IKT Comparative Product-Test of repair methods for lateral connections

Members of the project steering commitee discuss the test apparatus

Do repaired lateral connections remain permanently watertight against infiltration? How do contractors, machinery and materials perform in practical tests? The results: varied right across the board, from VERY GOOD to DEFICIENT …

IKT recently performed an impartial, independent product test on rehabilitation of lateral connections. The background to this work is that damage to lateral connections has been the most common form of damage found in drain/sewer systems during DWA (German Association of Water, Wastewater and Waste) surveys for several years in a row. Damaged lateral connections can permit infiltration of soil and ground water, cause environmental harm and soil subsidence, and result in higher maintenance costs for network operators.

As many network operators are clearly aware, rehabilitation of lateral connections is necessary. But, the performance of contractors using different rehabilitation techniques is an area of great uncertainty for the network operators.

Project steering commitee

For this reason, just on twenty municipalities that operate sewer networks met in a steering commitee and conceived, together with IKT, a practically-orientated test programme. The aims were to comparatively evaluate the quality of contractors' performance and generate market pressure for performance improvement.

This IKT Comparative Product-Test was financed by the environment ministry of the German state of North Rhine-Westphalia (NRW) and by the members of the steering commitee. The steering commitee convened a total of nine times, to take all the crucial decisions concerning the project. These included specifying the contractors to be included, the nature and scope of the test programme, and the test criteria to be used. Finally, the group also performed the concluding evaluation of the results and awarded of grades.

Figure 1: Members of the municipal steering commitee define damage scenarios

Rehabilitation of lateral connections in ground water zones

The steering commitee decided to apply this IKT Product Test to two different test situations concerning leak tightness against infiltration:

- Case 1: Lateral reconnection to a liner-rehabilitated main sewer:
  - The test apparatus comprised a section of re-lined main sewer to which lateral connections needed to be re-connected.
- Case 2: Lateral connection repair in a non-rehabilitated main sewer:
  - Here, the test required damaged lateral connections were to be repaired, with no prior rehabilitation of the main sewer.

Selection of candidate contractors and market reaction

A market survey was undertaken which found that there are ten manufacturers of rehabilitation robots, and fifty-two rehabilitation contractor companies possessing the RAL-GZ 961, S10.1 to 4, QA system operating in the German market.

All of these contractors were invited to participate in the Comparative Test. They were also given the opportunity of obtaining on-the-spot detailed information on the test apparatus and the damage scenarios, and to quote for undertaking repairs on the test apparatus.

One manufacturer agreed to participate, whilst a second named a rehabilitation contractor in which it had confidence. Of the fifty-two rehabilitation contractors approached, eleven submitted a quotation, from which the steering commitee selected four. These six test candidates were paid for their work from the project budget.

Tab. 1: Contractors in the test	Case 1: Lateral reconnection to a liner-rehabilitated main sewer	Case 2: Lateral connection repair in a non-rehabilitated main sewer
IBG HydroTech GmbH	X	X
KATEC Kanaltechnik Müller & Wahl GmbH	X	X
Kuchem GmbH	X	X
PLITT-ROHRSANIERUNGSGESELLSCHAFT mbH	X	X
Swietelsky-Faber GmbH Kanalsanierung	X	X
Onyx Rohr- und Kanal-Service GmbH	X	
Geiger Kanaltechnik GmbH & Co. KG		X

All the other contractors either declined to participate for diverse reasons (e.g. alleged remoteness of the test apparatus from real practice, their systems being revised, deadline pressures and lack of capacity) or did not respond at all. The replies received from the manufacturers can be viewed in the full version of the project report (download: www.ikt.de/downloads/warentest-berichte, German version only). An overview of the companies participating in the tests is shown in Table 1.

Rehabilitation tasks and test programme

The system tests and quality assurance are the central elements in the test programme.

For the system tests for Case 1, „Lateral reconnection to a liner-rehabilitated main sewer", two lines of concrete pipe (DN 300), with concrete manholes (DN 1000) were installed in IKT's large-scale test facility, and a GRP or needle-felt (NF) CIPP liner was installed into them. Each pipe line was subdivided into six sections, such that each contractor was able to rehabilitate a section of both pipe lines each featuring three damage scenarios involving lateral connections of DN 150 vitrified clay pipe (Figure 2).

