Sulphur concrete offers excellent resistance to the effects of seawater and weathering

Sulphur concrete was developed with the intent of extracting value from the sulphur by-products of oil and gas production. It is perfectly suited for use in marine, saline environments in applications such as sea walls. Between 2008 and 2011, a multiyear field test was conducted using sulphur concrete panels at the pier of IJmuiden.

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In many respects, sulphur concrete bears a great resemblance to cement concrete. Both materials are hard, strong and consist of aggregate (sand and gravel) with a binder to ensure consistency. The binder used in sulphur concrete consists of modified sulphur as a replacement for cement concrete.

Sulphur concrete has been around since approx. 1980. During early development, the material was mostly developed in Canada and the US. The strength of sulphur concrete is based, in part, on the creation of a modified sulphur structure. Shell has been involved in developing the material since 2005, and has patented a method of sulphur modification.

This sulphur modification leads to a considerable improvement in the material, as the sulphur stability and the sulphur bond to the aggregate is influenced in a positive manner. The patented binding agent is called Shell Thiocrete. It is well suited for the production of pre-cast applications because of the well controlled production process.

IN SHORT – FIELD TEST

- Sulphur concrete resembles cement concrete, but has several improved properties
- High resistance to acids and salts and high compressive and flexural strength
- Field test with eight sulphur concrete panels between 2008 and 2011 at IJmuiden
- No reduction in performance was recorded, with no effect on flora and fauna

The oil producer's involvement in the development of sulphur concrete can be attributed to the need to develop high-quality sulphur applications. Sulphur is a by-product of the extraction and refinement of sulphur-rich oil and gas products, which takes place in several regions, including the Middle East, Kazakhstan and Canada. Sulphur's economic value increases when it is possible to apply this by-product to the production of high quality precast applications.

Location of the field test of sulphur concrete panels at the pier of IJmuiden.

SULPHUR CONCRETE

To produce sulphur concrete, the material is heated to approximately 130°C. The sulphur is in a melted state at this temperature. The other raw materials for sulphur concrete are added to the melted material: sand, gravel and filler. These raw materials will also have been preheated. Once all the raw materials have been added, the material is poured and cooled in a controlled setting. The solidified product is sulphur concrete.

The exposed panels, before and after removal of growth.

Properties

Even though it closely resembles cement concrete, the material outperforms cement concrete in several areas. Sulphur concrete is extremely resistant to chemicals, such as acids and various salts, which normally erode cement concrete. The material is also stronger than most regular concrete types and is quite dense. The demoulding time for small products is very short and the product can be applied immediately after cooling – or, In comparison, cement concrete develops strength over a longer period.

Sulphur concrete is also a durable material. It can be recycled, first by crushing the material into granules and then re-melting and recasting it, creating new products. From an LCA study (lifecycle analysis) with several scenarios, it is evident that the CO_2 footprint – depending on the scenario – is 50 to 70 per cent lower than that of Portland cement concrete, when used in the same application.

Sulphur concrete's combination of properties supports its use in several specific applications, such as sewerage elements, paving (also in chemically aggressive surroundings) and marine applications such as ballast block-systems.

A field test at the pier of IJmuiden, using test panels (so-called Eco-panels), was conducted between 2008 and 2011, in collaboration with Rijkswaterstaat and Deltares, to demonstrate that the material is indeed well suited in marine and saline environments.

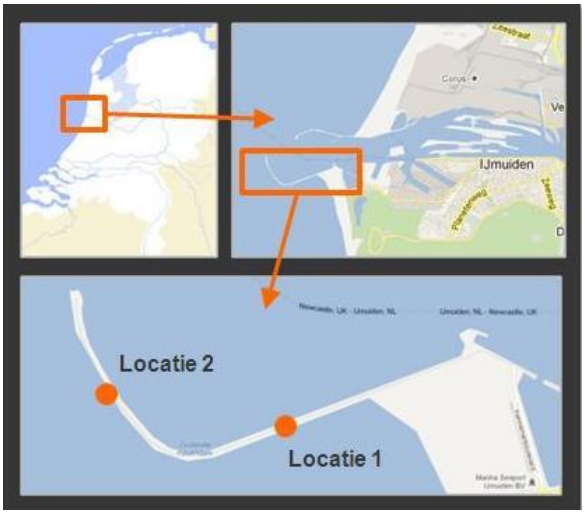
Field test at IJmuiden

Eight panels were installed in the tidal zone at the pier of IJmuiden. The panels were therefore exposed to varying conditions – dry and wet – to tidal action and climatic weathering. The panels were 500 by 750 millimetres in size, and 70 millimetres thick.

The aim of the field test was to demonstrate sulphur concrete's resistance to marine conditions. Research was also conducted to ascertain the extent to which the samples influenced the ecosystem.

The panels were manufactured with several surface finishes, including grooves, roughened surfaces and depressions. These finishes made the panels more susceptible to hydraulic action and abrasion, and to the growth of marine flora and fauna. SGS Intron (durability) and EcoConsult (ecology) were approached for this study.

The durability of the panels was determined by the quality of the exposed samples, and a comparison was made with the performance of the new product. For this purpose various properties for the new panels were determined in 2008; the exterior of the upper surface of the panels, and then, in particular, the occurrence of damage or defects, the strength of the material (under compression and flexure) and the porosity of the material. These properties were once again measured in the three year old panels. Samples from the panels were tested to determine strength and porosity. The natural level of water absorption in sulphur concrete is extremely low, as sulphur is hydrophobic.



TEST LOCATIONS

Overview of test locations.

Durability results

Comparisons between the properties of the original panel and the aged panel reveal that there was scarcely any reduction in performance.

The aged sample surface displayed hardly any defects, such as tearing, peeling or pop-outs. The material appeared to be resistant to marine conditions.

To some extent, surface wear-and-tear was evident where the sulphur coating had disappeared from the panels. This is natural wear and tear, comparable to the fading of a concrete coat in cement concrete.

Before and after aging, the compressive strength of the sulphur concrete was approximately 60 MPa, and the flexural strength was approximately 9 MPa. This is stronger than the strength of most normal concrete types. A decrease in strength was not detected.

The porosity of the samples increased to some extent – to approximately 1% m/m. The original porosity amounted to 0.2% m/m. This increase was caused by hydraulic action and abrasion of the sulphur coating. This coating is impenetrable to fluids. Porosity also remained low after removal of the sulphur coating: the porosity of cement concrete is about ten times higher than that of the aged Eco-panels.

Prior laboratory studies have already indicated that long-term submersion of sulphur concrete in sea water, with high levels of salt, had no negative effect on the material. There was no material loss and the water absorption was low. The results of the practical test are in line with this study.

Ecology results

The test in IJmuiden demonstrated that the sulphur concrete panels did not have any negative effect on marine flora and fauna. The exposed panels were completely covered in extensive degrees of seaweed and algae. The panels therefore also formed suitable habitats for many marine organisms, such as crabs.

Applications

The field test confirmed that after three years of ageing, under severe marine conditions, the samples displayed very little surface wear and tear. This reinforces the favourable perspective for the application of sulphur concrete in marine conditions. Some of the possible applications include ballast block-systems (such as piers), marine foundations for wind farms, and offshore structures and support structures for land extraction projects, comparable to the Second Maasvlakte.

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