PIARC INTERNATIONAL WINTER ROAD CONGRESS

TOPIC 8. ROAD BRIDGES IN WINTER CONDITIONS

ASSESSMENT AND REPAIR OF BRIDGES SUBJECTED TO DE-ICING SALTS

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ASSESSMENT AND REPAIR OF BRIDGES SUBJECTED TO DE-ICING SALTS

Agenda

- Background. Climate and usage of de-icing salts in Denmark
- Types of defects from de-icing salts
- Inspection and testing
- Rehabilitation methods including cases
- Conclusions

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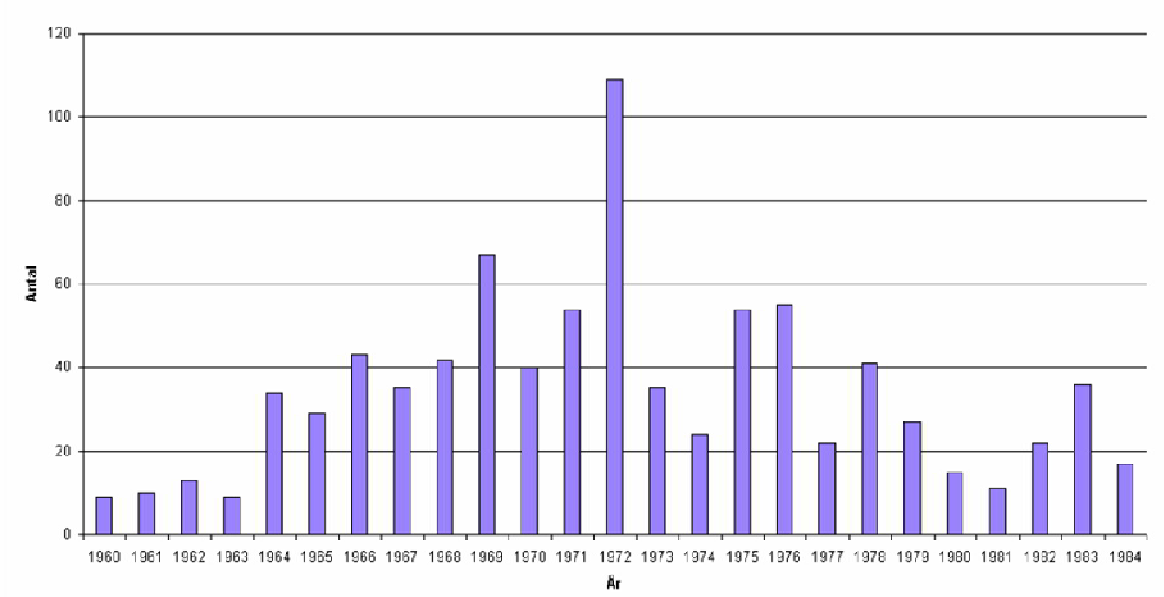
The Danish Highway Bridges:

- The vast majority: RC or post-tensioned concrete bridges
- The number of bridges constructed (by the Danish Road Directory) in each year between 1960 and 1984 appears below:



Main repair works:
1980s: Many columns were repaired/replaced due to corroded reinforcement as a result of de-icing salts
1990s: Many edge beams were replaced. (Actual life time 20-30 years.)
2000->: Replacement of waterproofing including resurfacing.

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Defects related to de-icing salts:

De-icing salts in Denmark (Area 43.000 km2) is approximately 300.000 ton per year. The average temperature is close to 0°C in December, January and February thus leading to many days with frost and a heavy usage of de-icing salts.

High chloride content leads to corrosion of the reinforcement.
The de-icing salts usually consist of NaCl. The Na^+ will provide additional alkali that can speed up ASR.

Cracks from ASR will allow additional water ingress that will reinforce the chloride impact and subsequently the deterioration of the structure (corrosion and spalling).

