ASSERT subproject:
New cartridge holder with integrated sensors
Resistivity & shear strength monitoring

Markstabilisering	*Stabilisering och tätning av lösa jordar.*
Resistivitet	*Resistivitet (invers till ledningsförmåga) i material, relateras till mekaniska, hydrauliska egenskaper.*
ASSERT	*Kvalitetskontroll av markstabilisering med elektrisk resistivitetstomografi*

Effektiv och tillförlitligare kvalitetskontroll:

- *Starkare infrastruktur som varar längre*
- *Skador kan åtgärdas i tidigare skeden*
- *Minskat materialsvinn. Cementbaserade bindningsmedel stor utsläppskälla för CO_2.*
    - *!!Exempel från VL nibben petersen*

OKTOBER 2021
MIKAEL.LUMETZBERGER@TG.LTH.SE

2.Koncept

Kolvprovtagning med borrbandvagn	Beredning av prov i labb

↓ ↓

Ostört prov i hylsa

↓

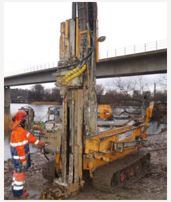
Oförstörande resistivitetsmätning

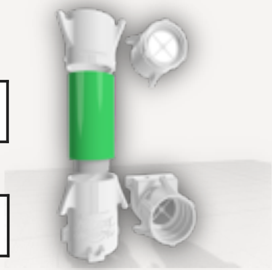
↓

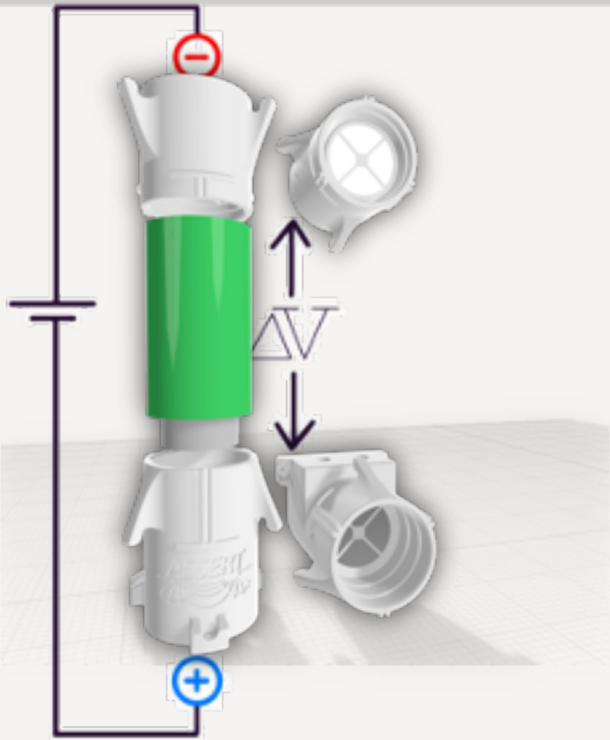
Oförstört prov i hylsa

↓

Mekaniska tester







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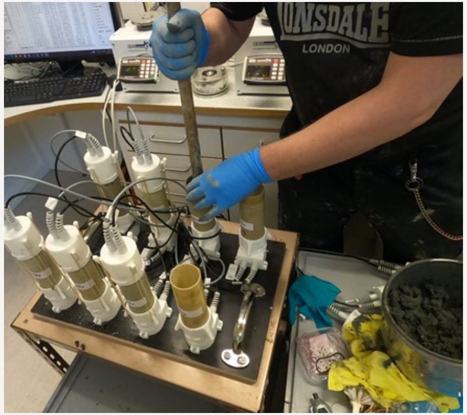
3.Funktion

Beredning av kalkcement | *Packning på monteringsbräda* → *Automatisk resistivitetsmätning under härdningsperiod* → *Mätning av skjuvhållfasthet med enaxiell tryckpress.*

Terrametersystem fjärrstyrs med script som hanterar mätning och uppladdning av data.



