Repair of sewage manholes

Abstract of the
final report (274 pages) on the research project:
Repair of sewer manholes
by the IKT – Institut für Unterirdische Infrastruktur, D – Gelsenkirchen –
(Institute for Underground Infrastructure)

This summary should serve as a
quick and simple overview
on the testing procedures and test results
for XYPEX
distributed by BAWAX GmbH/Germany.

The full report can be found at:
http://www.lanuv.nrw.de/wasser/abwasser/forschung/pdf/Abschlussbericht_Abwasserschacht.pdf

Contents

1 Introduction

In Germany there are about 10 million sewer manholes.
Approximately 10% of them show significant leaks / defects.
These deficiencies lead to the following negative effects:

- Rising costs for municipalities due to pressing groundwater into leaky manhole systems (additional amount of dirt in the water treatment plant)
- Groundwater contamination due to leaking sewage
- Hazardous traffic conditions caused by rotten shaft systems

There is therefore an urgent need for action. Ongoing shaft repairs are necessary. The previous restoration quality is often poor and needs to be considerably improved. Therefore, the Department of Climate Change, Environment, Agriculture, Nature and Consumer Protection of North Rhine-Westphalia assigned the Institute for Underground Infrastructure in Gelsenkirchen (IKT) to investigate different sealing systems. In a large-scale experiment on 18 shaft samples at a scale of 1:1, in 2011 the sealing systems of different manufacturers were tested, evaluated and compared with regard to their practical use.

2 Table of the tested products

Manufacturer	Sealing material	Material group
BAWAX GmbH, Celle	XYPEX PATCH'N PLUG, XYPEX CONCENTRATE	Mortar
Minova Carbo Tech GmbH, Essen	Carbo Stop U, Carbo Crack Seal H	Polyurethane Resin
ASAG Umwelttechnik, Neukirchen-Vluyn	Auto Sil Rapid, Auto Sil Water	Lightning cement, silicate-based, sealing slurries
Spesan Handels-GmbH, A-Linz	Spesan WS	Polyurethane Resin
Minova Carbo Tech GmbH, Essen	cft-Harz	Polyurethane resin
Pagel Spezial-Beton GmbH Co. KG, Essen	E2F	Cement paste
Minova Carbo Tech GmbH, Essen	Carbo Cryl Wv	Acrylate gel
IPA Bauchemische Produkte GmbH	IPA Unimörtel Rapid, IPANEX Stopfmörtel, IPANEX Flächendicht WF	Mortar
Hermes Technologie GmbH & Co. KG., Schwerte	Ergelit KS 1	Plastic Modified Cement Mortar
Pagel Spezial-Beton GmbH & Co. KG Essen	KA 20	Plastic Modified Cement Mortar
PCI Augsburg GmbH	Kanament	Plastic Modified Cement Mortar
MC-Bauchemie Müller GmbH & Co. KG Bottrop	ombran MHP	Plastic Modified Cement Mortar
Remmers Baustofftechnik GmbH	SD 1-W	Silicate Mortar
ASAG Umwelttechnik, Neukirchen-Vluyn	Autoschicht	Polymer-Silicate-Resin
Trelleborg Pipe Seals Duisburg GmbH	Eprocoat	Polyurea
PSL Handels GmbH, Arnsberg	Oldodur WS 56	Polyurethane
Innovative Sewer Technologies GmbH, Bochum	Polyfill	Polymer-Silicate-Resin
Warren Environmental, Inc., US- Carver, MA	Ultracoat	Epoxy Resin

Table 1: Manufacturer and Materials Overview

3 Test Method

On a large-scale test station of the IKT comparative studies for all sealing and coating procedures were carried through in a relation 1 : 1 under defined and equal ambient conditions. The core of the large-scale test stand was a steel tank of 15 m length and 6 m width and height respectively. As part of the project, 20 manholes made of precast concrete were installed in a gravel-sand mixture with a maximum particle size of 8 mm and tested under varying water pressures. 11 manholes were provided for coating action. Another 7 were sealed by different methods. Two shafts were used as pumping wells for dewatering of the system.