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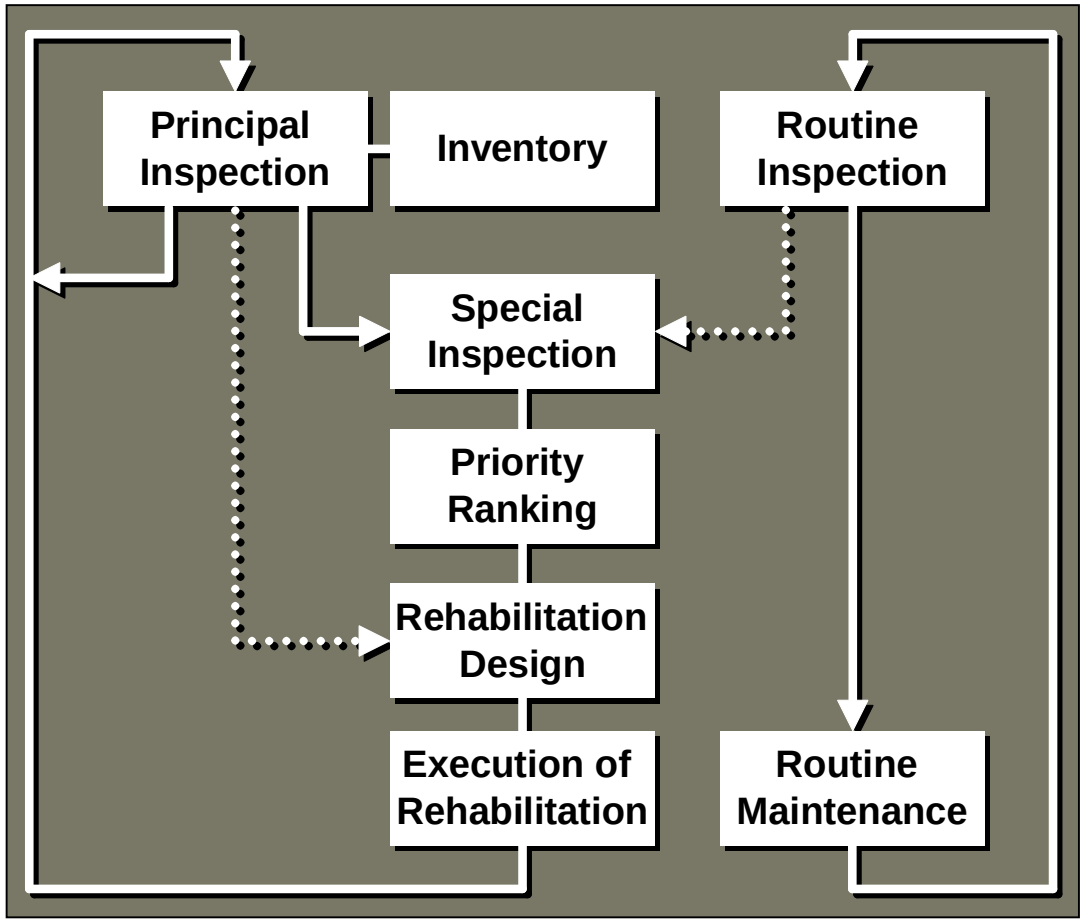

