Statens vegvesen

From Research to Practice: Field Testing Mortars for Cathodic Protection

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Agenda

- Background and objectives
- Technical description of the test site
- Testing program
- Results and discussion
  - Laboratory
  - Field
- Conclusions

Background

The test field was part of the R&D program Better bridge maintenance (NPRA), with contributions from:

- Roy Antonsen, Stig-Henning Helgestad, Odd-Magne Rognan, Eva Rodum, Øyvind Bjøntegaard, the Norwegian Public Roads Administration laboratory in Oslo
- Contractor: Visinor
- Sensor technology: Protector AS
- Suppliers of mortar

Foto: Karla Hornbostel, Statens vegvesen

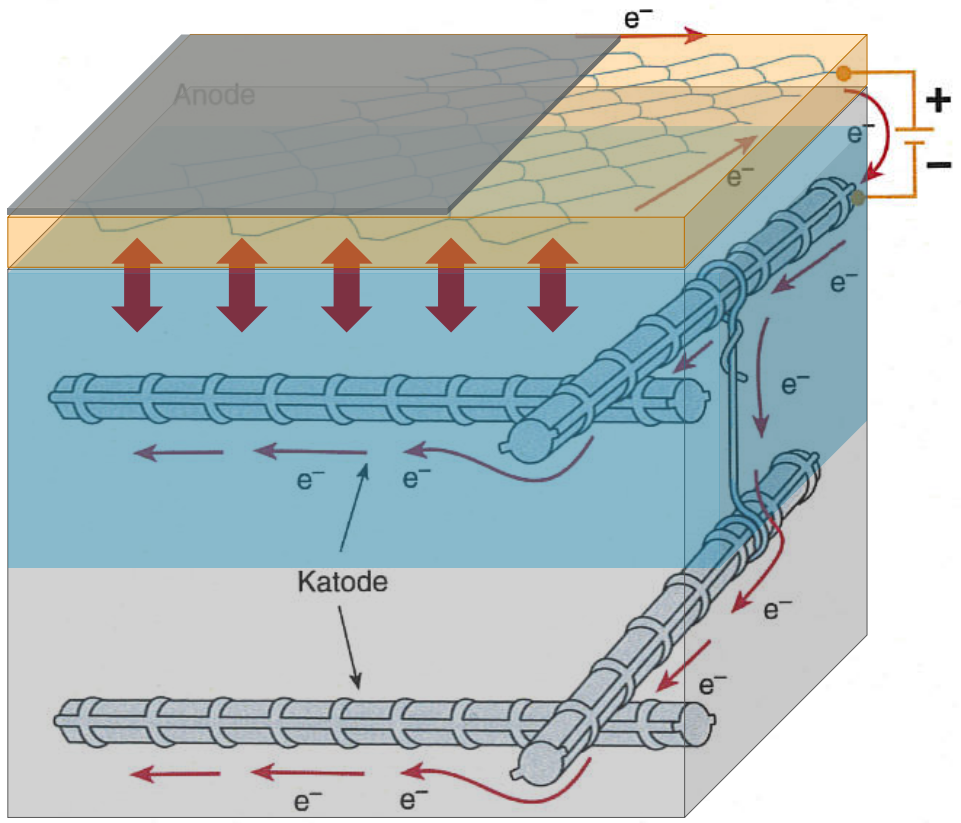
Background

Principle of cathodic protection of steel in concrete with impressed current

Surface treatment

Mortar to spray in the anode (CP)

Repair mortar (Rep)



The ability to conduct current can be described as
Specific electrical resistivity

Lindland, Jan (2016): Betongrehabilitering, Reparasjonsmetoder, utførelse og kontroll, Norsk forening for betongrehabilitering, Oslo, Norway.

Background

NS-EN 12696:2022 (NS-EN 12696:2022 2022)

«The impact of variations in concrete resistivity on the cathodic protection system shall be considered. There is no firm guidance on limits of electrical resistivity with respect to cathodic protection, but the designer shall consider whether full protection can be achieved where required for the range and absolute values of concrete resistivity found on the structure."

Note to concrete reinstatement: "Typically, these repair materials have an electrical resistivity within the range approximately half to twice that of the parent concrete when measured under the same conditions as the parent concrete. However, the electrical resistivity of the parent concrete is that of an aged material (age > 20 years), whereas the electrical resistivity of the repair material reflects the properties at a relatively young age; it is anticipated that there is a significant ageing effect over time. Also, measurements made in the laboratory on prisms do not represent the conditions of the structure. A good quality repair made with materials known to be compatible with cathodic protection installations has been found to be more important than arbitrary resistivity limits."

Objectives and limitations

- The main purpose of the investigation was to look at test methods and appropriate limit values for specific electrical resistance of mortars used in cathodic protection, both for repair mortars used in mechanical repair prior to installation of CP and the mortars themselves used for imbedding the anodes (CP mortar).

- The investigation studied the relationship between specific electrical resistance measured in the field and in the laboratory, respectively.

- In addition, the efficiency of cathodic protection with titanium mesh enclosed by CP mortars with varying electrical conductivity is investigated.

