu sisäputki, puolipohjaus ja pohjan betonointi

Tässä tutkimuksessa arviotiin uudentyypistä korjausmenetelmiä. Tutkimuksessa rajauduittiin tarkastelemaan sellaisia korjausmenetelmiä, joita käytäntöön rumpuputken aiheuttama koko pienenee mahdollisimman vähän. Rumpujen korjaaminen on kannattavinta kohteissa, joissa rumpun asennussyvyys on suuri tai tien aikuivaiminen aiheuttaa suuret liikenteenjärjestelykustannukset.


Aiemmissa rumpuputken mekaanisen toiminnan mallintamisissa käytetyn PLAXIS 3D-ohjelmiston rinnalla mallinnettiin tässä tutkimuksessa rumpuputkeen syntyvää rasituksia kokeilla myös ANSYS-ohjelmistolla. Tämän osalta todettiin, että korjatuun rumpuputken mekaaninen käyttäytymisestä on saatavissa arvioida arviointisotien materiaaliparametreilla. Suurin yksittäinen laskennallista virhettä aiheuttaa visuaalisesti teki, että korjattavassa rumpuputkessa käytetyn syvyysti sivuvaltaan rumpuputkea.

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Ministry of Education publication type: D5 Text book, professional manual or guide or a dictionary
Organisations: Department of Civil Engineering, Research group: Earth Constructions, Research group: Structures and Their Behaviour, Research group: Mechanics of Structures, Research area: Earth and Foundation Structures
Authors: Kalliainen, A., Haakana, V., Korhonen, M., Mäkinen, J., Kolisoja, P.
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Publication date: 2016

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Research output: Scientific - peer-review › Article
The effects of improved energy efficiency on indoor environmental quality in multi-family buildings

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State: Published
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Organisations: Department of Civil Engineering, Research group: Structures and Their Behaviour, Research area: Structural Engineering, Research group: Building Physics and Acoustics, Natl Inst Hlth & Welf, Finland National Institute for Health & Welfare, Dept Environm Hlth, Kaunas Univ Technol, Kaunas University of Technology, Dept Environm Technol
Authors: Du, L., Prasauskas, T., Leivo, V., Turunen, M., Kiviste, M., Martuzevicius, D., Haverinen-Shaughnessy, U.
Publication date: 2016

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http://www.indoorair2016.org/
Research output: Scientific - peer-review › Conference contribution

Vesihuollon strateginen kehittäminen haltuun: Ydin- ja tukitoiminnon tarpeen hahmottaa selkeästi

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Authors: Katko, T. S., Hukka, J. J.
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http://kuntatekniikka.fi/lehtiarkisto/022016/vesihuollon-strateginen-kehittaminen
Research output: Professional › Article

Tien ja radan sitomattomissa rakennekerroksissa käytettävien kiviaisten ljuuden ja hienontumisen tutkiminen : kirjallisuusselvitys

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Ministry of Education publication type: D4 Published development or research report or study
Organisations: Department of Civil Engineering, Research group: Track Structures
Authors: Kuula, P.
Number of pages: 115
Publication date: 18 Nov 2015

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Volume: 68
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Original language: Finnish
Concern over arsenic (As)-rich drinking water has gained worldwide attention since the 1990s, when the problem was discovered in West Bengal in India and in Bangladesh. Since then, authorities and research institutes have focused on risk assessment and management for As in Finland. Nationwide geochemical mapping projects determined background levels and revealed regions with a higher than average As content in bedrock and soil. Approximately 10% of the citizens in Finland use drinking water from private wells. Groundwater, especially from drilled bedrock wells, may contain As concentrations higher than 10 μg/L, the European Union quality guideline for As in drinking water. Here, we present the outcome of two European Union projects, RAMAS and ASROCKS, which based their conclusions on nationwide databases and thousands of samples. Both RAMAS and ASROCKS focused on the Tampere-Häme region of Southern Finland, where bedrock and soil contain more As than in other parts of Finland on average. Over 1000 groundwater samples revealed that drilled bedrock wells may contain As-rich water in certain geological units. Naturally occurring As in bedrock and soil may also cause the mobilization of As during rock aggregate production and construction activities, potentially impacting on groundwater aquifers, surface waters, and biota. Arsenic concentrations in aggregate production and construction exceeded the regional background levels in some bedrock and aggregate product samples, but during leaching tests As concentrations were found to be low. Based on the results, risk management tools were revised and guidelines for the rock aggregate industry were established in cooperation with authorities, companies, and other stakeholders. To our knowledge, the guidelines established were the first in the world. The guidelines for As for the aggregate and construction industries can be applied in other countries and adapted to local conditions.
Laastin ja betonin lämmönjohtavuuden ja ominaislämpökapasiteetin määrittäminen lämpövirtalevylaitteella

