Report by UWI doctoral researcher Maria Sielaff (T2)

Project number: T2
First and last name of doctoral researcher: **Maria Sielaff (née Grüneberger)**
(Working) title of doctoral project: **Sulphuric acid corrosion of cementitious materials in laboratory performance tests and sewer systems**
Name of supervisors: Prof. Dr. rer. nat. Dietmar Stephan (TUB), Prof. Dr.-Ing. Matthias Barjenbruch (TUB), Regina Gnirß (Berliner Wasserbetriebe)

2. Description of doctoral project and research results achieved to date:

Motivation

The increasing connection degrees, longer sewer systems and decreasing amounts of sewage in the cities and villages cause higher detention times of the sewage in the sewer system. This leads to anaerobic conditions in the sewer pressure pipes and ultimately to an increasing production of H_2S. When being released to the sewer atmosphere in the gravity sewer pipe the H_2S gas causes odour nuisance and can be a health risk for sewer workers. The H_2S gas is also oxidised by sulphur oxidising bacteria (SOB) to sulphuric acid attacking the building materials of the sewer system. This causes biogenic sulphuric acid corrosion (BSC) especially of cementitious building materials in the sewer system. Figure 1 depicts the processes in gravity sewer pipes leading to BSC. The costs for mending and replacement of sewer system components due to BSC was estimated to be as high a US$ 14 billion per year in the US [1].
The use of concrete and mortar with high resistance against BSC can help reducing the costs of mending and repair in the sewer system among other measures that reduce the H_2S production and release to the sewer atmosphere. Performance tests for cementitious building materials are used to test the resistance against acid attack and therefore contribute to the development of new concretes and mortars with high acid resistance. Many acid resistance tests with different boundary conditions have been developed worldwide for concrete and mortar with different applications. Some of those acid resistance tests have been compared in a literature study by De Belie [2]. But there is no study comparing different acid resistance tests using inorganic acids in practice. Also, there is no study comparing the corrosion in laboratory performance tests to BSC in sewer systems using the same building materials.
The aim of this study was the comparison of four purely chemical acid resistance tests developed and used in Germany and Belgium. Those tests were developed for the BSC application in sewer systems and cooling towers. The same concrete compositions are tested in a research pilot plant of BWB simulating a small-scale sewer system with real Berlin sewage.

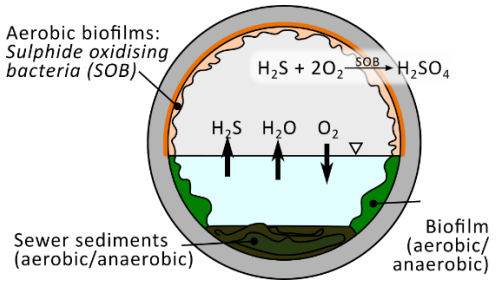

Figure 1: Processes leading to BSC in gravity sewer pipes

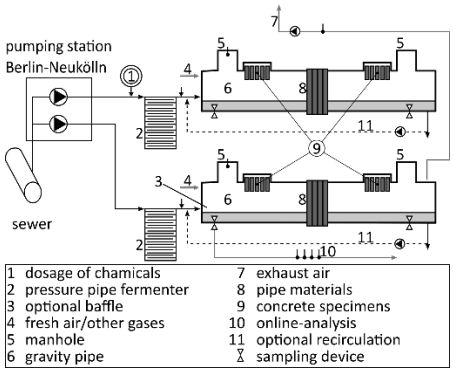

Figure 2: Schematic sketch of the research pilot plant of BWB

The results of this study should give a deeper insight in corrosions processes during BSC in sewer systems. It will also be investigated if the tested laboratory performance tests are comparable among another and if they are applicable to BSC in sewer systems.

Building materials, laboratory performance tests, and research pilot plant

Five concrete and mortar compositions with differing acid resistance were used for all laboratory performance tests and in the research pilot plant.
Three tests developed in Germany and one test developed in Belgium were used for this study: the test developed by MPA Berlin-Brandenburg (MPA test) [3], the test developed by LPI Ingenieursgesellschaft mbH (LPI test) [4], the test from DIN 19573 appendix B (DIN test) [5], and the TAP test developed at University Ghent, Belgium [6]. All tests can be run using sulphuric acid and are therefore used for concrete and mortar applied in sewer systems. The other boundary conditions of the tests differ strongly. The MPA test, LPI test, and DIN test were performed at TU Berlin, while the TAP test was conducted at Magnel Laboratory for Concrete Research, Belgium, during the internship.