The test site

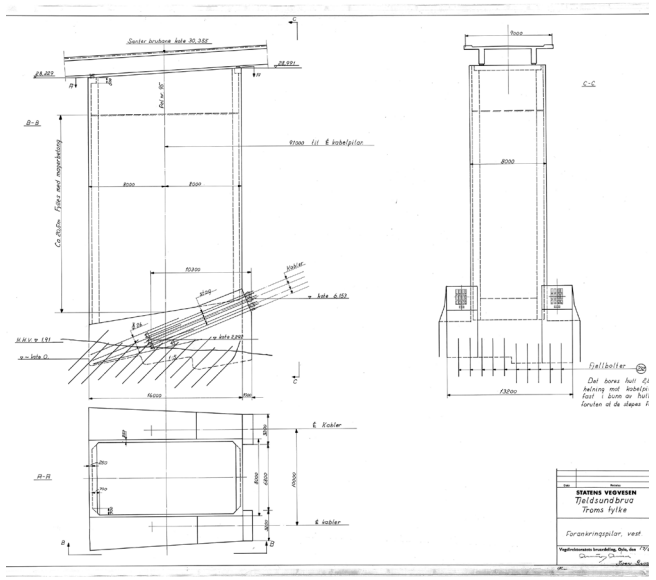
Anchorage pillar

Foto: Roy Antonsen, Statens vegvesen

Technical description of the test site

North side

with mechanical repair



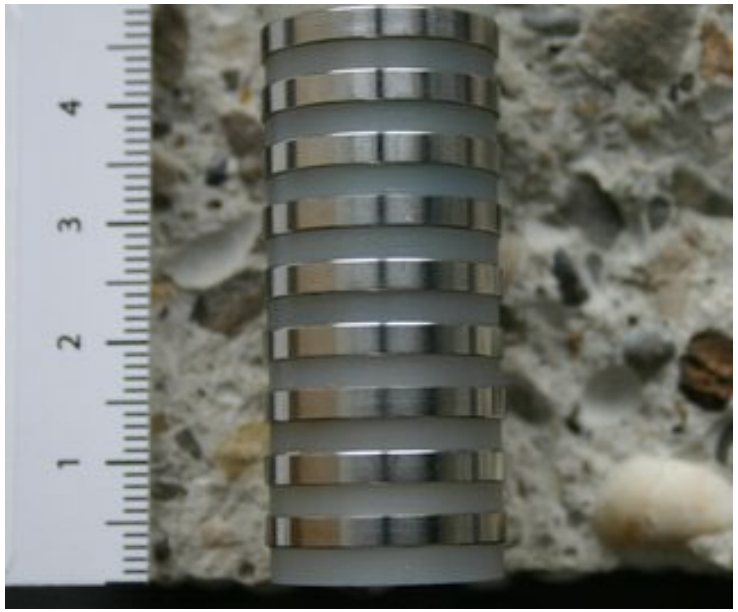
Anchorage pillar

South Side

without mechanical repair

Foto: Karla Hornbostel, Statens vegvesen

Technical description of the test site



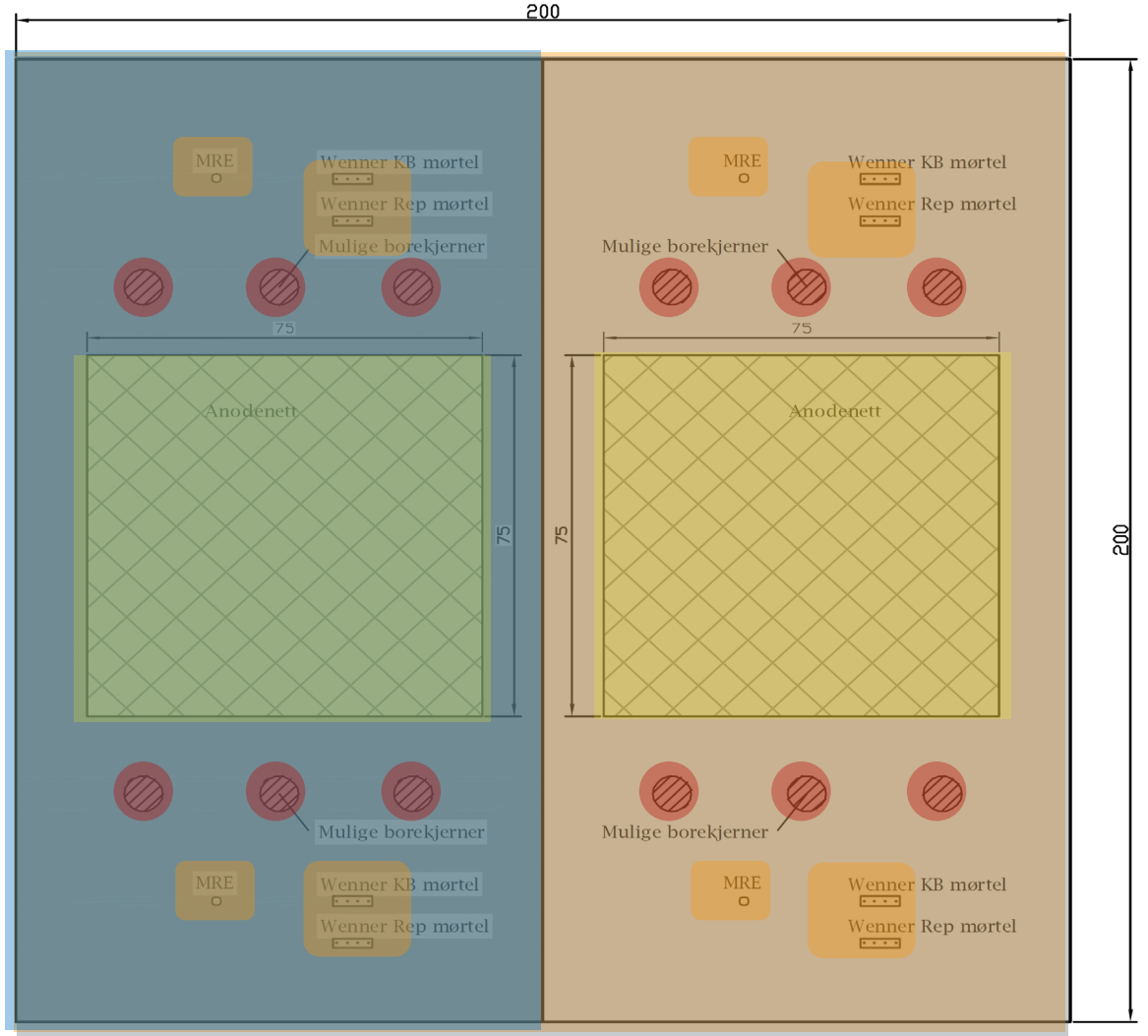


Foto sensorer: Protector AS

Testing program – field

- Electrical resistivity
  - Sensor
  - NDT equipment
- Temperature
- CP-data (depolarisation, current, voltage)

Laboratory testing

- Laboratory specimens produced in the field
- Sprayed mortar and core drilling

Foto: Stig Henning Helgestad, Statens vegvesen

Laboratory testing

- Laboratory specimens produced in the laboratory
- Low and high water content

Foto: Stig Henning Helgestad, Statens vegvesen

Testing program – laboratory

Egenskap	Standard/Metode	Kort beskrivelse
Trykkfasthet	NS-EN 12390-3 Metode 421 i SVV Håndbok R210 [5]	Utført på både prøver fra felt og prøver utstøpt i laboratoriet
Frostbestandighet	NS-CEN/TS 12390-9 Metode 445 i SVV Håndbok R210	Kun utført på prøver fra felt
Kapillær sugehastighet og porøsitet	Metode 426 i SVV Håndbok R210	Forenklet prosedyre
Resistivitet	Metode 443 i SVV Håndbok R210	Utført både på vannlagrede og prøvestykker oppbevart i plast