Betonisten ratapölkkyjen väsytyskuormituskokeet
In fatigue load tests, unused Finnish concrete railway sleepers B97 and BP99 were loaded. The purpose of the loading tests was to analyse the fatigue properties of the sleepers and the effect of the fatigue on the stiffness of the sleeper. Furthermore, the significance of cracks was estimated in the study. The load levels were chosen so that it was possible to estimate the significance of the fatigue in a real operating situation. The fatigue limit that has been determined based on the loading tests and the calculatory limit state of crack formation are distinctly higher than the bending moments that have been measured in the field tests. Consequently, the deterioration of the railway sleepers under the traffic load and due to the fatigue is very unlikely.

Test in scala reale su argille sensibili: l’esperienza finlandese
In real scale tests on sensitive argillic soils: the Finnish experience
A proposal for some modifications of EN 1997-1 design approaches

All Eurocodes are currently under a critical review, while the work for a second generation of codes are about to start in 2015. For the geotechnical design EN 1997-1 is facing high demands for harmonization and simplification of the present code.

The paper presents some proposals for improving the code regarding ultimate limit state (ULS) design. The goal is to make the code better in accounting for uncertainties involved in the design and possible consequences of an ultimate limit state. When applying a material factor approach (MFA), the partial safety factors are suggested to depend on both the uncertainty of the material and the consequence of failure. Such an approach is well suited for slope stability analysis. However, the authors suggest that also the uncertainties involved with loads should be placed on the material factors. For retaining wall design and load factor approach (LFA) is suggested in addition to MFA similar to present Design Approach (DA) 1 in the Eurocode. This approach gave the most consistent design for all cases in a comprehensive study preformed. Some modifications are though suggested also for DA1 to make the design simpler and even more consistent.
Konvektiivinen lämmönsiirtyminen ratapenkereessä

Modern track evenness demands are high which is why frost heave causes considerable problems in Finland. Nowadays railway ballast and sub-ballast are often of crushed rock whose thermal performance differs from that of the traditional gravel. Many studies around the world have found that convective heat transfer may occur in very coarse crushed rock aggregate. This can lead to increased heat transfer from the embankment which allows frost to penetrate deeper than normal calculation methods predict.

Many studies have been conducted on free convection internationally, and there is a calculation model for estimating its probability. However, the calculation involves problems because the calculation model considers intrinsic permeability, which is difficult to define for coarse materials. Intrinsic permeability can be calculated from water permeability. Unfortunately, water permeability is difficult to determine for coarse materials. The results of research conducted abroad are not as such applicable in determining convection in Finnish railway embankments because of different grain sizes. Therefore, new laboratory test apparatus was built. Three materials of different gradation were tested in the lab: 31.5/63 mm ballast aggregate, 5/16 mm crushed rock aggregate, and 0/63 mm sub-ballast material.

Strong natural convective heat transfer via air occurred in the railway ballast tested in the lab. If the medium was moist air or water, convection could occur at smaller temperature differences. No significant convection occurred in the crushed rock and sub-ballast material via convection, but when water was added to the sample, thermal conductivity of the material increased significantly due to convection. The same phenomenon was observed in the case of 5/16 mm crushed rock, but adding of water did not increase thermal conductivity significantly.

