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The Situation of Waterproofing in Europe – Part 2

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Abstract

In their last article the authors discribed the refurbishment of an open-air exposed sewage treatment plant in Germany using environmentally friendly, resin modified, mineral products.

In this second article about infrastructure refurbishment the authors discribe the most recent generation of polymer modified, mineral products for use in a concrete corrosive hydrogen-sulphide environment.

For environmental reasons sewage treatment facilities are now systematically being covered. This dramatically changes the environment inside the plants and converts the inside atmosphere to a sulphuric acid generator. The need for protection against concrete corrosion is evident

Open sewers and sewage treatment plants tend to exhaust odours which smell unpleasantly. High temperatures in summer tend to reinforce the inconvenience of bad smell. But also sanitary aspects speak against such open-air exposed facilities.

In Europe the trend is therefore towards covering open sewers and treatment plants and when designing and building new mainly to consider closed structures in favour of health and environment.

This change in design concept however also changes the environment. In enclosed structures such as sewer lines, and covered aeration and sedimentation tanks where the air above the sewage is not exchanged, the atmosphere is gradually contaminated by H_2S which is generated by the bacteria "Thio Concretivorus" based on organic matter in the waste water.

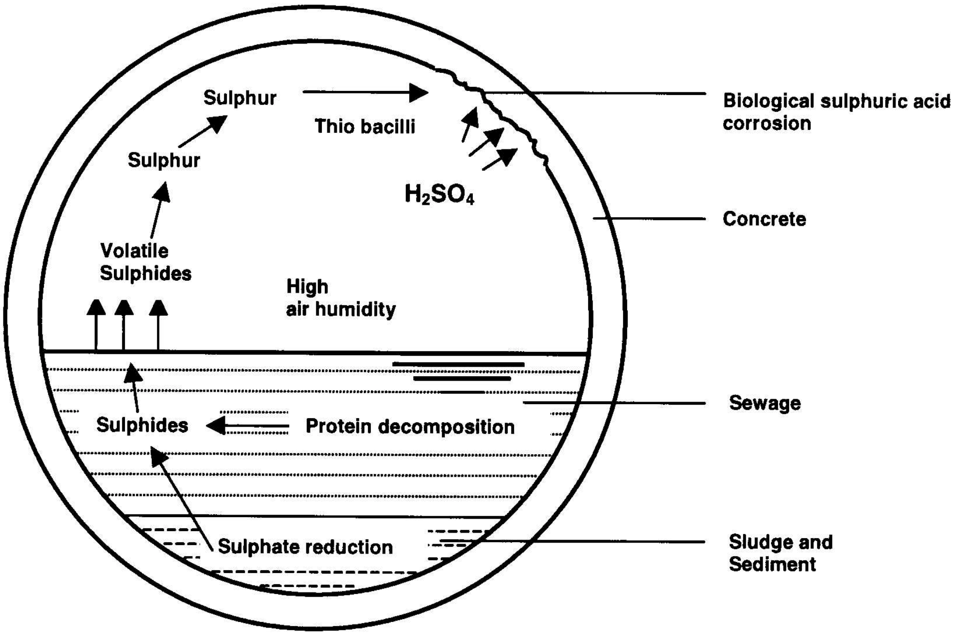
The H_2S-gas oxidizes under the influence of oxygen to form sulphur trioxide (Equation1. below), which subsequently combines with condensed water on the concrete surface above the water level to form concrete aggressive sulphuric acid (Equation 2.)

1. $$2 H_2S + 3 O_2 \longrightarrow 2 SO_3$$

2. $$SO_3 + H_2O \longrightarrow H_2SO_4$$

The so-called thio-bacteria are able to survive and generate H_2S also in environments of very low pH-values, resulting in sulphuric acid concentrations in the condensed surface water of up to 23%.

The mechanism of concrete corrosion in a closed sewer



Concrete Corrosion

When the basic prerequisite for concrete corrosion - the reduction of the pH value - is available, the concrete starts to disintegrate from the surface in areas where condensed water forms. The aggresive condensed water dissolves the cement stone which again leads to erosion of the concrete. Losses of 3 mm per year have been registred in closed sewer lines. The low pH-value gradually destroys the alkaline concrete enviroment which again over time will lead to corrosion of the concrete reinforcement bars.

Without corrective measures expensive infrastructure can be seriously damaged in less than a decade, so the need for preventive measures is evident.

Repairs involving resin based products have proven difficult in permanently moist environments because most resinous coatings depend on a fairly dry substrate in order to adhere and cure. Such conditions are usually not available in a remedial situation. Cementitious coatings on the other hand can succesfully be installed in moist environments, but lacked until recently the necessary capacity to resist acid attacks.

Recent developments in the field of polymer modified cementitious coating materials have dramatically moved the borders towards durability in a low pH-environment so that such products now can be considerd for refurbishment of corroded concrete in sewer structures as well as a preventive treatment for new sewer lines and sewage treatment plants.