Resultater laborat orieprøving

I. Electrical resistance testing – production of specimens

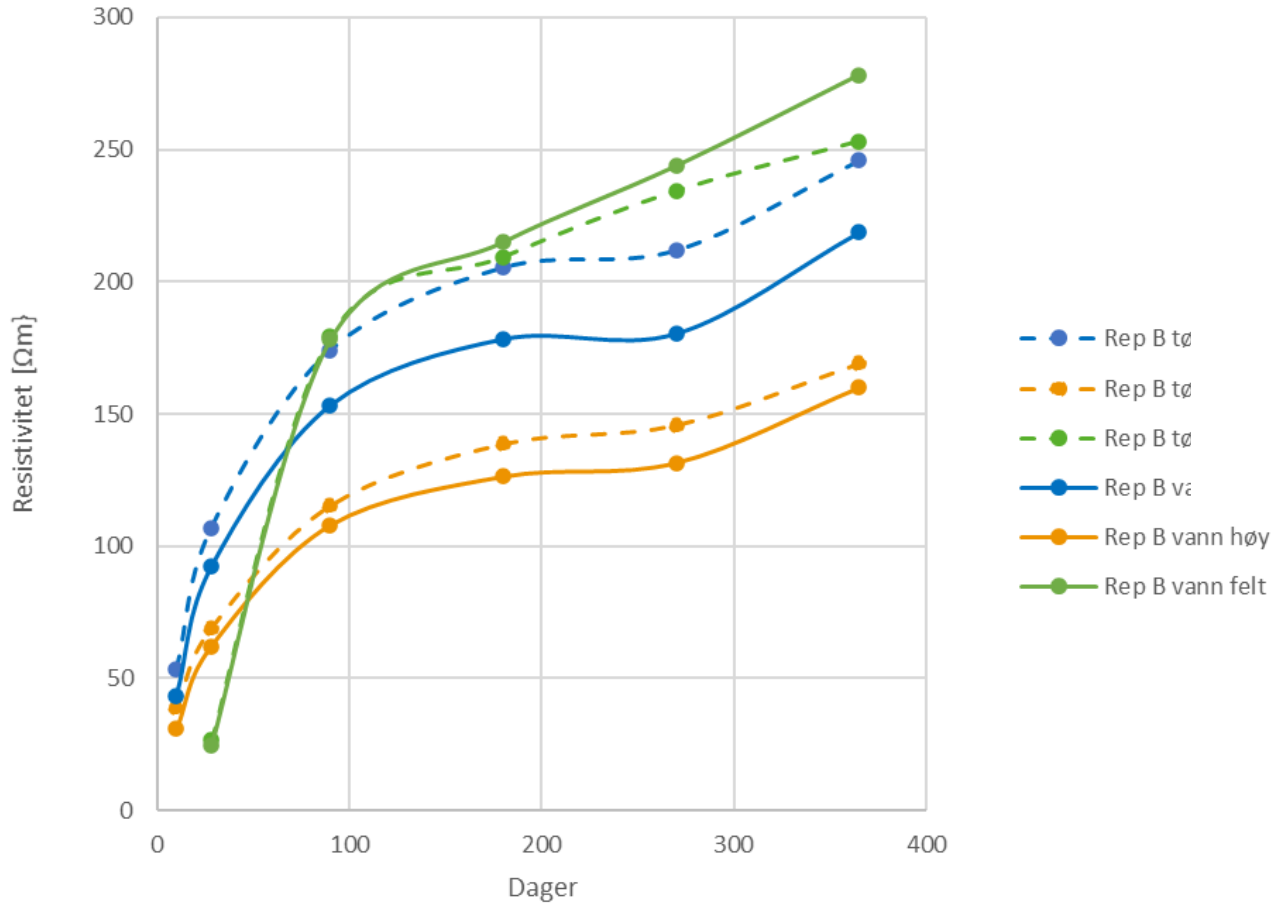
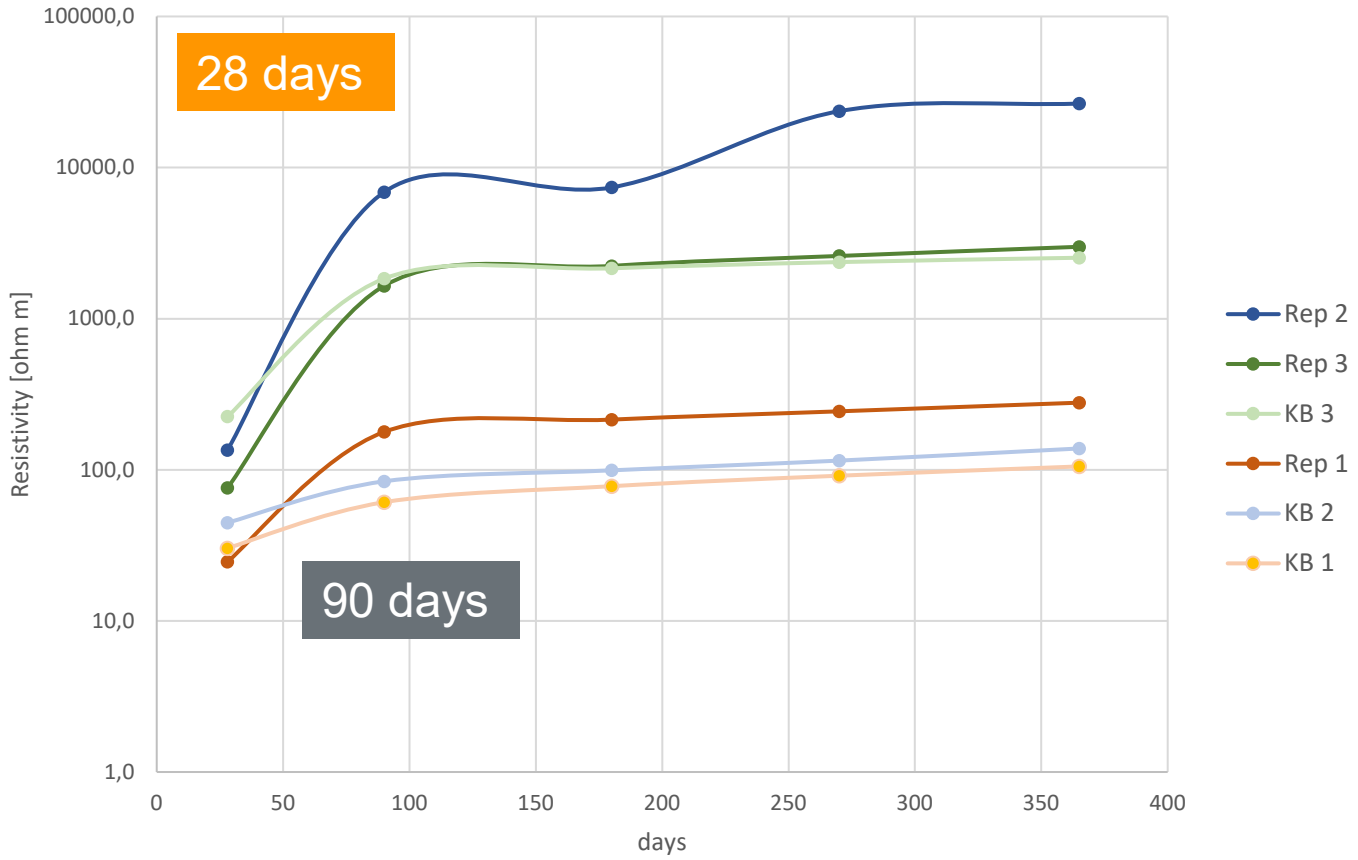