Two actual railway embankments on which temperature data was available were also tested. The data allowed estimating the temperature differences in the embankments. Based on the results from the test embankments in Seinäjoki, Finland, the thermal performance of the gravel embankment and crushed rock embankment differed, but the possibility of natural convection could not be proved nor completely excluded. The study showed that crushed rock ballast and sub-ballast material may allow natural convection to occur if its grain size distribution is close to the most coarse and even-grained materials allowed by the current guidelines. Sorting of the material in the building phase can increase this susceptibility to convection.
Shear bands in soft clays: strain-softening behavior in finite element method

Strain-softening behavior of soft sensitive clays is very often neglected in geotechnical design. During undrained loading, such materials show a dramatic loss of strength after the peak stress, until residual strength is reached at large strain. As a consequence, local failure occurs and plastic strains localize in a shear band. shear band modeling in Finite Element Method requires a regularization technique to overcome mesh dependency. NGI-ADPSOFT2 model is able to simulate the post-peak softening behavior of sensitive clays. In this study, the influence of strain softening on the stability of sensitive clay slopes is studied using the NGI-ADPSOFT2 model. The analyses are conducted using the finite element software PLAXIS 2D AE. The advantages of using a strain-softening soil model are discussed.
Anisotropic total and effective stress stability analysis of the Perniö failure test

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ASROCKS-Hankkeen heikkouuttomenetelmien vertailu

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Authors: Tarvainen, T., Hatakka, T., Backman, B., Ketola, T., Härmä, P.
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**Bibliographical note**
Finnish mine waste disposal areas

In 2013, a total of forty-six mines and quarries were operating in Finland, and several new mining projects were in progress. Both mining and environmental legislation and dam safety regulations have been developed and renewed during recent years, and the mining and permitting authorities have changed.

Due to problems at the Talvivaara Mine in 2013, the Finnish government decided to implement a voluntary stress test for Finnish mines. The method was developed based on the stress test designed for nuclear power plants by the European Nuclear Safety Regulators Group (ENSREG). Altogether twenty-one mines or concentrating plants were chosen to be tested, and twenty responded. In the stress test questionnaire there were fifteen questions on seven risk scenarios that the nominated expert group assessed to be both potential and significant. There are sixty-seven tailings dams in Finland. Nine of them have been classified as Class 1 ("consequence class"), that is, dams which could cause loss of life in the event of dam failure. The study showed that the hydrological design of tailings dams has to be reconsidered. One finding of the stress test was that the dam safety legislation and the guidelines do not define criteria for the closure of tailings dams. Based on the results, mining companies are monitoring their dams quite well and are aware of dam safety risks, probably thanks to the detailed dam safety legislation. However, the base of the waste areas is typically ignored. Old mining waste areas are mainly built on natural soil layer without any liners. New mining waste areas require an environmental permit, which contains requirements for the bottom liners as well.

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Organisations: Department of Civil Engineering
Authors: Leppänen, M., Laasonen, J., Välisalo, T.
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Links:
http://www.geosyntheticssolutions.com/
Research output: Scientific - peer-review › Conference contribution
Kiviainesten otto arseenialueilla - opas kiviainesten tuottajille, maarakentajille ja viranomaisille.

**General information**
State: Published
Ministry of Education publication type: D4 Published development or research report or study
Organisations: Department of Civil Engineering
Authors: Härmä, P., Tarvainen, T., Backman, B., Hatakka, T., Ketola, T., Kuula, P., Luoma, S., Pyy, O., Sorvari, J., Loukola-Ruskeeniemi, K.
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https://www.gtk-kauppa.fi/products/view/14373

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Source-ID: 414
Research output: Professional › Commissioned report

Liite 6: Yleistä kaivannaisjättealueista ja patoturvallisuudesta

**General information**
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Organisations: Department of Civil Engineering, Research group: Earth Constructions
Authors: Leppänen, M., Välisalo, T. (ed.), Laasonen, J.
Publication date: 2014

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**Publication series**
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http://www.ym.fi/fi-FI/Ajankohtaista/Julkaisut/YMra_22014_Kaivosten_stressitestit_2013%2828221%29
Research output: Professional › Chapter

Stiffmaster - A continuous track stiffness measurement device

**General information**
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Organisations: Department of Civil Engineering
Authors: Luomala, H., Peltokangas, O., Nurmikolu, A.
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