For Case 2, „Lateral connection repair in a non-rehabilitated main sewer", the test apparatus was installed in several medium-sized IKT test facilities. Each test apparatus comprised a manhole structure (DN 1000) consisting of prefabricated concrete elements and a DN 300 main sewer consisting in each case of a section of PVC piping connecting to sections of concrete and vitrified clay pipe. Six damage scenarios involving DN 150 vitrified clay pipe laterals (3 x concrete pipe, 3 x vitrified-clay pipe) were then simulated in each test facility.

The municipalities in the steering commitee defined the damage scenarios for both cases: defective, leaking sewer connections in various connection zones at the side, crown, and between the side and crown of the main sewer (Figure 2).

Each test apparatus was buried under sand such that the contractors could only access the pipe sections to be repaired via the manholes.

The rehabilitation objectives for the contractors were to restore the water tightness and correct functioning of the joint. Achieving this was left to each participant, i.e., they alone were responsible for the planning, conception, selection of materials, rehabilitation and finishing work. There was no time limit.

Test programme and evaluation system

The system tests started after completion of rehabilitation of the lateral connections. The prime emphasis here was on external water pressure (exclusion of ground water). In addition, operating loads caused by high-pressure (HP) cleaning were simulated, and any associated damage assessed by means of visual inspection.

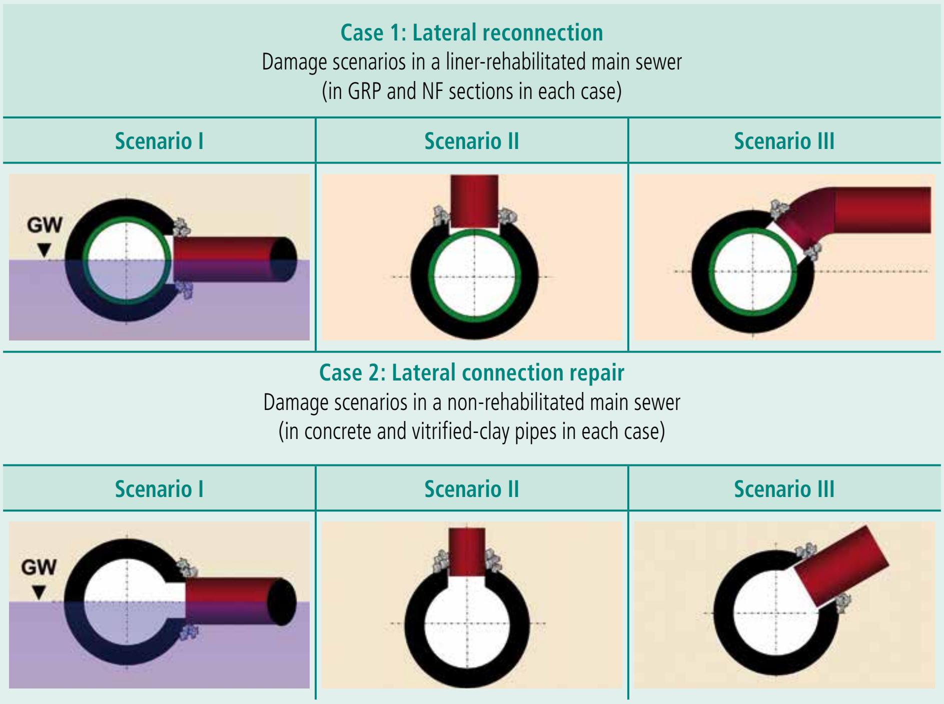


Figure 2: Damage scenarios for lateral reconnection and lateral connection repair, diagrams in principle

The essential elements of the tests were identical in both cases (lateral reconnection and lateral connection repair):

a) Application of external water-pressure load at a point two metres above the pipe crown
  - Short-term: < 72 h
  - Long-term: 4 months for lateral reconnection, 2 months for lateral connection repair

b) Sewer cleaning
  - standard HP operational load: approx. 80 bar at nozzle, 15 cycles

Additional information that was recorded, but not used in the evaluation and grading of performance, included how the repairs behaved under short-term and long-term groundwater exposure at 4.50 m head and after HP cleaning at approx. 100 bar at the nozzle, at 5 cycles. Internal-pressure tests were also performed after opening of the test lengths.