**Bilder från Statens Geotekniska Institut, utförd i samarbete med tekniker på SGI:s geotekniska labb i Linköping*

4.Resultat

Metodik

Effektiv, repeterbar	*Kvantifiera mätosäkerheter*

*Mätprecision ±0,2%**

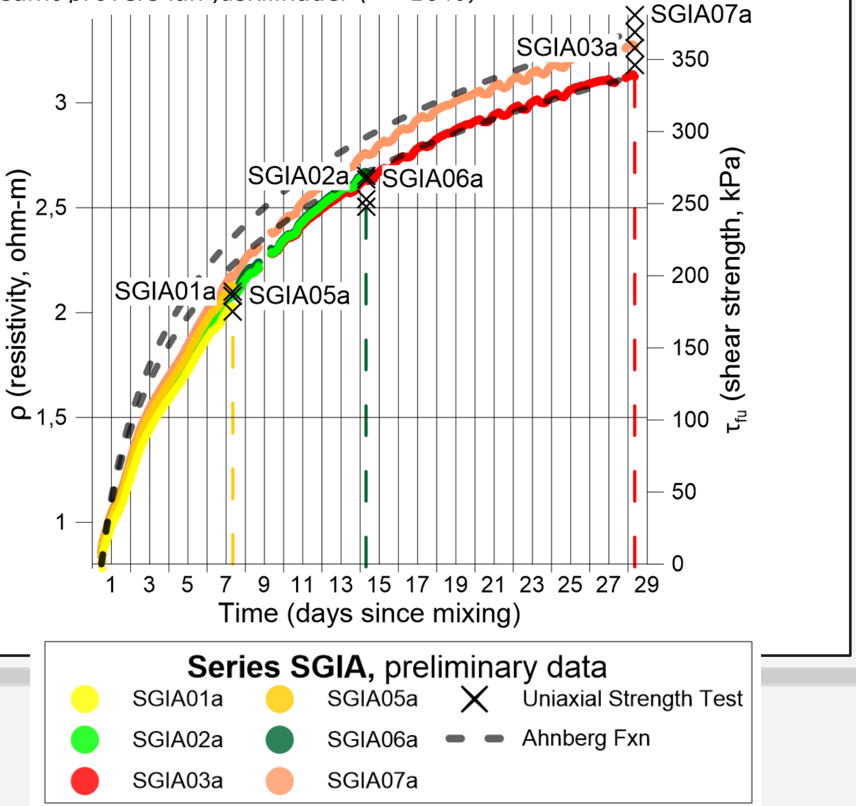
**(95% konfidensintervall, x datapunkter)*

Databas. Observera.	*Kvantifierbara sammanhang*

SGI serie A Maj-Augusti. 8 prover.

-Mätning dygn 7, 14, 91 (enaxiala tryckförsök: skjuvhållfasthet).

-ρ-värden (preliminära): Ska justeras efter temperaturvariationer samt provers längdskillnader (≈±10%)



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5. Diskussionsunderlag

Metodik

Effektiv, repeterbar	Kvantifiera mätosäkerheter

*Mätprecision ±0,2%**

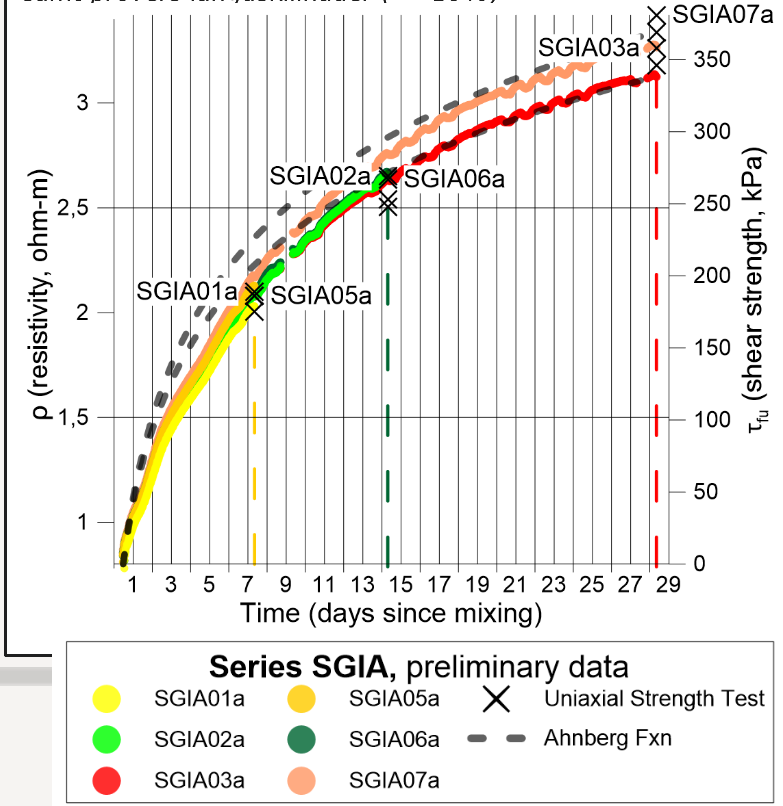
**(95% konfidensintervall, x datapunkter)*

Databas. Observera.	Kvantifierbara sammanhang

SGI serie A Maj-Augusti. 8 prover.