Photo 1: Experimental setup of the shaft systems in large-scale test stand

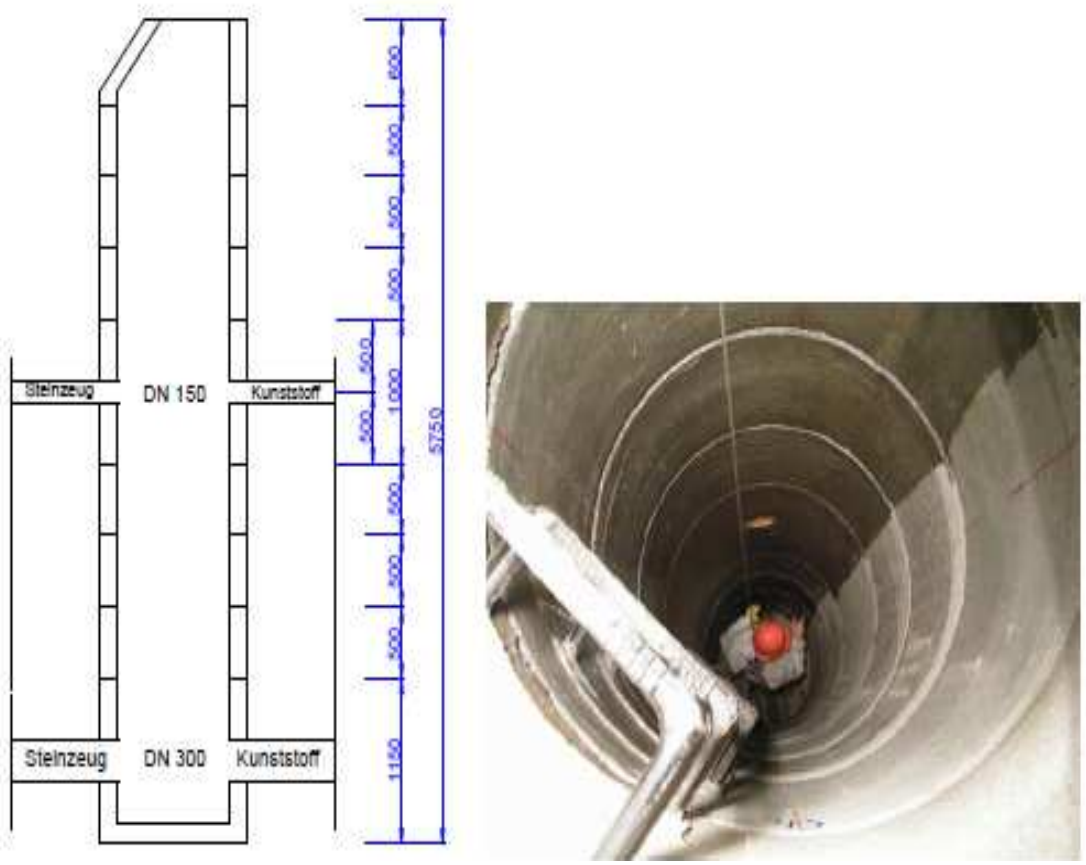


Figure 2: Shaft construction in large-scale test stand - section (left), look at a completed well (right)

Photo 3: Installation of shafts in the test series as:
Lower pipe layer DN 300 (left); medium pipe layer DN 150 (center); completed installation (right)

Before and during installation of the precast concrete elements, each different slot ring was exposed to damaging conditions. These simulated local and surface leaks as well as leaking manhole joints. Mainly holes in different sizes and numbers were drilled. There were three different damage types as shown in Table 2. Each precast concrete element in the shafts was provided with two damaged areas.

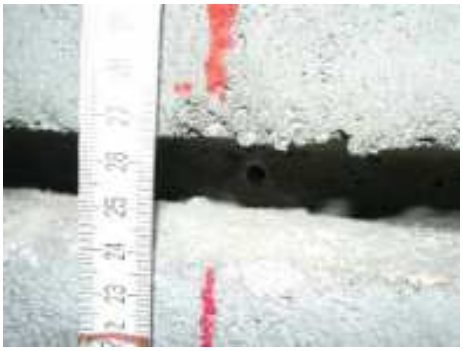
Damage (Abbreviation)	Number of drilling holes	Diameter of drilling holes	Pictures of the damaged areas
"Local injury " (LS)	each 1	10 m	
"Surface leakage" with a release agent (FU)	each 9	9 mm	
„Damage to man-hole joint“ (SF)	each 4	6 mm	