Water Tightness was evaluated on the basis of the observations made during the 2 m head short-term and long-term groundwater loading tests. Differentiation was made between three states:

- No abnormalities
- Perceptible abnormality in the form of visible discoloration and/or moisture
- Visible infiltration

Functionality determined whether the sewer´s functional capability had been restored. For this each repaired point was visually assessed by the participating municipalities for stability and potential obstructions to sewer flow. Assessments were made after the repair was completed and following high pressure cleaning.

Contractor's quality assurance covered such criteria as their process manual, operator training (in use of robots), provision of test/inspection certificates for the material used, and supervision of the installation. The criterion of „no particular abnormalities" was included in the scoring to record, if necessary, any other special features of the performance of the activities.

The weighting of scores against these criteria is summarised in Table 2.

Validation of the test methodology

The operation of the rehabilitation methods used by the contractors was observed under practical conditions in the field, and performance was investigated using supplementary on-site tests, in order to validate the testing design at IKT's test facility. The essential installation operations were observed on site, the nature and scope of preparatory work recorded, and any deviations from the information contained in the process manuals and/or from the work performed at IKT test facilities noted.

Tab. 2: Evaluation system

System tests (85 %)	Quality Assurance (15 %)
Water Tightness (50 %): • Short-term GW exposure, 2.0 m (20 %) • Long-term GW exposure, 2.0 m (80 %) Additional information (collected but not included in the evaluation and grading) • Short- and long-term GW exposure, 4.50 m (only for liner-rehabilitated main sewer) • Internal-pressure tests after conclusion of test programme and removal of soil from around the test apparatus	• Process manual (20 %) • Operator training (20 %) • Test/inspection certificates for material used (20 %) • Contractor's supervision (20 %) • No particular abnormalities (20 %)
Functionality (50 %): • after completion (20 %) • after high-pressure cleaning (80 %) Additional information (collected but not included in the evaluation and grading) • Visible abnormality caused by maximum pressure HP cleaning (only for liner-rehabilitated main sewer)	

Test results, Case 1: „Lateral reconnection"

Kuchem GmbH achieved the best result for „Lateral reconnection to a liner-rehabilitated main sewer", with the grade of VERY GOOD. Contractors KATEC Kanaltechnik Müller & Wahl GmbH, Swietelsky-Faber GmbH Kanalsanierung, and PLITT-ROHRSANIERUNGS-GESELLSCHAFT mbH each achieved a GOOD grading. A ADEQUATE grade was achieved by Onyx Rohr- und Kanal-Service GmbH. IBG HydroTech GmbH A was graded as DEFICIENT and the evaluation identified a clear need for further optimisation of its relatively recently developed robot system.

Water Tightness

Where a damaged connection had visually been assessed to be correctly rehabilitated and was initially water tight, it was generally found that they also remained so throughout the testing. Twenty lateral connections (59% of the 34 repairs undertaken) exhibited no abnormalities in terms of Water Tightness up to the end of the testing (including the long-term groundwater simulation at 4.50 m head).

Lateral connections with visually conspicuous irregularities, such as missing material at the point of damage or highly textured surfaces (8 of 34 repairs, approx. 24 %) were found not to be water tight as early as the short-term groundwater simulation at 2 m. Under long-term groundwater simulation at 2 m there was no significant further deterioration in their condition in terms of infiltration. Seven other lateral connections did, however, exhibit new abnormalities, in the form of visible moisture and/or discoloration.

Long-term exposure

Up to the end of the external water-pressure tests, a further deterioration in infiltration performance was observed only in one individual case, even under the significant rise in the water table to 4.5 m. At the end of the programme of testing, nine of thirty-four repaired sewer laterals (approx. 26 %) manifested visible infiltration.

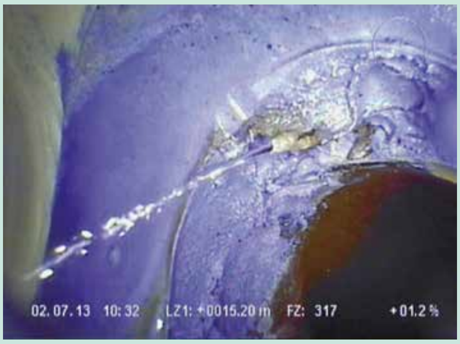
Examples of evaluations following long term water tightness testing are shown in Figure 3.