The research pilot plant of BWB is illustrated in Figure 2 and consists of two parallel lines. In both lines Berlin sewage is pumped in a 200 m pressure pipe fermenter and then flows in a 25 m gravity pipe. In one line the dosage of chemicals influencing the H_2S production is possible. Different parameters, e.g. the H_2S concentration in the sewer atmosphere, can be monitored. Samples of the five concrete compositions are stored in both gravity pipes since January 2017. Samples are taken every 6 months.

Current state of work

The laboratory performance tests were conducted from August 2016 to June 2018. All concrete and mortar specimens from the laboratory performance tests were analysed according to the regular testing procedures with the exception of three concrete compositions in the LPI test. The results for two concrete and mortar compositions O and S are shown in Figure 3. The analysis results indicate that the outcome from MPA und LPI test is not transferable to the DIN and TAP test due to the tests' different boundary conditions and the different methods of analyses [7]. Therefor the samples from DIN test and TAP test are also analysed with the same method (reflected-light and polarising-light microscopy) as in MPA and LPI tests. An example is shown in Figure 4. Additionally, selected specimens are analysed with micro X-ray fluorescence analysis (µ XRF, example shown in Figure 5). The microscopic analysis and µ XRF are not completed yet.
The concrete specimens in the research pilot plant were sampled three times in July 2017, January 2018, and July 2018. The specimens from July 2017 and January 2018 show no measurable signs of corrosion yet while the samples from July 2018 could not be analysed yet due to parental leave.

Future work planned

The concrete compositions of LPI test investigated last will be analysed with light microscopy. Also, the remaining specimens of DIN test and TAP test will be analysed with light microscopy. Further samples from the four laboratory performance tests will be analysed with µ XRF. The light microscopy and µ XRF results will lead to a better comparability of the different concrete and mortar compositions and the different laboratory performance tests.
The concrete specimens in the research pilot plant will be sampled again in January and July 2019. All specimens will be analysed with light microscopy. Selected specimens will be analysed with µ XRF. Those results will allow an evaluation of the applicability of the laboratory performance tests regarding BSC in sewer systems. The remaining concrete samples can give information of the corrosion progress for six years in the research pilot plant, if they are sampled biannually.

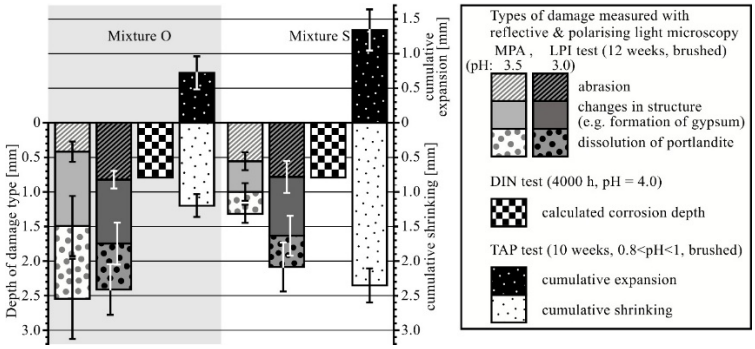

Figure 3: Results of the four acid resistance tests for the mixtures O and S with standard deviation for MPA, LPI and TAP test [7]

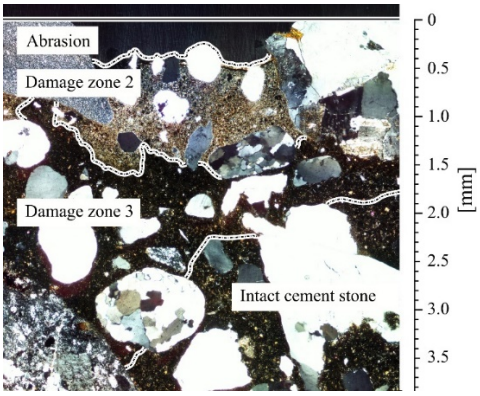

Figure 4: Polarising light microscope images of thin section in crossed-polarised light of concrete O after MPA test. Different damage zones are highlighted [7]