Foto: Stig Henning Helgestad, Statens vegvesen

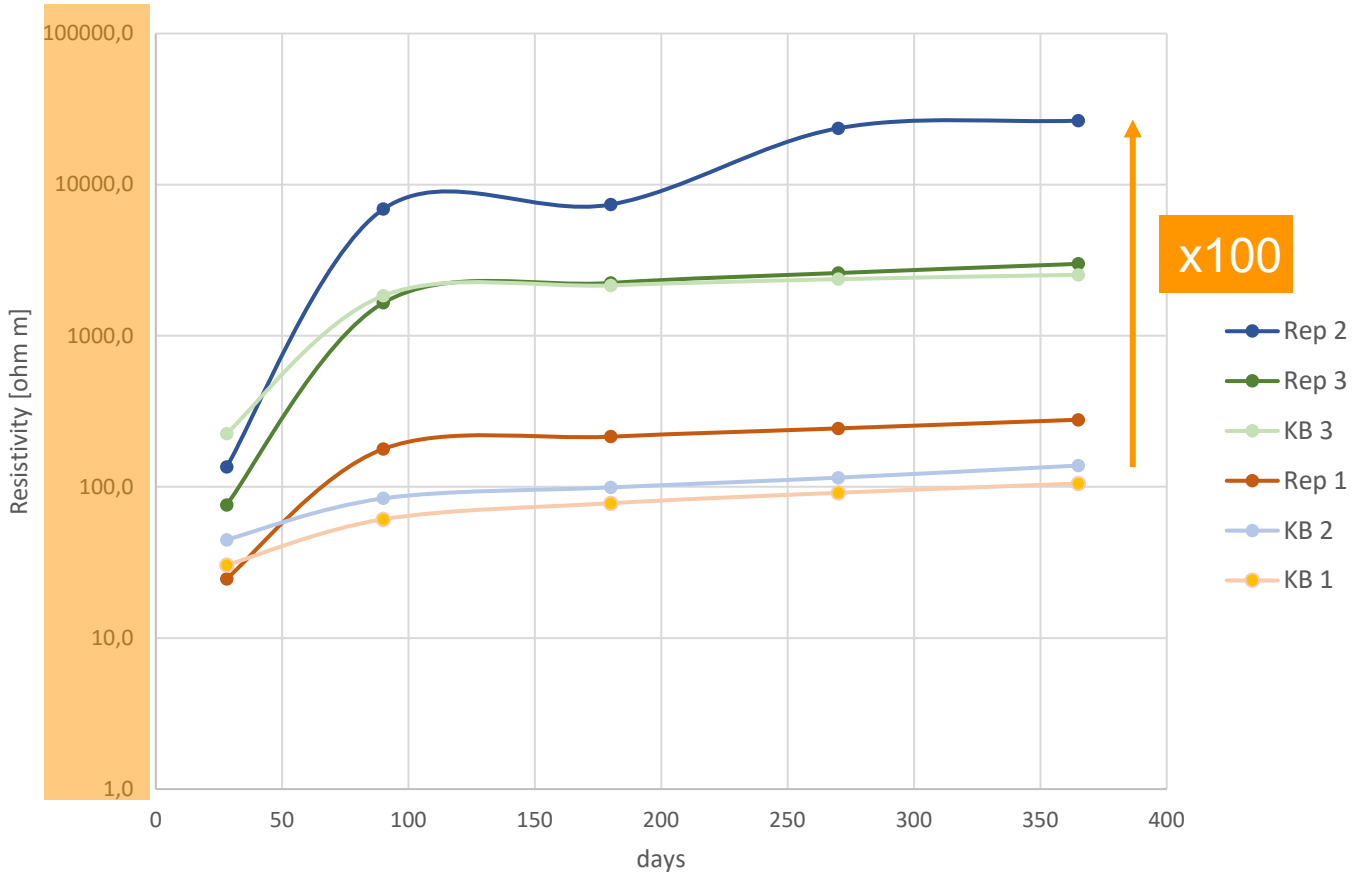
Results laboratory testing

II. Electrical resistance testing – time dependency



Results laboratory testing

III. Electrical resistance testing – difference between products

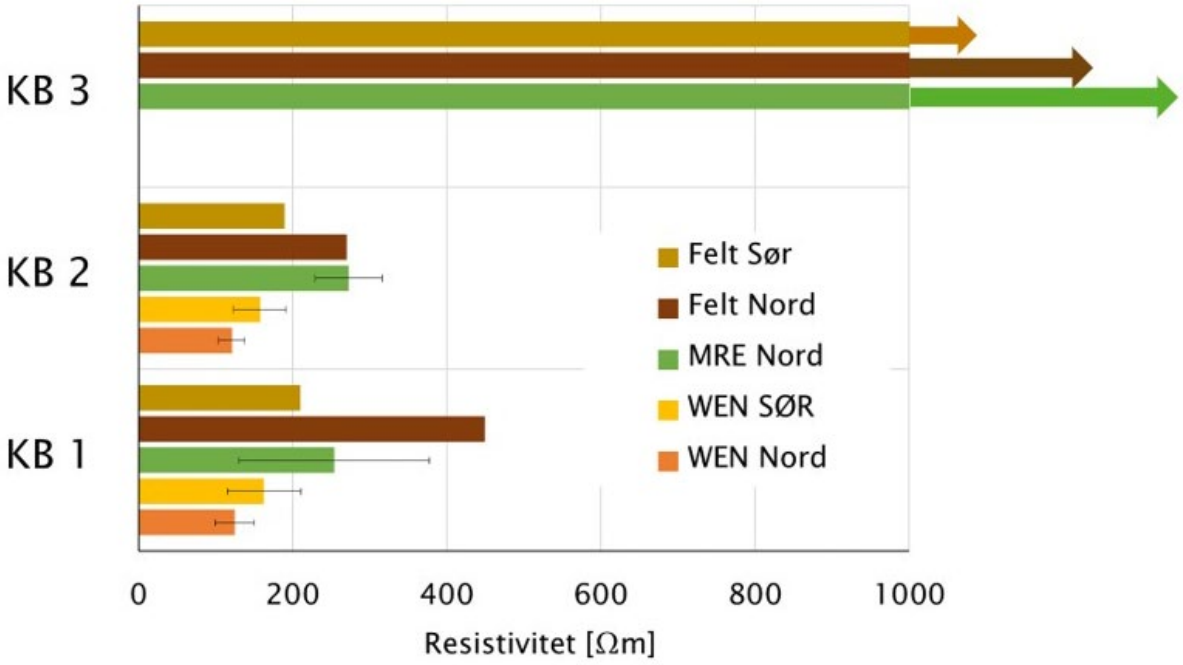


Conclusion from laboratory testing

- Electrical resistance of dry spray mortars should be documented on sprayed samples.