Table 2: Damage types in the precast concrete

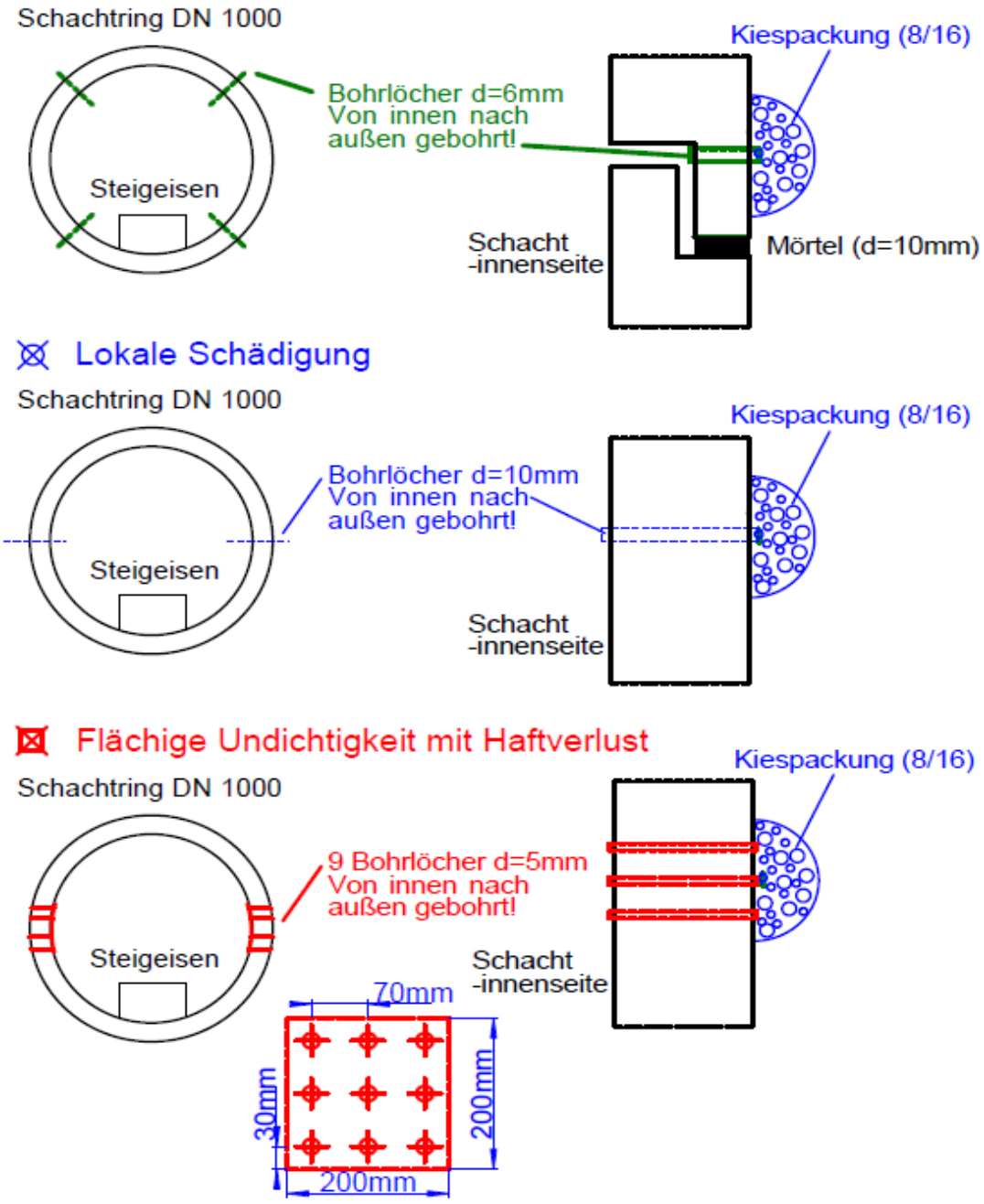


Figure 4a: Sketch of the simulated (typical) damage in shaft systems

In order to expose the damaged areas to different water pressures, 6 manholes were installed, lying upon another and each one showing the same defect.
Depending on the height of the manhole rings, the damaged areas were exposed to a different water pressure. To test and evaluate the sealing, it was necessary to consider the position of the damaged areas by assigning a load step number (1 = lowest position = highest water pressure up to 7 = highest location = lowest water pressure) taken into account (see Figure 4b).