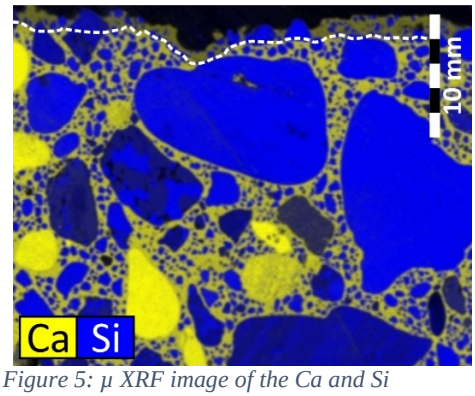

Figure 5: µ XRF image of the Ca and Si distribution of concrete O after TAP test. The dashed line marks the corrosion depth and the Ca depleted zone in the cement stone

Collaboration

The work in the research pilot plant is done in close collaboration with kollegiate Daneish Despot. The general thematic work regarding sewer processes is done in collaboration with project T3 (Katharina Teuber). The collaborations resulted in publications and is described in [8;9].
The research project is part of the common topic group “Interfaces in sewer systems“.
The MPA test and DIN test were done in collaboration with Kiwa GmbH Berlin.
International collaboration was done to perform the TAP test at Magnel Laboratory of Concrete Research at University of Ghent, Belgium, as part of an internship from February to May 2017.

References

1. Koch,G.H., Brongers,M.P.H., Thompson,N.G., Virmani,Y.P. & Payer,J.H. (2002): Corrosion costs and preventive strategies in the United States. *US Department of Transportation, Federal Highway Administration*, Georgetown Pike
2. De Belie,N. (2008): Evaluation of methods for testing concrete degradation in aggressive solutions. *Proceedings of the RILEM Workshop on Performance of cement-based materials in aggressive aqueous environments – characterization, modelling, test methods and engineering aspects*, Ghent, Belgium, 73-84.
3. Hüttl,R., Lyhs,P. & Silbereisen,R. (2009): Beton auf Basis CEM II mit erhöhtem Widerstand gegenüber Säureangriff. *Proceedings of 17th ibausil*, Weimar, Germany, 17(2), 0295-0303
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6. De Belie,N., Monteny,J. & Taerwe,L. (2002): Apparatus for accelerated degradation testing of concrete specimens. *Mater. Struct.*, 35(7), 427-433
7. Sielaff,A.M. & Stephan,D.A. (2018): Comparative study on acid resistance tests for cementitious materials applied in sewer systems. *RILEM TC 253-MCI Internat. Conf.*, Toulouse, France, 153-162
8. Teuber,K., Grüneberger,M., Despot,D., Dietmar,S., Barjenbruch,M. & Hinkelmann,R. (2016): Urban Water Interfaces: Interfaces in Sewer Systems. *The 6th German-Russian Week of the Young Re-searcher*, Moscow, Russia
9. Teuber,K., Grüneberger,M., Despot,D., Dietmar,S., Barjenbruch,M. & Hinkelmann,R. (2017): Modeling and Measuring of Interfaces in Sewer Systems. *37th IAHR (International Association for Hydro-Environment Engineering and Research) World Congress*, Kuala Lumpur, Malaysia

3. Comments on the qualification programme and supervision strategy:

As a natural scientist from the field of mineralogy and petrology working now in the civil engineering field the core courses gave good insight and understanding to the biotic and abiotic processes related to (urban) water.
The gender courses helped a lot for self-organisation and effective use of working time. They also gave good input for negotiations, self-marketing and presentations, e.g. at conferences. The yearly summer school, the interim workshop, the collaboration workshop, and the Student Research Council were very useful to learn about the other UWI projects and start collaborations and exchange with the other student. As organiser of the Students Research Council I could improve my organisational skills regarding small scientific events. I felt well supported by my supervisors, the UWI speakers and especially by the coordination team.