A: Tight lateral connection in the GRP lined pipe

B: Tight lateral connection in the NF lined pipe

C: Discoloration

D: Moisture, with no infiltration



E: Leaking lateral connection (jet of water)

F: Leaking lateral connection (gushing water)

Figure 3: „Tightness" test criterion after long-term groundwater simulation test for „Lateral reconnection to a liner-rehabilitated main sewer"

Five of the thirty-four lateral connections (approx. 15 %) exhibited abnormalities in the form of discoloration or moisture; and continued observation of these lateral connections would appear recommendable in practice. It should be noted, however, that HP cleaning is capable of removing these marks and that these abnormalities are then no longer perceptible. However, no waste-water was being fed through the test apparatus and in reality this may cause significant discoloration to the liner and the rehabilitated lateral connection, complicating or preventing identification of infiltration-induced abnormalities.

Figure 3 Photopgraphs A-F show examples of evaluations for the Water Tightness criterion of re-connected laterals following the long-term groundwater simulation test.

Functionality

For the Functionality criterion (Table 3), no significant differences were apparent in the liner-rehabilitated main sewer between the GRP lined pipe (average overall grade: 2.7) and the NF lined pipe (average overall grade: 2.8). Serious differences are apparent between the test participants, as gradings ranged from 1.7 to 5.1. Four contractors achieved a GOOD grade, one a SATISFACTORY grade and one was graded DEFICIENT.

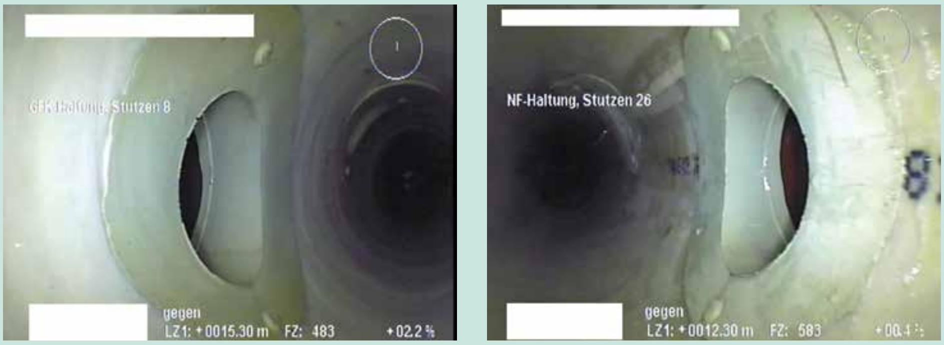


Figure 4: The best-graded lateral connection for the „Functionality" criterion, in each case after HP cleaning; GRP lined pipe (left); NF lined pipe (right)

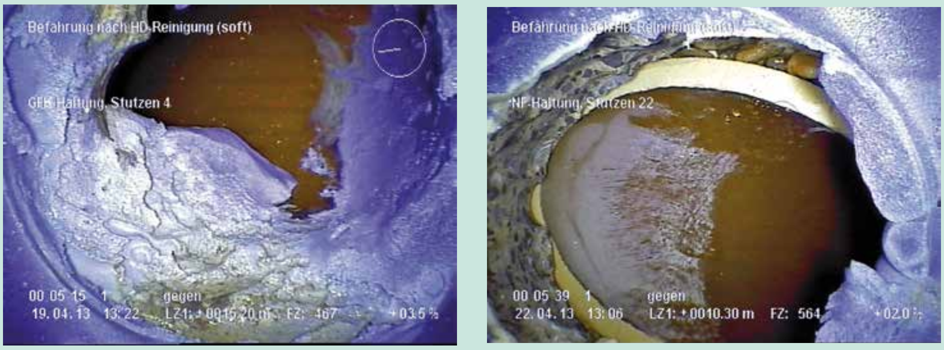
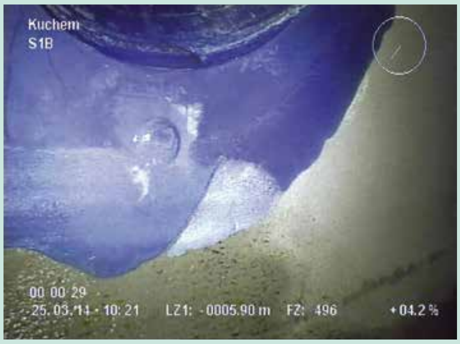