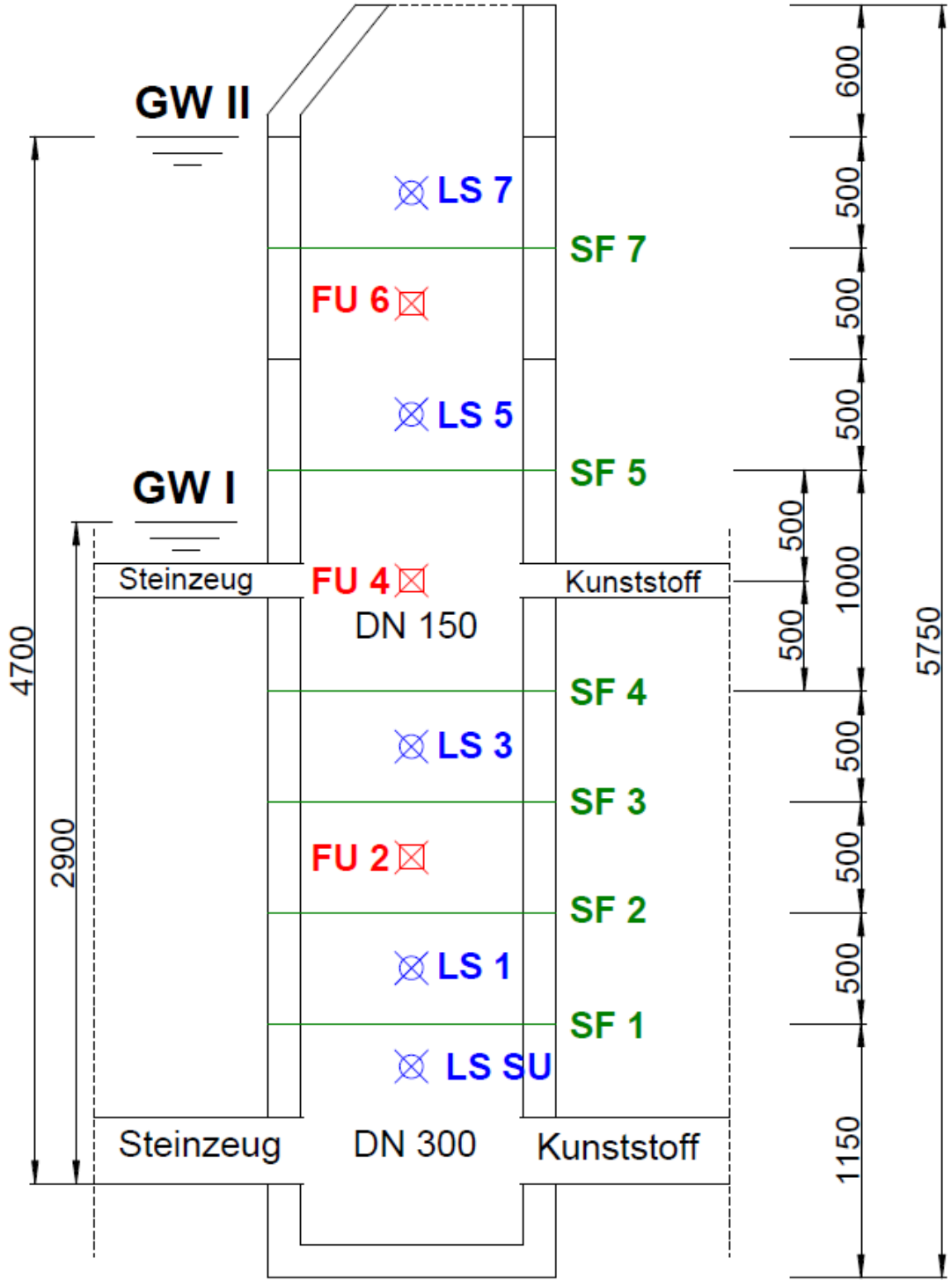


Figure 4b: section of the shaft body

4 Test Method

4.1 General Description

In the experiment, 11 shafts were provided with *coating* systems, whereas 7 shafts were provided with *sealing* systems.
The main difference in the testing procedure between these systems was the time of installation. The **coating systems** were installed 28 days prior to flooding, giving the mortar sufficient time for curing. The **sealing systems**, which include the XYPEX, were installed against the water pressure after the flooding.