- Electrical resistance of dry spray mortars increases over several months after spraying.
- High variability of resistivity between products.

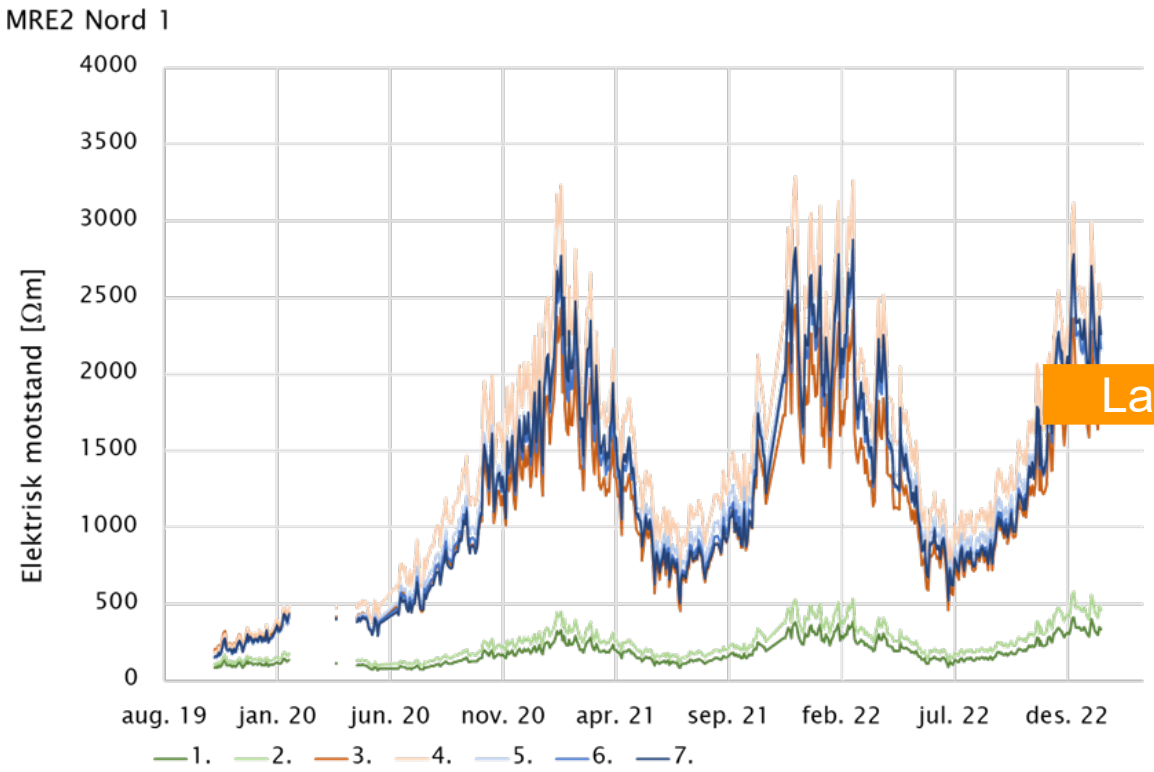
Results field testing

I. Relationship between different measurement methods for electrical resistance in the field using manual measuring equipment and embedded sensors for automatic logging