Figure 5: Poorest-graded lateral connection for the „Functionality" criterion, in each case after HP cleaning; GRP lined pipe (left); NF lined pipe (right)

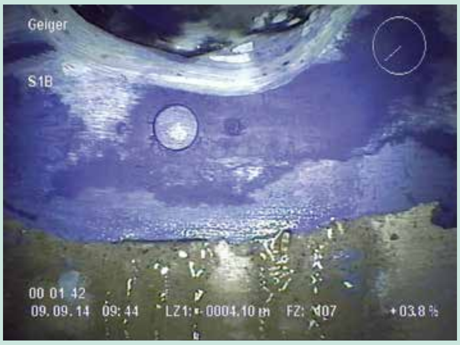
A: Tight lateral connection in concrete pipe

B: Tight lateral connection in vitrified-clay pipe



C: Moisture, with no infiltration, Example 1

D: Moisture, with no infiltration, Example 2



E: Leaking lateral connection in concrete pipe

F: Leaking lateral connection in vitrified-clay pipe

Figure 6: Repaired lateral connections in non- rehabilitated main sewer after long-term groundwater simulation

High-Pressure cleaning

Only minimal variations in grades, by a maximum of 0.3 points, were apparent after HP cleaning. It is notable that only slight visual abnormalities, in the form of spalling of material at the repaired lateral connections, occurred as a result of cleaning. This was observed more frequently in the NF lined pipe (13 of 18 lateral connections). Spalling was apparent only on two of eighteen lateral connections in the GRP lined pipe. Such spalling is generally harmless in terms of sewer functionality.

Damage Scenario I, at a 45° angle to the longitudinal axis (Figure 2) in relation to influx of groundwater was found to be the most difficult exercise for the majority of participants. No particular differences were noticeable between Damage Scenarios II and III.
Examples of evaluations against the Functionality criterion are illustrated in Figures 4 and 5 for the best- and the poorest-graded lateral connection after HP cleaning in the GRP and NF lined test pipes.

The contractors' quality assurance scored well with only a few areas of criticism. All results are compiled in Table 3.

Test results, Case 2: „Lateral connection repair"

KATEC Kanaltechnik Müller & Wahl GmbH and Kuchem GmbH both achieved the best result (Grade: 1.6) in the „Lateral connection repair in a non-rehabilitated main sewer" testing (Table 4). They are followed by PLITT-ROHRSANIERUNGS-GESELLSCHAFT mbH, with a grade of GOOD (2.2). Swietelsky-Faber GmbH Kanalsanierung and Geiger Kanaltechnik GmbH & Co. KG were graded SATISFACTORY. IBG HydroTech GmbH with its relatively recently developed robot system again exhibited a significant need for optimisation of its technique, and just achieved an ADEQUATE grade.

Where a lateral connection was visually determined to have been satisfactorily rehabilitated and was initially water tight, it generally remaind so. Approx. 67 % (24 of 36) rehabilitated laterals exhibited no abnormalities in terms of Water Tightness up to the end of the tests.

Long-term exposure

Up to the end of the external water-pressure exposure tests, only one further deterioration involving infiltration was observed, even after the significant increase in the length of exposure to groundwater. Seven of the thirty-six rehabilitated sewer laterals (approx. 19 %) exhibited infiltration at the end of the test programme.