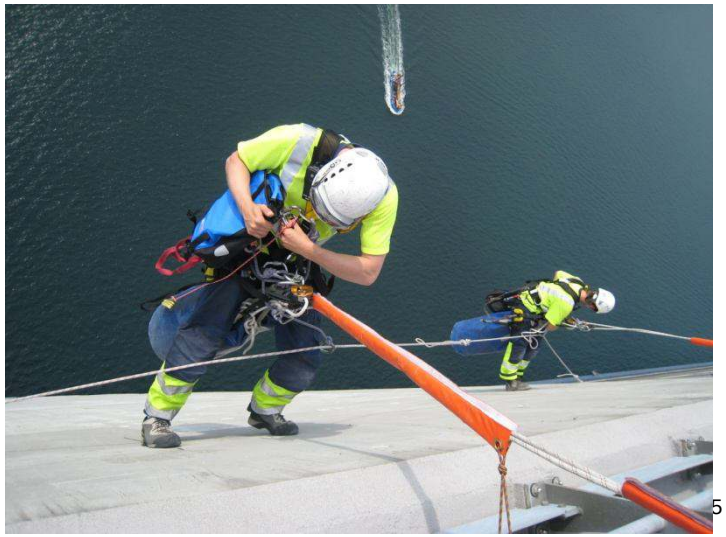

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The **visual** inspection provides overview and forms basis for hypothesis regard future development of defects.

NDT testing provides detailed information about extent of defects:

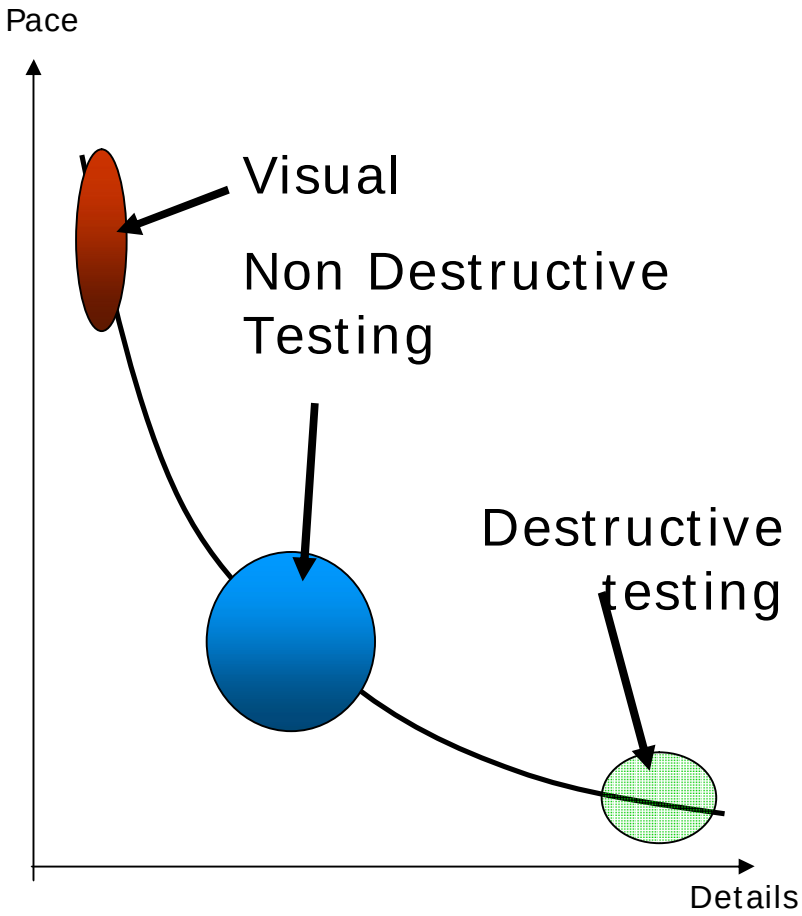
ECP (Half-Cell potential-mapping)

Covermeter

s'MASH (Impulse response) etc.

Destructive testing provides detailed information about small areas:
Breakouts, chloride testing, carbonation testing, cores etc.