-Mätning dygn 7, 14, 91 (enaxiala tryckförsök: skjuvhållfasthet).

-ρ-värden (preliminära): Ska justeras efter temperaturvariationer samt provers längdskillnader (≈±10%)



Kvalitetskontroll

Effektiv och tillförlitligare kvalitetskontroll:

- *Starkare infrastruktur som varar längre*
- *Skador kan åtgärdas i tidigare skeden*
- *Minskat materialsvinn. Cementbaserade bindningsmedel stor utslapplskälla för CO_2. !!Exempel från VL nibben petersen*

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Applikationer

Styrkeberäkning innan härdning
Geometrisk avbildning av pelare
Detektion av sprickor och inläkage
…Framtida labb och fältapplikationer

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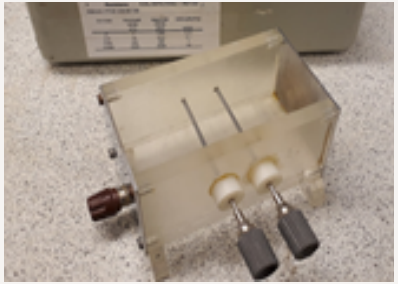
Nuvarande resistivitetsminstument SGI



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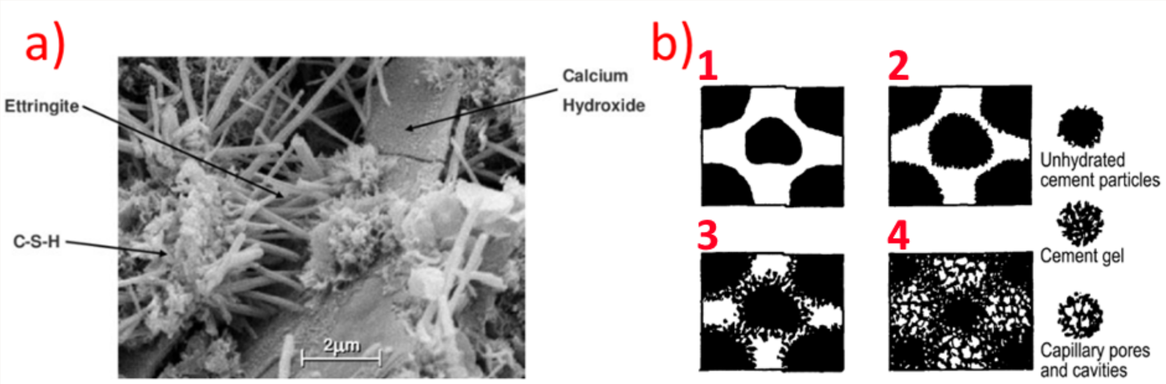
Cementeringsprocessen



NSG2019 ERT Ka … g Västlanken

Quality control of lime-cement pillar using electrical resistivity tomography

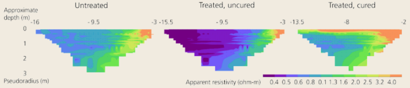
OLSSON P.-I., REJKJÆR S. & DAHLIN T. FIELD-SCALE QUALITY CONTROL OF LIME-CEMENT PILLAR IN CONDUCTIVE CLAY USING ELECTRICAL RESISTIVITY TOMOGRAPHY
PAPER 94 (*WE_INFRA_P25*) IN: NEAR SURFACE GEOSCIENCE 2019 - 1ST CONFERENCE ON GEOPHYSICS FOR INFRASTRUCTURE PLANNING MONITORING AND BIM

Conclusions

- Substantial increase in resistivity for treated volume after curing.
- Resistivity contrast in data space for untreated versus treated volume.
- Needs for improved field methods and equipment.