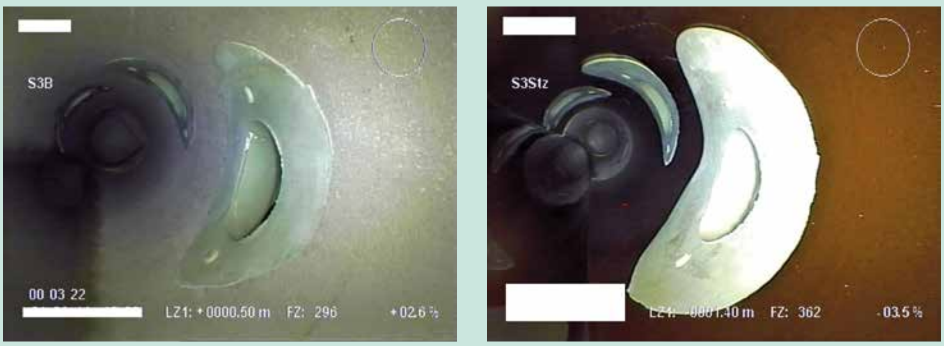


Figure 7: The best-graded lateral connection for the „Functionality" criterion, after HP cleaning in each case; concrete pipe (left); vitrified-clay pipe (right)

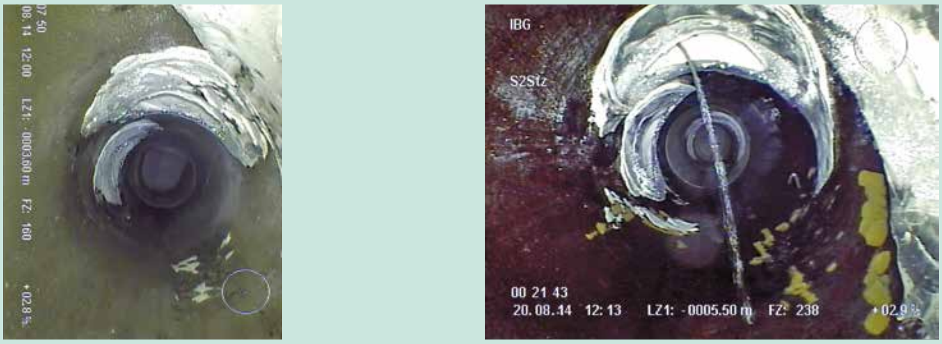


Figure 8: The poorest-graded lateral connection for the „Functionality" criterion, after HP cleaning in each case; concrete pipe (left); vitrified-clay pipe (right)

Five of the thirty-six lateral connections (approx. 14 %) exhibited abnormalities in the form of moisture. A risk is therefore present here and further observation of these lateral connections would appear advisable in practice.

Figure 6 Photographs A-F show examples of evaluations of lateral repairs after long-term groundwater simulation.

Functionality

No significant differences were apparent for the Functionality criterion between the repairs on concrete pipe (average overall grade: 2.5) and vitrified-clay pipe (average overall grade: 2.6). Significant differences were observed between the various contractors with grades varying from 1.9 to 3.6. Four were graded GOOD, one SATISFACTORY and one ADEQUATE.

Only minimal variations in the grades, by a maximum of 0.2 points, occurred after HP cleaning. As with the lateral reconnection scenarios, the rehabilitation of Damage Scenario I, involving a 45° angle to the longitudinal axis and influx of groundwater (Figure 2), proved to be the most difficult exercise for the majority of contractors. There were no significant differences in the case of Damage Scenarios II and III.

Examples of evaluations of lateral repairs against the Functionality criterion are shown in Figures 7 and 8 for the best and poorest results after HP cleaning in the concrete and the vitrified-clay main sewer pipes.

The contractors' quality assurance arrangements were found to be predominantly good and as with the lateral re-connections only a few points were criticised. All results are compiled in Table 4.

Conclusion

Lateral connection rehabilitation is reliably possible

The contractors participating in this IKT Product Test demonstrated that reliable sealing of lateral connections is possible, both in the „Lateral reconnection to a liner-rehabilitated main sewer" and in the „Lateral connection repair in a non-rehabilitated main sewer" cases. However, the range of performance across the contractors is extremely broad, from VERY GOOD to DEFICIENT.

Market reactions

It is surprising that only two of the ten manufacturers and eleven of the fifty-two rehabilitation contractors approached, were prepared to participate in this Comparative Test. This may, in part, be due to time and availability constraints, but IKT did offer a wide range of dates for installation. Many companies were unwilling to confront the rehabilitation tasks presented, and instead criticised the test conditions. This is despite these testing conditions being designed in agreement with the members of municipal sewer network operator steering commitee, to be extremely practically orientated and based on many years of on-site experience.