Test procedure:

- Application of coating systems to 11 shafts (dry)

- Observance of a waiting period of 4 weeks to ensure that the mortar coatings reach their nominal strength before being exposed to any stresses.

- GW 0: Documentation of the condition before flooding

- GW I - short-term: Flooding of the basin, water level up to 2.90 m above the floor,
  Holding period: one week
  Inspection of the condition of the coatings.

- GW II - short-term: Raising of water level to 4.70 m above the floor,
  Holding period: one week
  Installation of waterproofing systems in the remaining 7 completely untreated shafts (including XYPEX).
  Inspection of the coating conditions and seals after one week.

- GW II - long-term: Keeping the water level at 4.70 m above the bottom over a period of 5 months.
  Inspection of manholes and documentation

4.2 XYPEX waterproofing system

The XYPEX-system used is consisting of mineral seal products. **XYPEX CONCENTRATE** and **XYPEX PATCH'N PLUG** are composed of crystal-forming agents, cement, fine silica sand and various other components. Applied to a concrete surface, these catalysts diffuse into the concrete pores and form insoluble crystals. In a subsequent sealing of the capillary pores a higher density of the structure is thus obtained.

First, the dry mortar **XYPEX PATCH'N PLUG**, which can be compared with a flash mortar, was mixed with water according to the manufacturer's instructions (BAWAX GmbH, D-Celle). In the test this mortar was used to stop the water leaks and shut the manhole joints. **XYPEX CONCENTRATE** was produced in a slurry consistency and was spread with a wide brush on the entire shaft wall surface. It contains a high concentration of crystallization components. Finally, the slurry coat was sprayed with **XYPEX GAMMA CURE**.

The key process steps are as follows:

1. Stopping of heavy water ingress by using the XYPEX PATCH'N PLUG;

2. Re-profiling of ring joints and fractures in the shaft wall
   (see photo 5, left);

3. Application of the crystallization product or mortar XYPEX CONCENTRATE
   as slurry coat to the shaft wall from top to bottom
   (see photo 5, right).

Photo 5: Sealing with crystallization mortar: backfilled annular gaps in the shaft wall (left); application as slurry coat with a wide brush (right)

5 Results

5.1 General summary

The extensive results of the IKT have been prepared for scientific analysis. Multiple inspections of the treated shafts were carried out under various load levels. For the sealing of sewage ducts, the long-term observation under maximum load limits shall apply (GW II - long-term). For this reason, the results of all tested products have been summarized in the following table.

To complete this, we have added the most important test results of the system. Under paragraph 5.2 we look at the results for our product line XYPEX in detail.

Manufacturer	Sealing material	Sealing tech-nology	Material group	Density over the entire test duration period
BAWAX GmbH, Celle	XYPEX Patch`n Plug, XYPEX Concentrate	sealing by hand	mortar	yes
Minova Carbo Tech GmbH, Essen	Carbo Stop U, Carbo Crack Seal H	injection	polyurethane resin	no
ASAG Umwelttechnik, Neukirchen-Vluyn	Auto Sil Rapid, Auto Sil Water	sealing by hand	Blitzzement, Dichtschlämme auf Silikatbasis	no
Spesan Handels- GmbH, A-Linz	Spesan WS	injection	polyurethane resin	no
Minova Carbo Tech GmbH, Essen	cft-Harz	injection	polyurethane resin	no
Pagel Spezial- Beton GmbH Co. KG, Essen	E 2 F	injection	cement paste	no
Minova Carbo Tech GmbH, Essen	Carbo Cryl Wv	injection	acrylate gel	no
IPA Bauchemische Produk-te GmbH	IPA Unimörtel Rapid, IPANEX Stopfmörtel, IPANEX Flächendicht WF	sealing by hand	mortar	no
Hermes Technologie GmbH & Co. KG., Schwerte	Ergelit KS 1	manual	plastic modified cement mortar	no
Hermes Technologie GmbH & Co. KG., Schwerte	Ergelit KS 1	gentle spin (KS-ASS-procedure)	plastic modified cement mortar	no
Pagel Spezial-Beton GmbH & Co. KG, Essen	KA 20	manual	plastic modified cement mortar	no
PCI Augsburg GmbH	Kanament	manual	plastic modified cement mortar	yes
MC-Bauchemie Müller GmbH & Co. KG, Bottrop	ombran MHP	manual	plastic modified cement mortar	no
Remmers Baustofftechnik GmbH	SD 1-W	manual and jet application	silicate mortar	no
ASAG Umwelttechnik, Neukirchen-Vluyn	Autoschicht	gentle spin	Polymer-silicate-resin	no
Trelleborg Pipe Seals Duis-burg GmbH	Eprocoat	spray applicati-on	polyurea	no
PSL Handels GmbH, Arns-berg	Oldodur WS 56	spray applica-tion and gentle spin	polyurethane	no
Innovative Sewer Technolo-gies GmbH, Bochum	Polyfill	jet application	Polymer-silicate-resin	no
Warren Environmental, Inc., US- Carver, MA	Ultracoat	spray applica-tion	epoxy resin	no

