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EARLY DURABILITY PICTURE FROM THE LAB

Early lab results show that a low-carbon concrete performed well in the laboratory durability tests involving different temperatures and salt exposures.

As society moves toward large-scale offshore wind in cold northern seas, interest is growing in concrete that is not only lower in CO_2 but also resilient enough to withstand salt, ice, waves, and decades of freezing and thawing. In the OFFwind project, to explore whether such climate-smart concretes are realistic, new low-clinker mixes with volcanic ash and other alternative binders are being tested in the laboratory in accelerated tests and in real seawater from the Gulf of Bothnia. The following summary highlights what these early durability tests showed.

Early durability picture from the lab

The durability tests provide an encouraging first impression of how low-clinker, volcanic-ash-rich (VA) concretes behave in simulated Nordic conditions. In the accelerated laboratory series, specimens were exposed to high-concentration salt solutions at different temperatures. After exposure, the VA-rich mix (V2) clearly kept its compressive strength, and in cold sodium-chloride exposure (NaCl 10 °C), it even outperformed both the reference concrete with 100 % Portland cement and the moderately blended mix (V1).

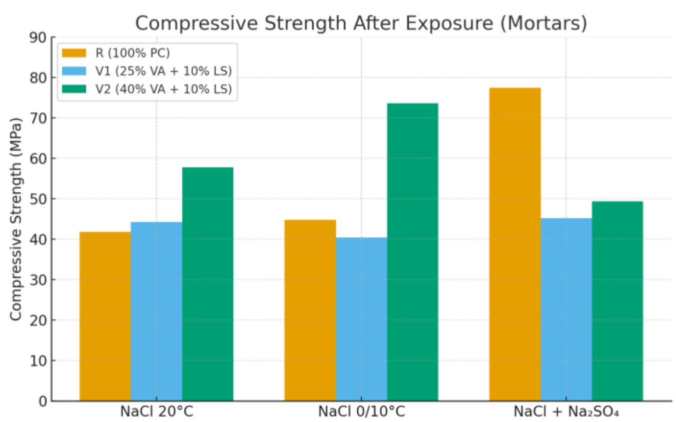

Figure 1. Results of the accelerated durability evaluation.

This suggests that the VA binder copes very well with the combined action of salt and cold temperature, which are key stressors in the Gulf of Bothnia region.

When sulfate was added to the solution (NaCl + Na_2SO_4), the balance shifted. Here, the Portland-cement mix retained higher strength than the VA-rich concrete, suggesting a potential sensitivity to sulfate-rich conditions. This could be is important: it shows that low-carbon concrete can be more robust than traditional concrete in some exposures (cold saltwater) while still needing careful optimisation in others (strong sulfate attack).

The longer-term marine water tests performed by Novia, where concrete prisms are stored in real Gulf of Bothnia seawater (in the lab) give complementary information. Over one year of exposure, compressive strength for almost all mixes increases steadily. Several of the low-clinker and slag/VA mixes not only keep up with, but in some cases overtake, the conventional reference concrete in strength probably due to delayed hydration reaction.

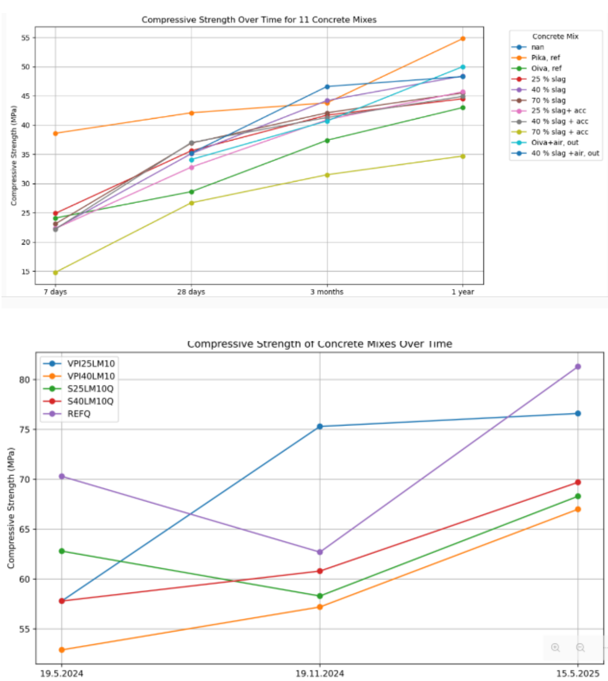

Figure 2. 1-year marine water lab test results.

So far, the natural seawater environment has caused only mild effects, with no clear drop in strength for any mix. The SEM observations showed a comparatively dense pore structure developing in the VA-rich material. It suggested that as the microstructure becomes denser, water and ions find it harder to move through the concrete, which may improve also the durability in conditions such as chloride attack.

Taken together, these results are still early and "directional" rather than final, but they point in a promising direction. In cold NaCl environments similar to Nordic splash and tidal zones, well-designed low-clinker mixes with volcanic ash appear at least as durable as conventional cement.

How do these findings compare with the literature?

A large body of international research supports the idea that replacing part of the Portland cement with supplementary cementitious materials (SCMs), such as slag, fly ash or natural pozzolans, can improve long-term durability in marine and chloride-rich environments. Studies on fly-ash and slag concretes in seawater have repeatedly reported lower chloride penetration and better performance against reinforcement corrosion than pure Portland-cement concrete, provided curing is adequate.

Natural pozzolans, including volcanic ash, are often found to refine the pore structure, reduce permeability and enhance resistance to chloride ingress and certain types of chemical attack.

Several studies also highlight improved freeze-thaw resistance when pozzolans are used in suitable dosages, exactly the kind of behaviour suggested by the good performance of the VA-rich mix in cold NaCl cycles.

The situation for sulfate attack is more complex. Classic work on blended cements shows that sulfate resistance depends strongly on the type and amount of SCM, the temperature and the sulfate source; some slag- and pozzolan-rich blends perform very well, while others can be more vulnerable.

The fact that the reference mix in the current tests performs better in the NaCl + sulfate is therefore not surprising and underlines the need for more targeted mix optimisation and long-term testing in sulfate-rich exposure.

Nordic and arctic studies have long shown that concrete in offshore and coastal structures must withstand a combination of frost, salt and mechanical loading from ice and waves, and that traditional short laboratory tests do not always capture real service-life behaviour. The current programme, which combines accelerated salt solutions with long-term immersion in actual Gulf of Bothnia water, follows this line of thinking by pairing "quick" signals with more realistic exposures.

What is next?

Looking ahead, a much broader and longer evidence base will be required before low-carbon binders can be adopted at scale for Nordic offshore wind foundations with the same confidence as traditional Portland-cement systems.

Multi-year field stations in the Gulf of Bothnia would be especially valuable, because realistic combinations of low temperature, variable salinity, seasonal ice cover and repeated freeze-thaw action could be captured in a way that laboratory tests cannot fully reproduce. It would also be useful if existing coastal and marine concrete structures around the Baltic and Bothnian coasts were systematically mapped, so that "real-life" verification could be carried out. In this way, laboratory data could be checked against actual exposure, and the most promising low-clinker recipes could be refined with confidence. A stronger focus on coupled degradation mechanisms is also needed

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