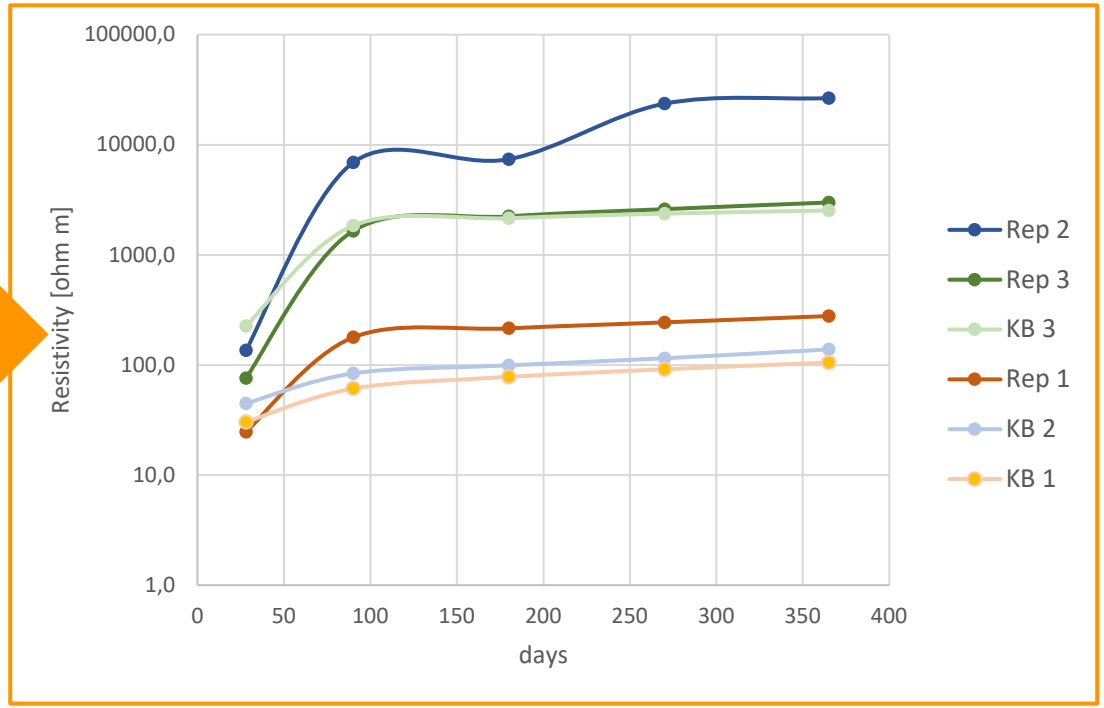


Results field testing

II. Repair and CP mortars' specific electrical resistance in the field, over time, depending on temperature, exposure conditions and surface treatment

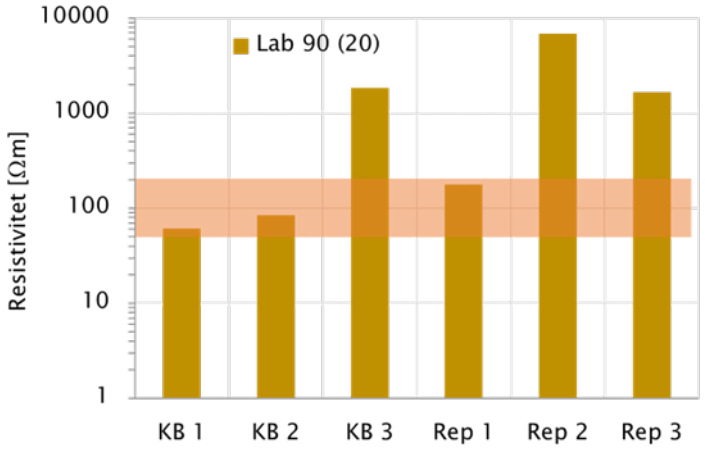


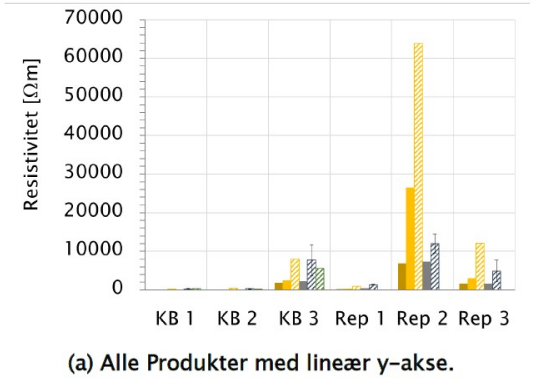
Lab



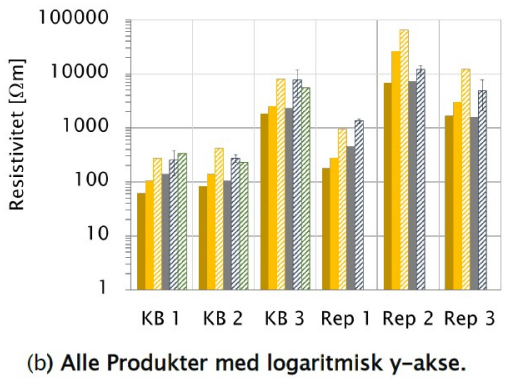
Results field testing

III. The relationship between long-term field measurements and laboratory measurements of mortars' specific electrical resistivity

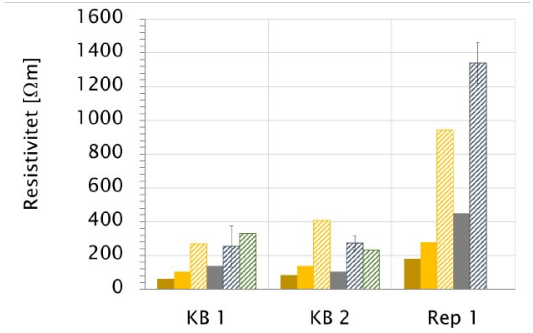




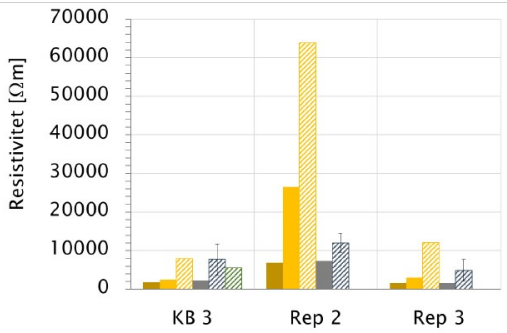
(a) Alle Produkter med lineær y-akse.



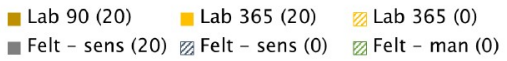
(b) Alle Produkter med logaritmisk y-akse.



(c) Produktene KB 1, KB 2 og Rep 1.



(d) Produktene KB 3, Rep 2 og Rep 3.



Results field testing

IV. The effect of the repair and CB mortars' specific electrical resistance on the cathodic protection of the reinforcement

