Silane modified polyether sealant failure in drinking water pipes

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ABSTRACT

The paper reports the results obtained in the course of the analysis of a failed silane modified polyether (SMP) sealant. The sealant was applied in the socket area to prevent leakage of old cast iron drinking water pipes. It failed after a lifetime in service of 2 years. The investigations by means of thermogravimetric analysis (TGA), dynamic scanning calorimetry (DSC) and Fourier-transformed infrared spectroscopy (FT-IR) were performed in order to elucidate the causes that lead to the observed failure. The understanding of the failure mechanism is of crucial importance for the subsequent development of a durable drinking water pipe rehabilitation system.

INTRODUCTION, EXPERIMENTAL, RESULTS & DISCUSSION

The Vienna Waterworks operate approximately 300 km to 400 km cast iron pipes, which have an average age of 80 to 100 years. In spite of the long service life these cast iron pipes for drinking water are metallurgically and chemically still in a good condition. The problem with these pipes are the joints (socket area) that are leaking over the years owing to the decomposition of the former used sealing materials e.g., hemp fibres. As a remedial measure primarily the subsequent bridging of the leaking pipe joints is considered as a new piping is hardly possible in many cases. Despite some previous pilot projects of the Vienna Waterworks applying diverse methods described in the literature a sustainable rehabilitation procedure to seal the leaks could not be developed so far.

The investigated sealing system is normally used in the construction industry, it consists of a cover band made of an unspecified thermoplastic elastomer that is glued onto the substrate with a SMP sealant (one part ready to use formulation based on silane-terminated polyoxypropylene). Before the SMP sealant and the cover band were applied in the area of the sockets according to the instructions of the manufacturer the leaking cast iron pipe section was emptied and the walls were cleaned. Residual moisture should not be a problem for the system since the curing of the one part SMP sealant needs some water [1,2]. After the rehabilitation procedure the pipe section was purged and put into regular service. During the inspection of the pipe section after 2 years the formation of delaminated areas with bubble formation is detected in different sockets (Fig. 1a). The sealing system in these areas was removed and analyzed to elucidate the failure cause.

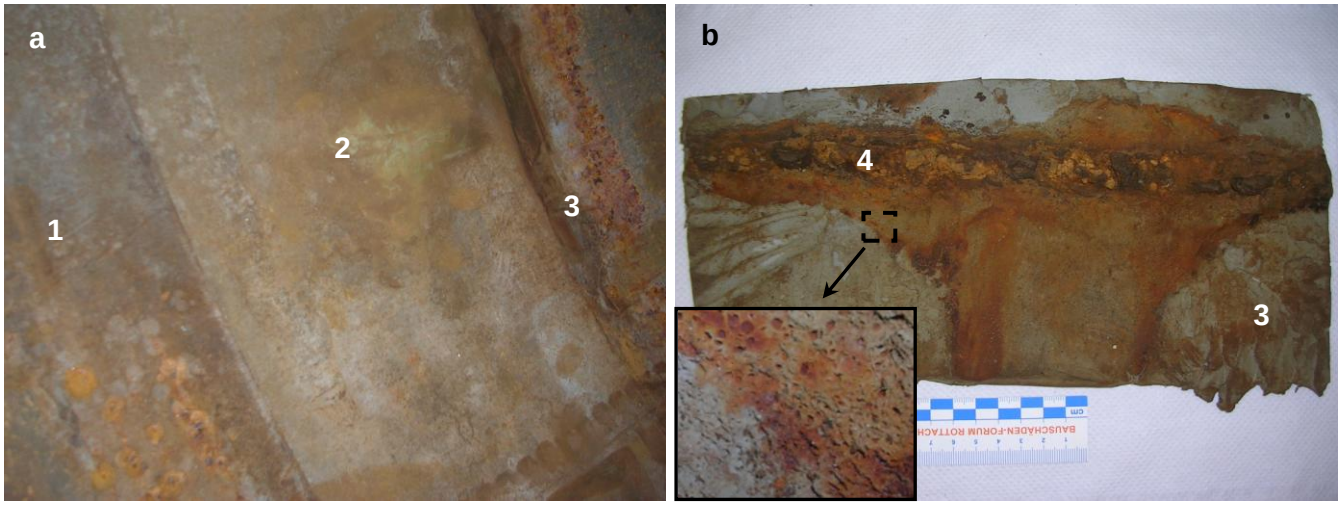

Fig.1. a) sealing system in place after 2 years in service b) back side of a removed sealing system part.
1-cleaned pipe wall 2-cover band with bubble 3-SMP sealant 4-corroded cast iron pipe residues

First the samples were examined with the naked eye: the sealant was discoloured (red, black and white areas) on large areas and corroded residues of the pipe were still adhering (Fig. 1b). In addition in the discoloured area some crevices could be found (insert Fig. 1b). The crevices could have developed during the application or

curing of the sealant. However, in non-discoloured areas such crevices could scarcely be noticed. Further, the samples had a light unpleasant odour that could originate from microbial activities.