Table 4: Overview results

5.2 Results for XYPEX in detail

Test results GW 0 (before flooding)

At this time, all shafts are still dry; the shaft to be treated by BAWAX GmbH still is untreated. The XYPEX waterproofing was installed only after the complete flooding of the shaft. Before flooding, 11 coating systems had already been applied.

Test results GW I - Short-term

- partial flooding of the shafts
- water level: 2.90 m
- XYPEX has not yet been installed

Test Results GW II - Short term (after one week)

- complete flooding of the shafts
- water level: 4.70 m (maximum load)
- installation of the XYPEX waterproofing under maximum water pressure and maintainance of the load
- **no** leaks could be detected

Inspection findings GW II - Long-term (after five months)

During the whole observation period under permanent maximum load conditions, **no** leaks were detected. The XYPEX-treated shaft was completely sealed.

Areas with extremely high penetration (damaged areas) showed discolorations of the applied mortar sludge in different size and intensity. These were arising because of the process of crystallization and are therefore completely harmless. The discolorations are reducing in the course of time, they might remain visible, but permanently dry – their appearance is of no significance (see photo 6).

Photo 6: Change of color and expansion of the damaged area within approximately 13 weeks.
Left: greater expansion and darker color of the damaged area
Right: lower expansion and lighter in color after 13 weeks

The measured surface moisture of light and dark areas of the pit-wall showed no differences. To meet higher optical requirements it is basically possible to remove the backing layer completely after four weeks, as there has already been a self-sealing process of the construction by advanced crystallization.

6 Conclusion

A total of prepared 18 sewer manholes were completely sealed by the participants, after 5 months only two of them were still completely waterproof!

With both shafts cement-based systems were used. All plastic-based coatings and injections failed.

Although some of the systems initially showed no leaks in the short-term study, leaking damages occurred in the following 5-month period. Against the background of the planned service life, the durability of these systems should be considered as insufficient.

Statement of the experiment in terms of XYPEX:
Besides XYPEX only the polymer-modified mortars of PCI showed no leaks, in both the short-term and long-term testing. In contrast to XYPEX, which was applied under pressing water and which initially stopped the running water, the application of the PCI system, however, happened before flooding the test chamber on a dry surface with subsequent 4 weeks of drying time.

Therefore, the XYPEX is the only waterproofing system in the test that led to a complete and permanent seal on wet ground against pressing water.

Enclosures: XYPEX compared to reference products

Damaged area		Pressure (mWs)	Resin injection			Gel injection	Mortar with crystal-formers XYPEX
			GW II- Long-term			GW II- Long-term	GW II- Long-term
pre-seal:			without	mortar	PU-foam	no	no
„Local injury“ (LS)	LS 7	0,2	C	not appli-cable	C	C	C
	LS5	1,2	C	not appli-cable	C	C	C
	LS3	2,7	C	not appli-cable	W =>C	C	C
	LS1	3,7	C	not appli-cable	C	C	C
	LS SU	4,2	W=>C	not appli-cable	W=>C	C	C
„Damage to man-hole joint“ (SF)	SF 7	0,5	W	W	W=>C	W	C
	SF 5	1,5	W	not appli-cable	W	W	C
	SF 4	2,5	W	W	C	C	C
	SF 3	3,0	W	not appli-cable	W	C	C
	SF 2	3,5	W	W	C	C	C
	SF 1	4,0	C	not appli-cable	C	C	C
„extensive leakage“ (FU)	FU 6	0,8	W	not appli-cable	C	C	C
	FU 4	2,0	W	W	W	W	C
	FU 2	3,3	W	W	W	W	C
Leaking manhole annulus (SF 6)		1,0	W	W	C	W	
Packers to SF 4		2,5	not applicable			L	Irregular appearance (bright and dark areas irrelevant for shafts)