Combination provides the full picture



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- **Prepare repair strategies**

  A. Repair visible defects now

  B. Do a complete rehabilitation now

  C. Minimum repair. Only defects related to the safety and the traffic of the bridge will be repaired.

- **For each strategy:**

  - Estimate all direct and indirect (road user costs) costs over a long period (e.g. 50 years)

  - Calculate net present value (NPV) of all costs at e.g. 5 % interest rate

- The strategy with the lowest NPV is the optimum strategy

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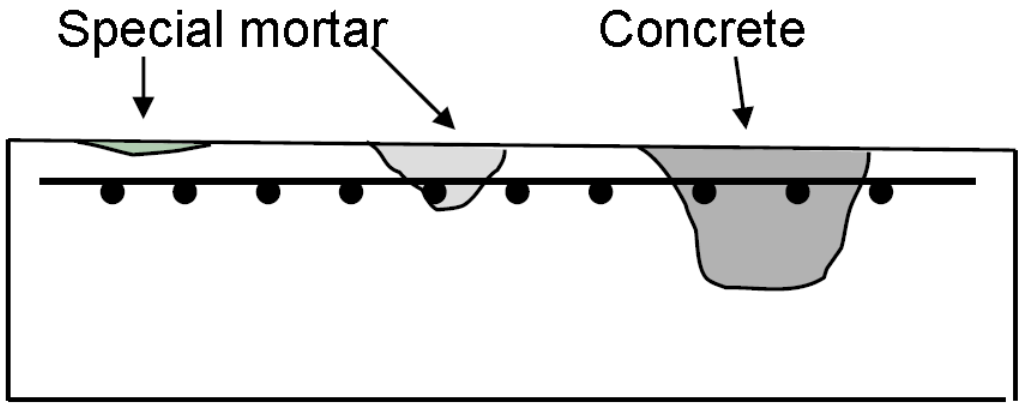
Repair of concrete containing chlorides. If the chloride content is **low**, less that approximately 0.05%, and no corrosion is present:

- Repair of any defects with special mortar or shotcrete
- Optional: Cathodic Protection
- "Surface treatment" (replacement of bitumen sheets for a bridge deck, paint system for other surfaces) including a prior proper cleaning (sand blasting or similar) of concrete.



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If the chloride content is **high**, more than approximately 0.05% and corrosion of the reinforcement is on-going:

- Repair all areas with high chloride content by removing contaminated concrete and applying sp mortar, concrete or shotcrete. If the area of the reinforcement is reduced it may be necessary to add additional reinforcement.
- Option: Cathodic Protection
- "Surface treatment" (replacement of bitumen sheets for a bridge deck, paint system for other surfaces)

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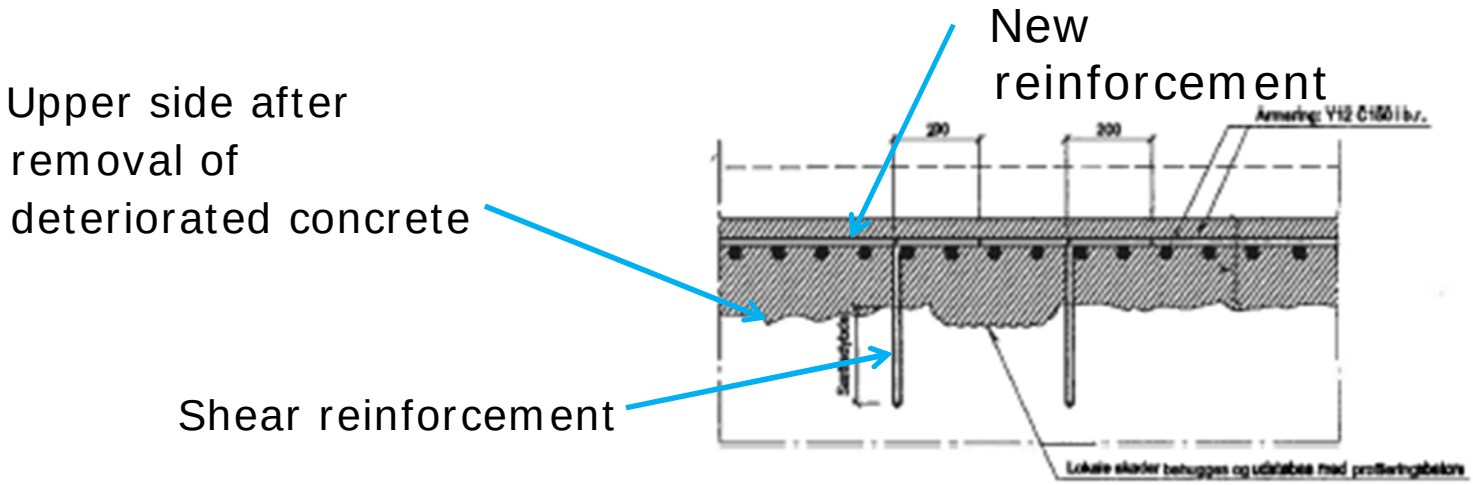
Repair method for a bridge slab with concrete overlays:
- Remove chloride contaminated concrete, perform a proper cleaning
- Establish shear anchors by mounting vertical reinforcement in drilled holes
- Provide horizontal reinforcement for the concrete overlays.
- Cast concrete overlays. The method is indicated below:



ASSESSMENT AND REPAIR OF BRIDGES SUBJECTED TO DE-ICING SALTS

CASE no. 1. REHABILITATION AND STRENGTHENING

This project comprises a complete rehabilitation and strengthening of a two-span post-tensioned motorway bridge. Prior to the rehabilitation, a special inspection and load capacity rating was undertaken. The bridge is situated near Roskilde approximately 30 km west of Copenhagen.

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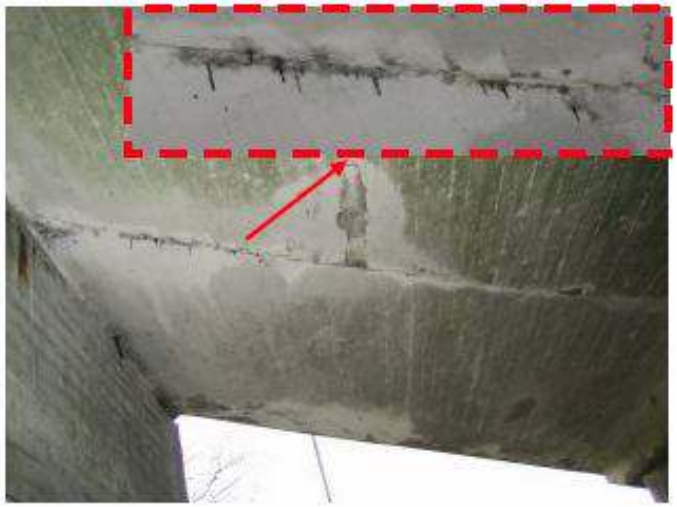
The overall condition of the bridge prior to rehabilitation was as follows:

- Defective waterproofing leading to water leakage through the slab
- Corrosion (minor) of the pre-stressing tendons at a cold joint.
- Insufficient load-carrying capacity (Class 70 (tonnes) while class 100 (t) is required at the location)