TGA experiments were carried out with a TGA 2050 (TA Instruments) under air atmosphere using a purge gas flow of 100 ml/min, an alumina pan with a sample mass of ca. 50 mg and a heating rate of 10 K/min from ambient temperature to 850 °C.

The DSC measurements in a DSC 2920 (TA Instruments) consisted of a heating run from –60 °C to 160 °C followed by a cooling run from 160 °C to –40 °C and a subsequent heating run from –40 °C to 160 °C. The heating respective cooling rate was 10 K/min and the sample compartment was purged with nitrogen gas with a flow of 50 ml/min. Samples of about 5 mg were encapsulated in aluminium crucibles, and an empty crucible was used as reference. The instrument was calibrated using an indium standard.

FT-IR spectra were recorded in diverse positions of the samples by means of attenuated total reflection (ATR) using a Tensor (Bruker Optics) equipped with a single reflection diamond unit (DuraSamplIR from SensIR) in the wave number range of 4000 cm^{-1} to 600 cm^{-1}. The resolution was 4 cm^{-1}.

A sample extracted from the core of a relative thick sealant layer was used as an “unaltered” reference. Further samples were taken from areas with slight discoloration and corrosion deposit, and from areas with clear discoloration and crevices.

The TGA of the reference showed that the SMP sealant is composed of about 50 mass% of polymer base material, of ca. 45 mass% of $CaCO_3$, and of ca. 5 mass% of other inorganic compounds. The degradation of the polymer part occurs in three stages which were separated by using the minima in the derivative mass loss curve. The peak maximum temperature was found at 410 °C. While the degradation behaviour of samples taken from areas with low visible surface changes was relative similar to that of the reference, that of samples from areas with clear discoloration and crevices was significantly different. First the onset of the degradation was shifted from ca. 250 °C to 215 °C, and second the polymer part showed no longer a clear 3 stage degradation. The peak maximum temperature of the derivative mass loss curve occurred in a temperature range of ca. 220 °C to 240 °C. Thus, the TGA indicated a notable alteration of the sealant in the clear discoloured area.

In the DSC for both sample positions (slight discolouration and clear discolouration) the temperature of the two crystallisation peaks found in the cooling run was shifted from 118 °C and 55 °C with the reference to 121 °C respective 58 °C. Moreover, in the second heating run a small endothermic peak appeared at 50 °C in the clear discoloured samples.

The FT-IR spectra showed the appearance of additional peaks at 797 cm^{-1} and 1540 cm^{-1} in all discoloured samples, while the intensity of the 742 cm^{-1}, 1415 cm^{-1} and 1730 cm^{-1} peaks decreased in comparison with the reference. Further, the peak intensity at 3300 cm^{-1}, 2850 cm^{-1}, and 1578 cm^{-1} increased.

CONCLUSIONS

The SMP sealant was not fluid enough to penetrate the entire gap of the socket that has been created by the decomposition of the former sealing materials. Thus, soil seepage water entered the through the remaining leaks in the socket joint from the outer side of the pipe. The seepage water caused the corrosion of the unprotected cast iron surface in the socket gap. By this process different (water soluble) iron compounds were generated. These iron based compounds together with some clay minerals [3] and bacteria present in the soil catalyzed locally the degradation of the interface between the cast iron and the SMP sealant.

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REFERENCES

[1] Meier-Westhues U. *Polyurethanes – Coatings, adhesives and sealants*. Vinzenz Network: Hannover, 2007, Chapter 7, pp. 283.
[2] Petrie E.M. *Handbook of adhesives and sealants*. McGraw-Hill: New York, 2000, Chapter 13, pp. 475.
[3] Xu S, Lehmann R.G, Miller G.R, and Chandra G. *Environ. Sci. Technol.* 1998, 32, 1199-1206.