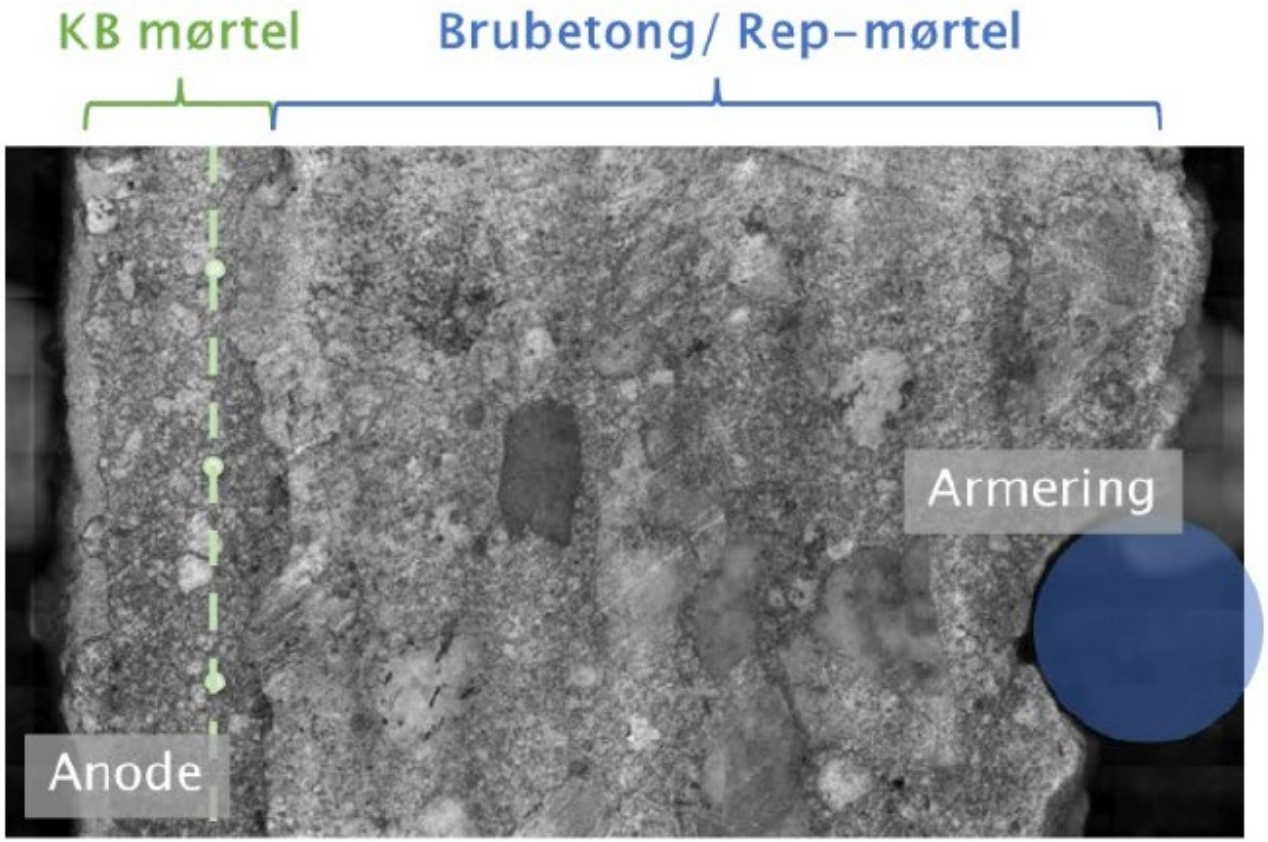
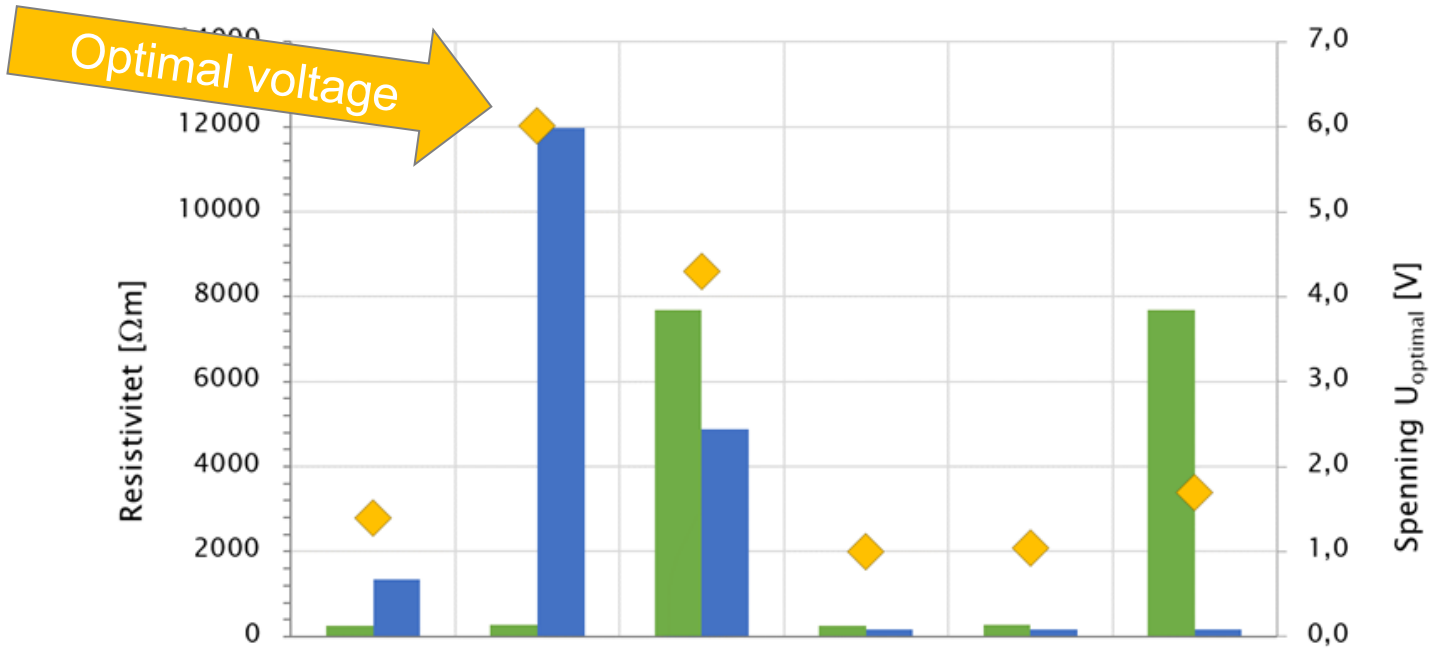


Foto: Tobias Danner, SINTEF

Results field testing

IV. The effect of the repair and CB mortars' specific electrical resistance on the cathodic protection of the reinforcement



Lab-resultater	Felt Nord 1	Felt Nord 2	Felt Nord 3	Felt Sør 1	Felt Sør 2	Felt Sør 3
KB mørtel	< 200	< 200	1500-2000	< 200	< 200	1500-2000
Rep mørte	< 200	>5000	1500-2000	Bru-betong	Bru-betong	Bru-betong