Participation in the following Research Training Group events:

1. Core courses
    - I – Urban interface processes – fluxes, transport, interactions (3 ECTS)
    - II – Modelling and measuring concepts of interface processes (3 ECTS)
    - III – Urban freshwater ecology (3 ECTS)
2. Elective courses
    - Interkulturelle Kompetenzen für wissenschaftliche Zusammenarbeit (25.11.2015, TU Berlin)
    - Gut bei Stimme bleiben. Stimmqualität, Artikulation, Regeneration (14. – 15.01.2016, TU Berlin)
    - Projekte erfolgreich starten und steuern (19. – 20.01.2016, TU Berlin)
    - Professionell Projektanträge planen! (21. – 22.01.2016, TU Berlin)
    - English academic writing (08. – 09.11.2016, TU Berlin)
    - Collaborative working (16.03.2017, Buberow)
    - Proposal writing (16.03.2018, TU Berlin)
3. Gender courses
    - Time is honey – the new approach to time, self and workload organization
    - Presenting yourself and self-marketing
    - Positioning and negotiation
    - Project coaching and new leadership
4. UWI lectures and Colloquium Hydrosciences: Participated in all UWI lectures as well as some lectures of the Colloquium Hydrosciences of the Chair of Water Resources Management and Modeling of Hydrosystems and the Chair of Urban Water Managment (2 ECTS)
5. Other UWI events
    - Orientation Seminar and UWI Opening Ceremony (08. – 09.09.2015)
    - Exposé Talks (08.12.2015)
    - Summer School (13. – 14.09.2016)
    - Kollegiate Seminar (22.09.2016)
    - Interim Meeting (19.05.2017)
    - Summer School (05. – 06.2017)
    - Student Research Council (17. – 18.03.2017)

Research stays or internships at other research institutions both at home and abroad:
Internship at University of Ghent, Magnel Laboratory for Concrete Research (27.02. – 03.03.2017 & 21.03. – 12.05.2017, Ghent, Belgium)

Participation in conferences, congresses, etc., at home and abroad:

2015:

- Workshop on Microscopy of Mineral Building Materials of GDCh Devision Constructional Chemistry (23. – 24.03.2015, Halle (Saale), Germany)

2016:

- DWA Seminar: Geruch und Korrosion im Kanal und auf der Kläranlage (02.11.2016, Magdeburg, Germany)

2017:

- 5th GEMS Workshop Thermodynamic Modeling of Cementitious Systems at EMPA (30.05. – 01.06.2017, Dübendorf, Switzerland)
- GDCh Tagung Bauchemie (18 – 20.09.2017, Weimar, Germany)

4. Individual publications:

II. Conference, poster presentations etc.:

- Grüneberger,M. & Stephan,D. (2016): Analysemöglichkeiten von Schäden an zementgebundenen Baustoffen durch BSK in Abwassersystemen. *DWA Seminar: Geruch und Korrosion im Kanal und auf der Kläranlage* (02.11.2016, Magdeburg, Germany), oral presentation
- Sielaff, A.M. & Stephan,D.A. (2017): Vergleichende Untersuchungen von Säureprüfverfahren für zementgebundene Systeme. GDCh Tagung Bauchemie (18.-20.09.2017, Weimar, Germany), abstract and oral presentation
- Sielaff, A.M. & Stephan,D.A. (2018): Comparative study on acid resistance tests for cementitious materials applied in sewer systems. *RILEM TC 253-MCI International Conference – Microorganisms-Cementitious Materials Interactions* (25.-26.06.2018, Toulouse, France), peer-reviewed paper and oral presentation
- Teuber,K., Grüneberger,M., Despot,D., Stephan,D., Barjenbruch,M. & Hinkelmann,R. (2016): Urban Water Interfaces: Interfaces in Sewer Systems. *Proceedings of the 6th German-Russian Week of the Young Researcher* (12. – 16.09.2016, Moscow, Russia), paper and oral presentation
- Teuber,K., Grüneberger,M., Despot,D., Stephan,D., Barjenbruch,M. & Hinkelmann,R. (2017): Modeling and Measuring of Interfaces in Sewer Systems. *Proceedings of the 37th IAHR (International Association for Hydro-Environment Engineering and Research) World Congress* (13 – 18.08.2017, Kuala Lumpur, Malaysia), reviewed paper and oral presentation