



Valuation of the 12 year old Concrete in the Ulkebugt Bridge, Sisimiut, Greenland

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Valuation of the 12 year old Concrete in the Ulkebugt Bridge, Sisimiut, Greenland



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ABSTRACT

The Ulkebugt bridge is a vital connection for the town Sisimiut, as it is the only link between the airport and the town. The bridge is a box girder bridge with one central pillar. Most of the pillar's concrete surface is exposed to seawater, with a tide variation around 4 meters. In addition to the seawater the bridge is exposed to the rough arctic climate. Furthermore, the mean temperature is below 0 °C for two thirds of the year with many freeze-thaw passages in late autumn and early spring, which increases the opportunity for severe frost damages. The focus has been to evaluate the quality and condition of the concrete pillar in terms of composition and the extent of the present deterioration mechanisms, best represented by frost damage and chloride ingress. Results show critical chloride content in the concrete will be reached in approximately 10 years at the depth of the reinforcement bars. However, the results also reveal the presence of some surface defects which probably is related to problems with workmanship, i.e. placing and compaction of the fresh concrete.

Key words: Concrete, bridge pillar, arctic, chloride

1 CHLORIDE INGRESS

1.1 Severity of chloride ingress

The concrete pillar is exposed directly to seawater, as it is shown in Figure 1. The pillar is founded on the seabed, so a major part of the concrete surface is constantly under water and thereby exposed to chloride ingress by capillary suction and diffusion. The ingress is relatively slow under water in this dense concrete and due to lack of oxygen there is no real concern for chloride driven corrosion. The most critical part on the surface is in the splash-zone with tide and wave action. In the Ulkebugt the tide has a variation of around 4 meters. The chloride ingress in the splash-zone gives the best opportunity to estimate the lifetime on the concrete pillar.



Figure 1 - The pillar on the Ulkebugt Bridge.

1.2 Estimated lifetime

The chloride initiated corrosion is probably the greatest threat to concrete due to a relative large amount of chloride in the concrete (now and in the future).

A projection of the chloride ingress has been conducted by use of Fick's 2. Law of Diffusion and the results are presented in Figure 2.

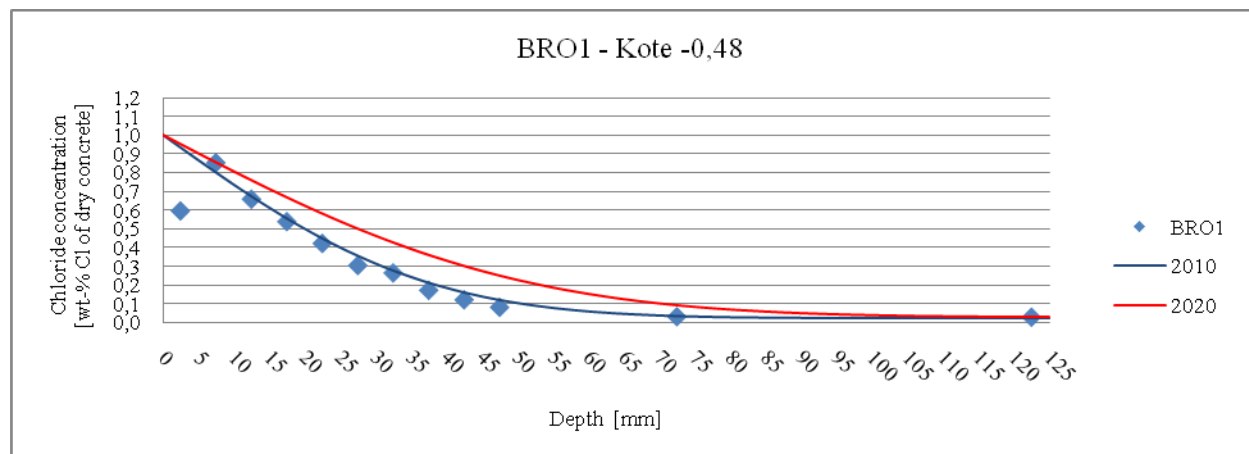


Figure 2 – Chloride profile of the concrete in the splash-zone. Year 2010 (blue) and 2020 (red). Measurement results are marked.