Testing cementitious coatings for durability against biologically generated sulphuric acid

Establishing a laboratory environment equivalent to the one described above (Thio-bacteria generated sulphuric acid) is a very costly and above all time consuming process. Therefore actual on-site testing in a representative environment seems a more viable way to check basic product features over a period of time.

The Pro Rheno Sewage Treatment Plant in Basel, Switzerland situated near the Swiss-German border treating a combination of city sewage and industrial waste water proved to provide a representative concrete corrosive environment suitable for testing the durability of protective coating materials.

When Vandex had completed the development of its two component polymer modified cementitious protective coating product VANDEX POLYCEM Z which included laboratory exposure to sulphuric acid at pH-level 1.0 and 0.0 it was decided to expose coated concrete slabs to the environment in the Pro Rheno plant.
(see tables below)
Concrete specimens (40 x 40 x 4 cm) were coated on one side with VANDEX POLYCEM Z (layer thickness approx. 3 mm) and placed in the gas zone and in the tidal zone of the final sedimentation tank. Reference specimens were stored under laboratory conditions in a climate room at 25°C/50% relative humidity. Measurements on the specimens in the gas zone resp. in the tidal zone are being compared to the reference specimen measurements after 6 and 12 month of exposure.

The experimental setup and the site conditions were monitored by BBL Basler Baulabor AG, an accredited Swiss laboratory which also executed the laboratory tests

Environmental conditions

The closed final sedimentation tank of the sewage treatment plant Pro Rheno offered the following environmental conditions (Experimental setup see Sketch A):

Gas zone

Data	Unit	Content
air humidity	Vol.%	78–92
Temperature	C°	22–35
H_2S-concentration	mg/m^3	5–25
SO_2-content	µg/m^3	440–890
CO_2-content	µg/m^3	0.1–0.2
NO_2-content	µg/m^3	25–125
pH-value condensation water	pH-value	4.5–5.1
air circulation		very low

Sewage

Data	Unit	Content
temperature	C°	22–35
pH-value	pH-value	4.0–5.5
NH_4^+	mg/l	25–65
Mg^{2+}	mg/l	220–450
SO_4^{2-}	mg/l	500–1250
Cl^-	mg/l	150–250
Sewage		industrial and domestic

Tests executed after 6 and 12 month storage

Specimen / Test	Climate room reference	Gas zone specimens after 6/12 months	Tidal zone specimens after 6/12 months
Adhesion according to ZTV SIB 90	X	X	X
Content of Sulphates according to DIN 38405	X	X	X
Water absorption A-value according to DIN 52617 [1)]	X	X	X
Visual assessment	X	X	X
Analysis of microstructure [2)]	X	X	X
Testing for	X	X	X

microorganisms [3]			

1) Water absorption after 30 minutes
2) Microscopic evaluation at thin layer section
3) Detection on selective agars

Test results (Only the results after 12 month exposure are listed)

Adhesion according to ZTV SIB 90 [N/ mm²]

Storage	Climate room 25/50 21d	Gas zone 12 months	Tidal zone 12 months
Specimen	7 d/L/0	7 d/G/12	7 d/S/12
1	1.82	2.12	1.89
2	1.75	1.79	1.92
3	2.05	2.63	2.21
4	2.11	-	-
5	1.72	-	-
Mean	**1.89**	**2.18**	**2.00**

Storage	Climate room 25/50 21d	Gas zone 12 months	Tidal zone 12 months
Specimen	7 d/L/0	7 d/G/12	7 d/S/12
1	1.82	2.11	1.75
2	1.65	2.19	2.58
3	1.92	2.35	2.35
4	2.03	-	-
5	1.85	-	-
Mean	**1.85**	**2.21**	**2.22**

Sulphate content according to DIN 38405 [% by weight]

Storage	Climate room 25/50 7d	Gas zone 12 months	Tidal zone 12 months
Specimen	7 d/L/0	7 d/G/12	7 d/S/12
0-2 mm	0.19	0.25	0.28
2-4 mm	0.17	0.14	0.16
4-6 mm	0.17	0.17	0.18
6-8 mm	0.12	0.15	0.10
8-10 mm	0.12	0.11	0.11

Storage	Climate room 25/50 42d	Gas zone 12 months	Tidal zone 12 months
Specimen	28 d/L/0	28 d/G/12	28 d/S/12

0-2 mm	0.18	0.28	0.29
2-4 mm	0.15	0.15	0.19
4-6 mm	0.14	0.14	0.17
6-8 mm	0.10	0.11	0.13
8-10 mm	0.11	0.10	0.13

Water absorption A-value according to DIN 52617 [kg/m²/0.5 h]

Storage	Climate room 25/50 21d	Gas zone 12 months	Tidal zone 12 months
Specimen	7 d/L/0	7 d/G/12	7 d/S/12
1	0.115	0.118	0.121
2	0.118	0.121	0.099
3	0.105	0.095	0.107
4	0.108	-	-
5	0.105	-	-
Mean	**0.110**	**0.111**	**0.109**

Storage	Climate room 25/50 42d	Gas zone 12 months	Tidal zone 12 months
Specimen	28 d/L/0	28 d/G/12	28 d/S/12
1	0.1n24	0.098	0.122
2	0.129	0.128	0.134
3	0.118	0.131	0.127
4	0.125	-	-
5	0.115	-	-
Mean	**0.122**	**0.119**	**0.127**

Assessment by accredited Swiss Testing Laboratory BBL

Upon completion of the testing after 12 month of exposure the BBL Basler Baulabor AG wrote the following conclusion:

After 6 and 12 months exposure specimens 7d/G and 7d/S show that no differences in adhesion and water absorption compared to the reference specimen in the climate room have taken place.