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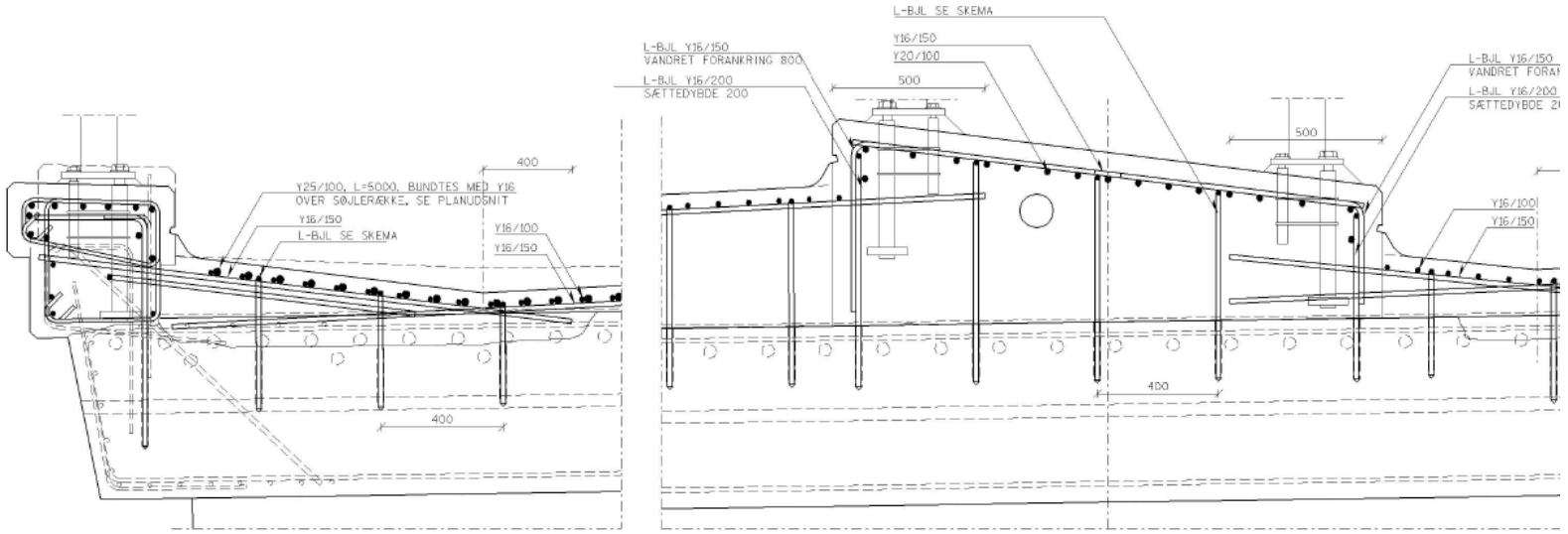
Design of repair and strengthening works:

- Existing surfacing and waterproofing comprises bitumen sheets, gravel, surfacing. Total thickness: 200-500 mm.
- New waterproofing and surfacing: Total thickness: 120 mm
- The above geometry allows a concrete overlays (thickness: 80-380 mm)



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- Conclusions
- The strengthening was successfully integrated with the repair works.
- Chloride contaminated concrete was removed by water jetting
- Since additional reinforcement was only required in a limited area, the strengthening was carried out at an additional cost of only **0.5%** of the total costs.

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CASE no. 2. Rehabilitation of a RC slab with ASR

Bridge constructed in 1972 with a RC slab. Total length of 114 m; Width of 13.7 m. Total area of 1560 m2.

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The overall condition of the bridge prior to rehabilitation was:

- Defective waterproofing leading to water leakage through the slab
- Corrosion of the reinforcement due to de-icing salts
- ASR in the slab
- Insufficient load-carrying capacity (lack of shear capacity over columns)