Table: Shaft seal body - Part 2: GW -– Long-term

Legend of reference table:

- Monitoring of the seal
- GW II- long-term = ground water level was adjusted to 4, raised 70 m above the floor (held for five months)
- C = close
- W = wet
- W => C = moisture flags, which subsequently dried
- L = leaky

			Injection of cement paste	Plugging and surface mortar (mineral)	Plugging and surface mortar limited to damaged area (silicate)
Damaged area		pressure (mWs)	GW II- Long-term	GW II- Long-term	GW II- Long-term
„Local injury“ (LS)	LS 7	0,2	not repaired	C	C
	LS5	1,2		W	C
	LS3	2,7		W	C
	LS1	3,7		C	C
	LS SU	4,2		C	C
„Damage to manhole joint“ (SF)	SF 7	0,5	C	not applicable	W
	SF 5	1,5	not repaired	W	W
	SF 4	2,5		not applicable	C
	SF 3	3,0		W	C
	SF 2	3,5		not applicable	W
	SF 1	4,0		W	W
„extensive leakage“ (FU)	FU 6	0,8	C	C	C
	FU 4	2,0	not repaired	not applicable	C
	FU 2	3,3		not applicable	C
Leaking manhole annulus (SF 6)		1,0	Moisture flags on the packer	not applicable	not applicable

Table: Shaft seal body - Part 1: GW – Long-term

Legend of the comparison table:

- GW II Short-Term = groundwater level was raised to 4.70 m above the floor (held one week) with optical monitoring after sealing
- GW II = long-term ground water level was adjusted to 4, raised 70 m above the floor (held for five months)
- C = close
- W = wet
- W=>C = moisture flags, which subsequently dried
- L = leaky

Damaged area		pressure (mWs)	Auto-layer	Eprocat	Oldodur	Polyfill	Ultracoat
„Local injury“ (LS)	LS 7	0,2	Cp- C	Flooding of the well after 1 day	Cp- C	Cp- C	Cp- C
	LS5	1,2	Cp- C		Cp- C	Cp- C	Cp- C
	LS3	2,7	Cp- C		Cp- C	Cp- C	Cp- C
	LS1	3,7	Cp- C		Cp- C	Cp- C	Cp- C
	LS SU	4,2	Cp- C		Cp- C	Cp- C	Cp – L = 3,6 ml/s
„Damage to man-hole joint“ (SF)	SF 7	0,5	Lp- L = ∑ 30 ml/s		Lp = 40 ml/s -D	Cp *- C*	Cp- C
	SF 5	1,5	Lp- L = ∑ 30 ml/s		Cp- C	Wp * - C*	Cp- C
	SF 4	2,5	$Lp^1 – L^1$		Cp- C	Wp * - C*	Cp- C
	SF 3	3,0	$Lp^1 – L^1$		Cp- C	Cp *- C*	Cp- C
	SF 2	3,5	$Lp^1 – L^1$		Cp- C	Cp *- C*	Cp - C
	SF 1	4,0	$Lp^1 – L^1$		Cp- C	Wp * - C*	Cp- L = 2,5 ml/s
„extensi-ve leaka-ge“ (FU)	FU 6	0,8	Cp- C		Cp- C	Cp- C	Cp - C
	FU 4	2,0	Cp- C		Cp- C	Wp - L = max. 120ml/s	Cp - C
	FU 2	3,3	Cp- C		Cp- L = 800 ml/s	Wp - L = max. 86 ml/s => F=> D	Cp - C
other:			1 = clear water entry, not measured	not applicable	spalling, cracking in the coating, flood-ing after eight weeks	Stirrups, SR5 leaking; sepa-rations and cracks in the coating	Stirrups, SR5 leak-ing

Table: Polymer Coatings: GW II - Long-term

Legend of reference table:

- Index: „p“: in front of the tray side surface preparation prepared with vegetable shortening
- No index: page not well prepared prior to surface preparation
- L = leakage; C = close; F 0 moisture flags; reprofiled about 5 mm deep
- W = wet

Damaged area		pressu-re(mWs)	Ergelit KS 1 (manually)	EprocatEr-gelit KS1 (KS-ASS)	KA 20	Kanament	Ombran MHP	SD 1 - W
„ Local injury “ (LS)	LS 7	0,2	Cp- C	Cp- C	Cp- C	Cp- C	Cp- C	Cp- C
	LS5	1,2	Cp- C	Cp- C	Cp- C	Cp- C	Cp- C	Cp- C
	LS3	2,7	Cp- C	Cp- C	Cp- C	Cp- C	Cp- C	Cp- C
	LS1	3,7	Cp- C	Cp- C	Cp- C	Cp- C	Cp- C	Cp- C
	LS SU	4,2	Cp- C	Cp- C	Cp- C	Cp- C	Cp – L = 3,6 ml/s	Cp- C
„Damage to manhole joint“ (SF)	SF 7	0,5	Wp - W	Wp - W	Lp = 40 ml/s -D	Cp- C	Cp- C	Cp *- C*
	SF 5	1,5	Wp - W	Wp - W	Cp- C	Cp- C	Cp- C	Cp *- C*
	SF 4	2,5	Wp - W	Wp - W	Cp- C	Cp- C	Cp- C	Cp *- C*
	SF 3	3,0	Wp - W	Wp - W	Cp- C	Cp- C	Cp- C	Cp *- C*
	SF 2	3,5	Wp - W	Wp - W	Cp- C	Cp- C	Cp - C	Cp *- C*
	SF 1	4,0	Wp - W	Wp - W	Cp- C	Cp- C	Cp- C	Cp *- C*
„ extensive leakage “ (FU)	FU 6	0,8	Wp - W	Wp - W	Cp- C	Cp- C	Cp - C	Wp - W
	FU 4	2,0	Wp - W	Wp - W	Cp- C	Cp- C	Cp - C	Wp - W
	FU 2	3,3	Wp - W	Wp - W	Cp- L = 800 ml/s	Cp- C	Cp - C	Wp - W
other:			not appli-cable	Moisture flags at several stirrups	Moisture flags at several stirrups	not applicable	Stirrups , SR2 leaking	Stirrups , SR2 leaking
			Additional voids and cracks with moisture flags			not applicable	Cracking on the moisture flags	

Table: Mortar Coatings: GW II - Long-term

Legend of the comparison table:

- Index: „p“: in front of the tray side surface preparation prepared with vegetable shortening
- No index: page not well prepared prior to surface preparation
- L = leakage; C = close; F 0 moisture flags; reprofiled about 5 mm deep
- W = wet

Enclosures – The used BAWAX products

XYPEX CONCENTRATE

XYPEX CONCENTRATE is the most chemically active product within the XYPEX waterproofing crystallization system. XYPEX CONCENTRATE is supplied ready for use and is mixed with water to form a cement slurry. It can be applied to surface and underground concrete. There are two standard coatings. XYPEX CONCENTRATE is also used as a dry pack for the sealing of joints or for the repair of cracks, faulty construction joints and cracks. XYPEX protects the concrete against the ingress of water and other liquids from any direction, as it causes a catalytic reaction, which produces an insoluble crystal formation within the pores and capillaries of concrete and cement-containing materials.

XYPEX PATCH´N PLUG

XYPEX PATCH'N PLUG stops penetrating water and can be used to seal cracks, holes and other defects on concrete surfaces. XYPEX PATCH'N PLUG is a quick-setting, non-shrinking material of hydraulic cement with high composite action, which was specifically designed for any kind of concrete repair. The superior performance of XYPEX PATCH'N PLUG is even improved by the unique crystal-forming substances of the XYPEX waterproofing system.

XYPEX GAMMA CURE

XYPEX GAMMA CURE acts as a protection against drying and keeps the optimum moisture back into the XYPEX coating. It dries after 2-3 days without film formation on its own. XYPEX GAMMA CURE is a curing agent that is specifically designed to the XYPEX waterproofing products for concrete by crystallization. XYPEX GAMMA CURE is an alternative to treatment with water moisture for the XYPEX application. It also helps to accelerate the XYPEX crystallization.