The lifetime of the concrete is limited by the chloride ingress. Corrosion of the reinforcement will initiate once the chloride level reaches 0.1 wt-% of the dry concrete. To make an estimated lifetime, it is important to know the thickness of the cover over the reinforcement. The requirement for the cover in the pillar in the splash-zone is 70 mm. Figure 2 shows that the critical chloride level at the depth of 70 mm will be reached in approximately 10 years.

2 ARCTIC CLIMATE

A part of this project's focus has been on the arctic climate, and what effects the climate would have on the concrete in the bridge pillar. Arctic climate are defined by having daily mean temperatures below 10 °C at the year's hottest month.

In Sisimiut the climate affects the temperatures in such way, that summers have low middle temperatures around 5 °C, and winters with temperatures almost reaching -20 °C. The mean temperature is below 0 °C for two thirds of the year with many freeze-thaw passages in late autumn and early spring, which increases the opportunity for severe frost damages

2.1 Frost damages

Frost damages are typically the first deterioration mechanism that comes into mind, when speaking about concrete constructions in cold areas with many freeze-thaw passages. Frost damages occur when water in concrete freezes. The focus on frost damages are temperatures below water's freezing point, and also the concrete water saturation, which is crucial for the extent of frost damages in concrete constructions.

The concrete core analysis show, that the concrete capillary porosity is relative low, which is giving the concrete a low permeability. This gives the concrete a good resistance against moisture and water ingress, reducing the risk for a critical water saturation of the concrete significantly and thereby minimizing the risk for frost damages. Furthermore, the concrete has a relatively high air content of approximately 10 – 11 % and a good distribution, which will almost eliminate the risk of frost damages. With these facts in mind, it is not surprising, that the different analysis shows no internal signs of frost damages.

However the concrete surface of the pillar shows in some areas signs (smaller and larger holes in the surface) which could indicate freeze-thaw damages. These holes are probably smaller and larger agglomerates of air voids, probably caused by an improper compaction of the fresh concrete in relation with a "closed" design of the formwork, which leads to a high amount of entrapped air voids (equal to agglomerates of air voids) along the form side. In places with larger holes, the seawater is allowed to enter far into the holes from start, making the concrete and reinforcement more vulnerable to chloride initiated corrosion. The result of insufficient compaction of the concrete is many deep holes in the concrete, which is contributing to the overall state of the concrete pillar.



Figure 3 – Deep holes into the concrete surface.

3 CASTING PROBLEMS

In order to obtain a high quality concrete, the concrete has to be proportioned correctly and the different constituents has to be of equally high quality. However, the final product is also greatly influenced by the execution of the concrete work, including mixing and casting of the concrete.

3.1 Casting below zero

Different conditions influence the concrete differently. Casting of concrete in the Arctic region is often done at temperatures below 0 °C, which can be executed with a good result and with the same quality as concrete casted at higher temperatures, if taken the right precautions.

When casting below zero it is essential to avoid water in the fresh concrete from freezing and hereby stopping the hydration process of the cement, resulting in a porous and low strength concrete. The concrete is, before having developed significant strength, also likely to develop cracks as a result of temperature differences between surface and the center of the structure.

In order to minimize the risk of the abovementioned damages different precautions has to be taken when casting below zero. Heating formwork and casting surfaces, such as dilatation joints, prior to casting, reduce temperature differences in the fresh concrete. The use of warm concrete and accelerators which speeds up the hydration of the concrete, reduce the risk of freezing of the water in the fresh concrete. The concrete must be covered and the form eventually heated after having finished the casting.

4 CONCLUSION

The concrete pillar is exposed directly to seawater. The most critical part on the surface is in the splash-zone with tide and wave action. Here the critical chloride level at the depth of the reinforcement bars will be reached in approximately 10 years.

The concrete surface of the pillar shows in some areas signs in form of smaller and larger holes in the surface which could indicate freeze-thaw damages. These holes are probably smaller and larger agglomerates of air voids, probably caused by an improper compaction of the fresh concrete in relation with a “closed” design of the formwork, which leads to a high amount of entrapped air voids along the form side. The seawater is allowed to enter far into the holes from start, making the concrete and reinforcement more vulnerable to chloride initiated corrosion.

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