Groundwater useful for quality control

Where the rehabilitation results from the tests indicated a good quality immediately after completion of the rehabilitation, no new quality deficiencies were generally observed after long term exposure to groundwater and after HP cleaning. The practical conclusion to be drawn is that acceptance inspection should best be performed only when groundwater is present. If no infiltration is then apparent at the lateral connection, the rehabilitation/repair work can be assumed with high probability to have been successful.

Lateral reconnection and lateral connection repair achieve similar results

Despite the serious differences between the contractors on rehabilitation quality, the results they achieved for the two applications studied were very similar.

Sewer cleaning has no particular influence on performance

No abnormalities were found in the non-rehabilitated main sewer (lateral connection repair) after completion of the HP sewer cleaning test. Spalling was observed in many cases in the liner-rehabilitated main sewer (lateral reconnection), but these instances would have no significant effects on the leak tightness and functionality of the rehabilitated lateral connections.

Further tests being prepared

Equipment manufacturers and rehabilitation contractors showed great interest in the definitive quality requirements of the municipalities from the development phase of the test programme onwards. The test programme devised for this project and now made generally available, provides for the first time a set of comparative product tests for the „Lateral connection rehabilitation in groundwater zones" application. These now form the basis for the award of IKT's „Lateral reconnection" and „Lateral connection repair" Product Test seals.

Test report for download

The detailed test report is available (German version only) on the Internet for free-of-charge download, see:
www.ikt.de/downloads/warentest-berichte

The Authors

Dipl.-Ing. (FH) Serdar Ulutaş, MBA,
Prof. Dr.-Ing. Bert Bosseler
Dipl.-Ök. Roland W. Waniek
IKT – Institute for Underground Infrastructure

Table 3. Results, Case 1: Lateral reconnection to a liner-rehabilitated main sewer

IKT Comparative Product-Test of repair methods for lateral connections

Rehabilitation task: Rehabilitation of three damage scenarios in each case in a liner-rehabilitated concrete main sewer (DN 300)

- Damage Scenario I: "Defective (leaking) sewer connection" at the side zone of the main sewer (45° angle to/in the main sewer's longitudinal axis); DN 150 vitrified-clay pipe is presented up to the concrete pipe (main sewer); influx of groundwater at start of rehabilitation
- Damage Scenario II: "Defective (leaking) sewer connection" at the crown of the main sewer (90° angle to the longitudinal axis of the main sewer); DN 150 vitrified-clay pipe is inserted into the concrete pipe (main sewer) at a distance from the CIPP liner of approx. 2 cm
- Damage Scenario III: "Defective (leaking) sewer connection" between side zone and crown of the main sewer (45° bend outgoing perpendicular to the longitudinal axis of the main sewer): DN 150 vitrified-clay pipe is inserted (to approx. half wall thickness of the concrete pipe) into the concrete pipe (main sewer)