In-situ field measurements

FIELD DATA PSEUDOSECTIONS



A multi-electrode borehole cable with take-out spacing of 0.5 m was inserted into slotted pipes and used for the measurements. The pipes were filled with tap water to ensure enough electrode contact. The instrument used was an ABEM Terrameter LS2 with a combined multiple gradient and bipole-dipole array sequence.

The field measurements were carried out at three different stages in the lime-cement pillar process:

1. Before ground improvement - *Untreated ground.*

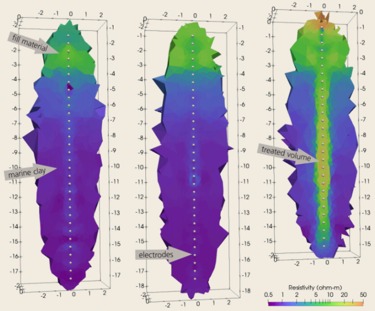
2. At ground improvement - *Treated, uncured ground.*

3. After ground improvement - *Treated, cured ground.*

The measurements for stage 2 were carried out in immediate connection with the construction of the lime-cement pillars and for stage 3 they were carried in the same pipe 36 days after treatment. In addition, the measurement for stage 1 was for practical reasons carried out in a separate pipe close by.

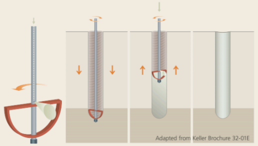
Full 3D inversions of the acquired field data was in this work carried out in BERT/GiMLi v. 2.2.9 (Günther et al., 2006; Rücker et al., 2017). The resulting inversion models are visualized with a vertical clip through the pillar centre and a coverage threshold of one. The inversion models indicate regions which are interpreted as fill material, marine clay, and treated volume as well as the position of the electrodes.

FIELD DATA INVERSION MODELS



Lime-cement pillars

THE PROCESS: MECHANICAL DRY DEEP SOIL MIXING



Existing quality control methods for lime-cement pillars involve two field steps where the first include quality control at the installation process with monitoring of production parameters such as rotation and penetration speed, air pressure and binder feed rate. The second quality control step involves determining the spatial continuity and mechanical properties of the treated subsurface after curing. These tests involve core drilling, complete exposure by digging and a reversed pillar penetration test where a wire-attached probe is pulled through the pillar from the bottom-up. The second step is due to its nature destructive and can only be applied after curing.

Gaps in pillar continuity can severely compromise the intended mechanic and hydraulic properties of the ground, thus it is of utmost importance to construct the pillars according to design. The result of ground improvement is also affected by the type of soil, the type of binder, and the parameters used in the production. Thus, there is a need for new methods capable of determine the in-situ mixing quality prior to curing.

The lime-cement pillars in this specific study were constructed down to around 20 m depth by SMG (Soil Mixing Group) using their dedicated equipment, a mixing tool with diameter of 80 cm and dry lime-cement compound. The mixing was targeting an addition of 50 or 80 kg binder/m^3 soil.

A slotted pipe (inner and outer diameter of 51 mm and 63 mm respectively, slots widths of 0.3 mm) was inserted in the centre of the lime-cement pillar immediately after construction to provide a path for inserting an electrode string into the centre of the pillar. The pipes were installed with a Geotech 605 geotechnical rig and pushed into the centre of the pillar after removal of the mixing tool. The pipes reached different depths ranging between 15 and 17 m depending on the installation method and on the local conditions.

Geoelectrical quality control

This work focuses on the first quality control step which needs to be done in direct connection to when the stabilization is being carried out, so that fixes can be done while equipment and crew are in place and before the binder has cured in treated parts of the volume.

Little strength growth has occurred since the binder has not cured yet, and thus seismic methods are unsuitable. The electrical properties, however, can change drastically when binders are mixed into the soil (Dahlin et al., 1999; Lindh et al., 2000). Electrical resistivity tomography is therefore an interesting option for mapping which parts of the subsurface that has been processed and identify zones that need to be supplemented.

The true diameter of jet columns can for example be estimated within 5% in a range of 0.9 to 2.5 m (Mooney and Bearce, 2017). However, for this to work in routine application the method must be further developed to become robust and easy to handle in the demanding environments. Furthermore, the results of the quality control need to be reported promptly in a form that allows for feedback to the contractor at site.

ACKNOWLEDGEMENTS & REFERENCES

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MIXING TOOL

GEOTECHNICAL RIG

SLOTTED PIPE WITH CABLE

GEOELECTRICAL SURVEY

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