A slight increase of the sulphate content can be observed at the surface. Inside the specimens no increase of the sulphate content is detectable.

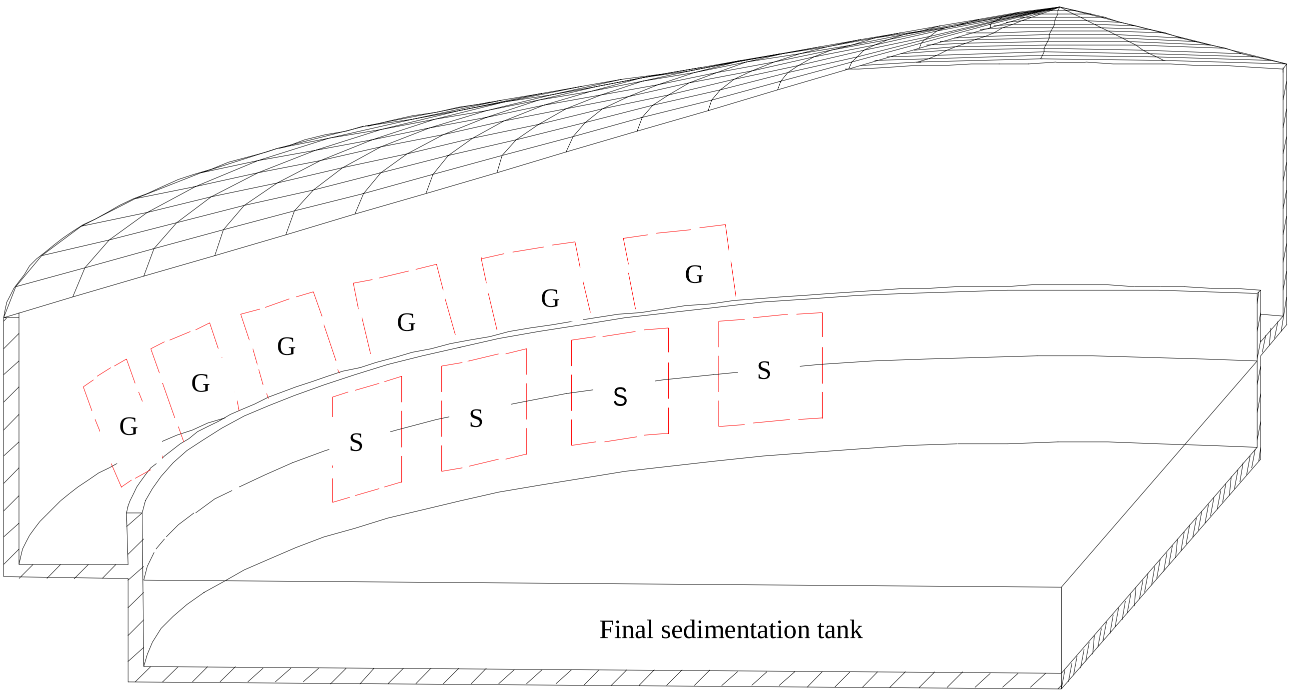
A visual inspection of the specimen does not reveal any cracks, blisters or discolouration. Microorganisms can not be detected.

The specimens 28 d/G und 28 d/S show the same results after a storage time of 6 and 12 months. No differences in adhesion and water absorption compared to the reference specimen in the climate room have taken place.

A slight increase of the sulphate content can be observed at the surface. Inside the specimen no increase of the sulphate content is detectable.

The VANDEX POLYCEM Z coating shows a very high resistance against sulphur containing compounds in water and against sulphur containing gas compounds. Thus it is suitable for the protective use in an environment with biogenic sulphuric acid attack.

Sketch A: Experimental setup



G Gas zone specimen

S Tidal zone specimen

Appendix A Labeling of the specimens

7 d series: VANDEX POLYCEM Z coating 7 days old at beginning
28 d series: VANDEX POLYCEM Z coating 28 days old at beginning

L: climate room G: gas zone S: tidal zone

Exposure / Time of exposure	Climate room 25°C, 50%	Gas zone final sedimentation tank	Tidal zone final sedimentation tank
start	7 d/L/0 28 d/L/0	- -	- -
6 months	7 d/L/6 28 d/L/6	7 d/G/6 28 d/G/6	7 d/S/6 28 d/S/6
12 months	7 d/L/12 28 d/L/12	7 d/G/12 28 d/G/12	7 d/S/12 28 d/S/12