ELGESETER BRIDGE IN TRONDHEIM DAMAGED BY ALKALI SILICA REACTION: MICROSCOPY, EXPANSION AND RELATIVE HUMIDITY MEASUREMENTS, TREATMENT WITH MONO SILANES AND REPAIR

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Extended abstract

Elgeseter bridge is probably the most thoroughly investigated concrete structure damaged by Alkali Silica Reaction (ASR) in Norway. The design with slender structural elements was a technological challenge for the engineers in the 1950's and a comprehensive testing program of materials and concrete mix proportions was carried out. Based on the test results durable concretes were designed and used for concreting Elgeseter bridge. Marine aggregates were not used due to the risk of reinforcement corrosion (not known to occur in concrete in 1949) and air void entrainment was added to reduce the risk of frost damage. To obtain the most optimal compressive strength a special cement type was produced for the construction of Elgeseter bridge. Most of the compressive strength values from control specimens gave satisfactory results except for a short period in the summer 1950 where results were significantly low and did not fulfill the Norwegian standard requirement.

Field inspections in 1989 and 1990 revealed that the only expansion joint in the road plate (originally 20 cm) was reduced to less than 1 cm in 1990. The crack pattern in the bridge suggested that ASR was a possible explanation for the observed expansions and cracking of concrete.

Micro structural analysis documented the occurrence of deleterious ASR caused by different rock types such as sandstone, greywacke, mylonite, phyllite and fine grained gneiss. A relationship between cracked reacted aggregates and cracks in the cement paste in cores as well as maximum cracks in structures is suggested, Jensen [1].

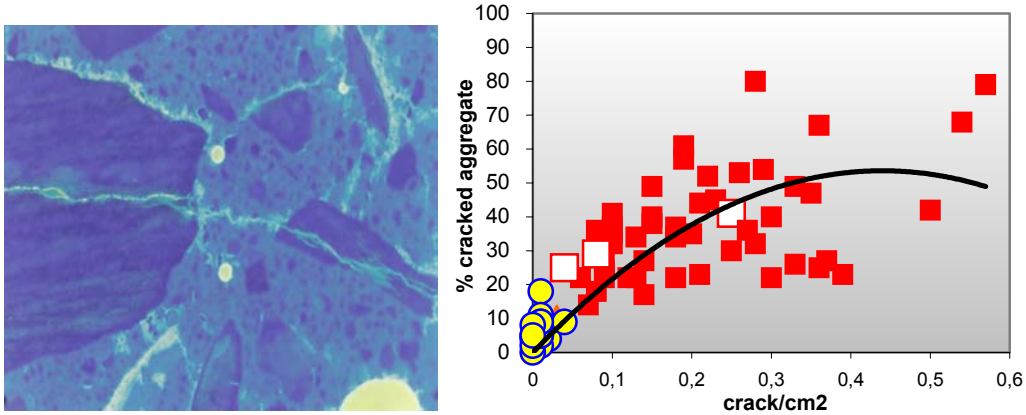

Figure 1: cracks in aggregates and cement paste in UV-light (left). Right figure is % cracked aggregates and cracks in cement paste from 83 cores in S. Norway with ASR (filled squares) and without ASR (circles). Results from Elgeseter bridge are shown as large empty squares.

The micro structural analyses also revealed low water/cement –ratio and many small air voids (<0.4 mm) in the cement paste suggesting frost resistant concrete. This has also been confirmed by more than 50 years service life.
In 1995 an in-situ system for measurement of relative humidity in concrete and expansion of cracks was developed and pilot tested. Results show that relative humidity varies from 100% to 87% (before impregnation with silanes) and generally is high on western faces exposed to rain water. Expansion of cracks varies from 0.04 mm to 0.15 mm yearly. Expansion results suggest that the rate is reduced the last few years.
In 1999 a survey was carried out with the aims to register distribution of cracks and crack widths in all the columns of Elgeseter bridge, Jensen [2]. Results show that crack widths vary from 0.05 mm to 3 mm and number of cracks in columns vary from 5 to 19. Largest cracks occur on western faces of columns. Estimations of crack expansions in columns showed highest expansions in columns located most westerly (column 1) and in the middle of the river.
In order to measure the effect of mono silane impregnation on ASR (indirectly the relative humidity and expansion of crack) three different types of silanes were applied on 3 whole columns in 1999 and 2000 [2]. Results suggest that impregnation with mono silane reduces the concrete's relative humidity 5 cm from the surface even when the columns are massive and ASR occurs in an advanced stage. Moreover, mono silane with a creamy consistency reduces the relative humidity to less than 80% 5 cm from the surface and should theoretically have "stopped" the ASR. Measurements of crack widths have also been carried out but the results are difficult to interpret.

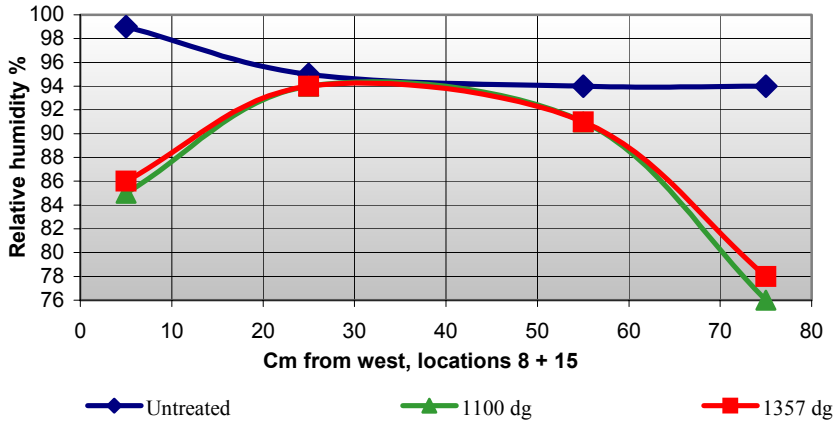

Figure 2: humidity profiles through column before impregnation (untreated), 1100 days and 1257 days respectively after silane C was applied.

In 2003 the Road Directory rehabilitated all the northern columns (axe 7, 8 and 9). The major repair work was to move columns back to a vertical position. Because the rehabilitation work caused some esthetical damage to the columns (and to "hide" existing cracks) an elastic cement latex surface protection product was applied all rehabilitated columns. Unfortunately the two columns impregnated with silane type B and C were also surface protected. However, measurement of relative humidity and expansion of cracks is planned to continue and include elastic cement latex applied two new columns.

References

1. Jensen, V (1993): Alkali Aggregate Reaction in Southern Norway. Doctoral technicae thesis. University of Trondheim (NTH), pp 262 + 9 appendices
2. Jensen, V (1998-2000): Post doctoral project. Norwegian Research Council