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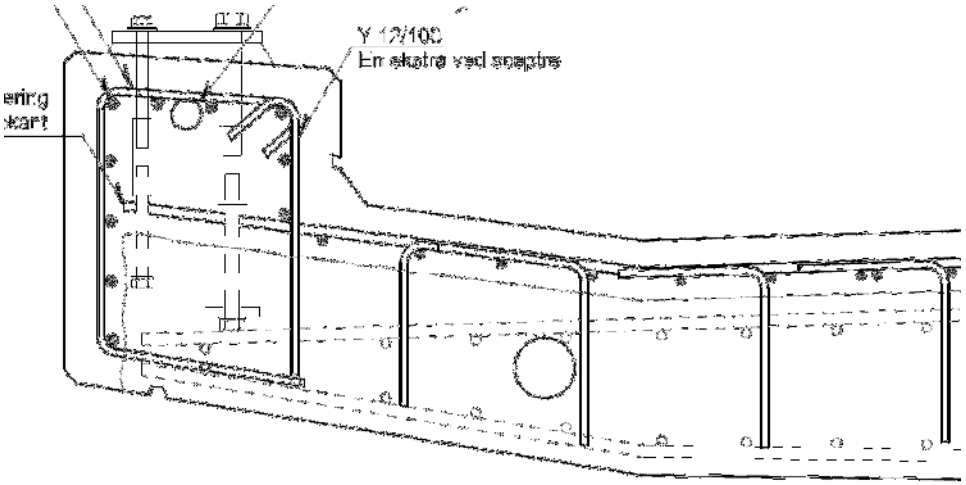
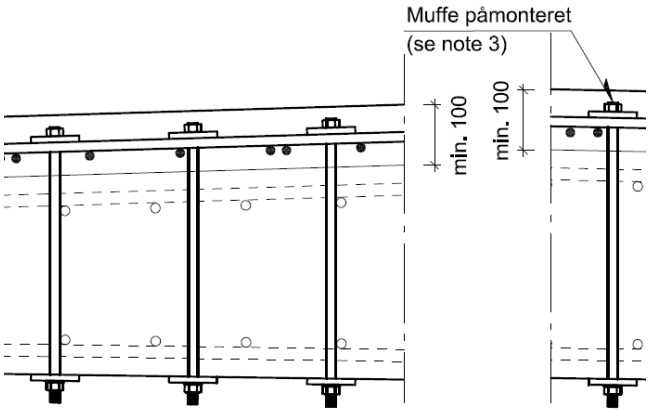
Rehabilitation:

New reinforced concrete overlays. The chloride infected and damaged concrete was removed.

Reinforcement (drilled and horizontal reinforcement) was installed.

Vertical bars (quality M30 8.8) drilled through the slab around each column with a steel plate on top and soffit of the slab. Abutments repaired.





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Rehabilitation.

Bars drilled through the slab (shear).
Fixed with steel plates

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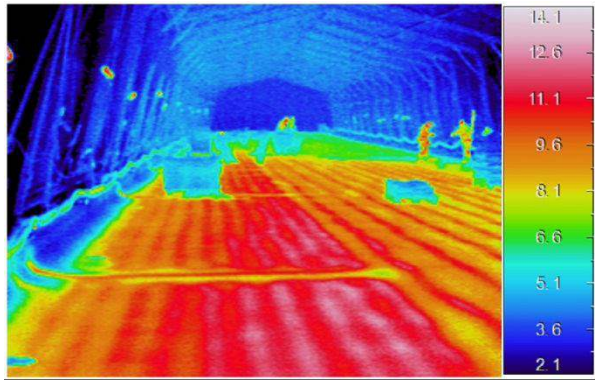
Execution of the rehabilitation during winter period 2010-11.

Concrete over layes with hoses for hot water. The heat is provided where it is needed (cost and CO2 friendly solution)



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Execution of the rehabilitation during winter period 2010-11.

Abutments with spalling concrete and corroded reinforcement due to chlorides. Full concrete repair including replacement of bearings:

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Conclusions after complete rehabilitation of the bridge:

- Corrosion of the reinforcement and the ASR has been halted
- The waterproofing and surfacing has been replaced
- Strengthening was successfully integrated with the repair works.
- The work could be carried out during the winter period at very low additional cost due to the heating system with cast in hoses.

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CONCLUSIONS

- The climate in Denmark with average temperatures of approximately 0°C in the winter period has led to an extensive use of de-icing salts. In many cases, these de-icing salts penetrate directly into the bridge decks and columns causing severe deterioration of the structures due to corroded reinforcement and an enhancement of alkali-silica reactions (if the concrete is ASR sensitive).
- In this paper it has been demonstrated how a complete rehabilitation of bridge decks subjected to de-icing salts can be undertaken.
- Often rehabilitation can be combined with a simultaneous and cost-effective strengthening of moment and/or shear capacity.
- Hoses cast in the concrete over lays is a inexpensive and efficient way to keep the surface temperature up so water proofing can be carried out

THANK YOU