Results field testing

V. The Effect of simplified mechanical repair on ongoing corrosion of the reinforcement

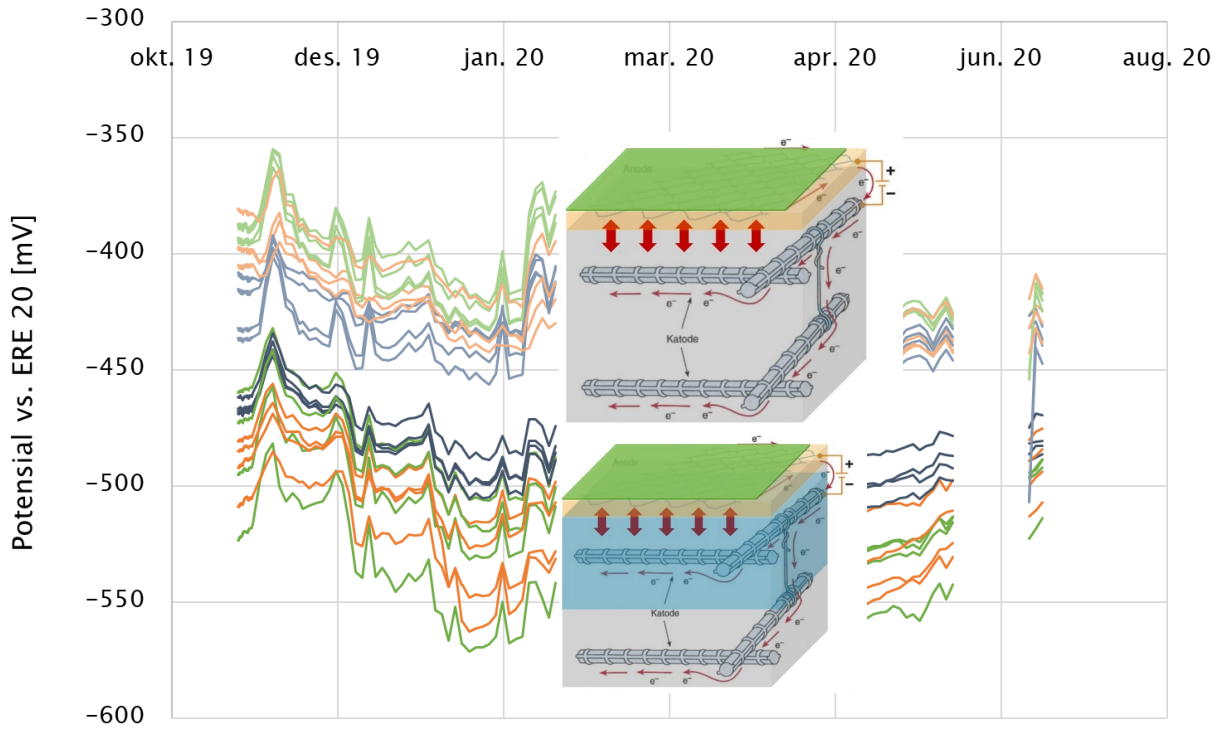


Foto: Karla Hornbostel, Statens vegvesen

Conclusion from field testing

- All the methods for measuring electrical resistance roughly rank the different mortars equally.
- The specific electrical resistance of the mortars increases with increasing age, especially in the first year.
- No clear effect of either exposure conditions or surface treatment after 3 years.
- Increasing specific electrical resistance in the repair mortars increases the need for applied voltage.
- There are no indications that simplified mechanical repairs have had a significant impact on the corrosion activity of the reinforcement.
- The frequently used limit values of 50 – 200% of the specific electrical resistance of bridge concrete are in a reasonable range, but must be used with discretion.
- It has not been found necessary that the specific resistance of the KB mortar is < 50 Ωm, but it will be a good rule of thumb that the electrical resistance of the KB mortar is less or equal to that of the repair mortar/concrete.

From Research to Practice

88.172 **Materialundersøkelse - betong**
C0

a) Omfatter prøveuttak, gjenstøping av borehull og opphugninger, analyse, rapportering etc. ved materialundersøkelser av betong og armert betong.

88.1729 **Uttak kjerneprøver**
C0

**** Spesiell Beskrivelse ****

a) Gjelder uttak av tre kjerneprøver som skal benyttes til måling av spesifikk elektrisk motstand jfr. 88.229.

c) Kjerneprøver skal være diamenter 70-100 mm med lengde minst 2 ganger diameter.

Prøver tas på referansefelt, plassering avklares med byggherre.

x) Kostnad angis som rund sum. Enhet: RS RS

88.2256 **Sprøytemørtling**
C0

a) Omfatter reparasjon med sprøytemørtling og bearbeiding av sprøytemørtlet overflate.
Ved katodisk beskyttelse inngår innsprøyting av anoder i prosessen.

x) Mengden måles som volum reparert betong. Enhet: dm3

**** Spesiell Beskrivelse ****

b) Det skal benyttes samme mørtel for både skader og innsprøyting av anodenett. Mørtel skal ha lav elektrisk motstand og være utviklet spesielt for formålet katodisk beskyttelse av armering i betong.

Produktspesifikasjon med beskriving av materialer og sammensetning skal forelegges byggherre før arbeidet påbegynnes.

Valgt mørtel skal ha spesifikk elektrisk motstand på snitt under 200 Ωm etter 90 døgn herdetid vannlagret. Enkeltverdier på prøver skal ikke overstige 250 Ωm.

Spesifikk elektrisk motstand skal dokumenteres av mørtelleverandøren før arbeidet med referansefeltet settes i gang. I tillegg skal entreprenør dokumentere spesifikk elektrisk motstand på prøver fra sprøytekassen jfr. prosess 88.222 og 88.229.

Documentation

- Description of the field station
- Hornbostel, K., Antonsen, R., Helgestad, S. H., Rognan O.-M. (2020): Feltforsøk - mørtel egnet for katodisk beskyttelse, Beskrivelse av feltforsøket FoU-programmet Bedre bruvedlikehold 2017-2021. Statens vegvesens rapport nr. 671.

Documentation

- Description of laboratory testing
- Helgestad, Stig H., Karla Hornbostel, Øyvind Bjøntegaard, og Roy E. Antonsen. «Feltforsøk – mørtel egnet for katodisk beskyttelse, Beskrivelse av laboratorieprøving.» Statens vegvesen rapport 851. Oslo, Norway: Statens vegvesen, 2023.

Documentation

- Description of results from field testing
- Karla Hornbostel, Eva Rodum, Roy E. Antonsen, Stig Henning Helgestad. «Feltforsøk – mørtel egnet for katodisk beskyttelseResultater etter 3 års feltprøving.» Statens vegvesen rapport 850. Oslo, Norway: Statens vegvesen, 2024.

Mange tak.

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Foto: Karla Hornbostel, Statens vegvesen