Contractor	**Kuchem GmbH**	**KATEC Kanaltechnik Müller & Wahl GmbH**	**Swietelsky-Faber GmbH Kanalsanierung**	**PLITT-ROHRSANIERUNGS-GESELLSCHAFT mbH**	**Onyx Rohr- und Kanal-Service GmbH**	**IBG HydroTech GmbH[1]**
Robot-based method using • Resin system	KA-TE PMO with • EPOXONIC Ex 1824 rapid	KA-TE PMO with • EPOXONIC Ex 1013 • EPOXONIC Ex 1824 rapid • MC BAUCHEMIE Konodur Robopox 10	KA-TE PMO with • resinnovation Harz 10	KA-TE PMO with • Sika Robotec 61	KA-TE PMO with • EPOXONIC Ex 1355 • EPOXONIC Ex 1824 rapid	IBG HydroCut injection system with • EPOXONIC Ex 1824 rapid
IKT test results	**VERY GOOD (1.5)**	**GOOD (1.6)**	**GOOD (2.0)**	**GOOD (2.3)**	**ADEQUATE (3.9)**	**DEFICIENT (5.0)**
System tests in test lengths (85 %)	**Good (1.6)**	**Good (1.8)**	**Good (2.0)**	**Good (2.5)**	**Adequate (4.0)**	**Inadequate (5.6)**
Functionality[2] (50 %)	**2.2**	**2.1**	**2.2**	**1.7**	**3.2**	**5.1**
after completion (20 %)	2.2	1.9	2.1	1.6	3.2	5.1
after HP cleaning (80 %)	2.2	2.2	2.2	1.7	3.2	5.1
Tightness[3] (50 %)	**1.0**	**1.4[4]**	**1.8**	**3.3**	**4.8**	**6.0[4]**
Short-term groundwater exposure 2.0 m (20 %)	1.0	1.0	1.0	2.5	4.0	6.0
Long-term groundwater exposure 2.0 m (80 %)	1.0	1.5	2.0	3.5	5.0	6.0
Quality assurance[5] (15 %)	**Very Good (1.0)**	**Very Good (1.0)**	**Good (2.0)**	**Very Good (1.0)**	**Satisfactory (3.0)**	**Good (2.0)**
Process manual (20 %)	+	+	+	+	+	+
Operator training (20 %)	+	+	+	+	-	+
Test certificates for materials used (20 %)	+	+	- (no DIBt approval)	+	+	+
Third-party supervision (20 %)	+	+	+	+	+	-
No particular abnormalities (20 %)	+	+	+	+	- (Material use-by date expired)	+
Additional information: Impression from on-site investigations	Practically-orientated implementation	Practically-orientated implementation	Practically-orientated implementation	Practically-orientated implementation	No date possible	No date stated
External water-pressure load 4.50 m	6x no problem	4x no problem, 1x infiltration, 1x not evaluated	4x no problem, 2x discoloration/moisture	4x no problem, 2x discoloration/moisture	2x no problem, 3x infiltration, 1x discoloration/moisture	5x infiltration, 1x not evaluated
Internal pressure testing at 0.5 bar after completion of the test programme and opening	5x tight, 1x not tight	3x tight, 1x not tight, 2x not evaluated	3x tight, 3x not tight	2x tight, 3x not tight, 1x not evaluated	3x tight, 3x not tight	5x not tight, 1x not evaluated
Visually apparent abnormalities from HP cleaning (max.)	6 abnormalities	3 abnormalities	No abnormalities	3 abnormalities	1 abnormality	No abnormalities
Year of manufacture of robot	approx. 1997	approx. 2008	2011	not known	approx. 1992	approx. 2012
Days of use on site	2,5 days	3.5 days	3 days	3.5 days	4.5 days	4.5 days
Time needed for rehabilitation (cutting) of 6 lateral connections (ca.)	9.3 hours (7.1 hours)	13.0 hours (4.6 hours)	16.5 hours (7.6 hours)	15.8 hours (11.0 hours)	21.1 hours (7.3 hours)	26.8 hours (3.8 hours)[6]
Material consumption for 6 lateral connections (ca.)	30 kg	34 kg	32 kg	41 kg	32 kg	27 kg
Costs per lateral connection (net)/ depot (ca.)	670 €/ NRW	810 €/ NRW	880 €/ NRW	630 €/ Lower Saxony	650 €/ Lower Saxony	440 €/ Hesse

1 All cutting work was performed by contractor Horst Drzysga; this company also supplied the equipment for further work.
2 Evaluation using visual assessment by municipalities by means of award of grades (1-6); decimal places permissible (20 % weighting after completion; 80 % weighting after HP cleaning)
3 Evaluation on the basis of external water-pressure exposure. Grades awarded by points: No infiltration 0/green; Problems – 0.5/yellow; Perceptible infiltration – 1.5/red. 0 points = 1.0; 1 point = 2.0; 2 points = 3.0; 3 points = 4.0; 4 points = 5.0; above 5 points = 6.0
4 Damage Scenario 2, NF lined pipe,, not evaluated due to cracking in connecting sewer (causes not clearly apparent)
5 Evaluation: "+"= demonstrated; "-"= deficient; Approval/Certificates/Analyses must apply to the materials used in the test
6 Three lateral connections were injected a second time

Evaluation key for test results: Very Good = 1.0 - 1.5. Good = 1.6 - 2.5. Satisfactory = 2.6 - 3.5. Adequate = 3.6 - 4.5. Deficient = 4.6 - 5.5. Inadequate = 5.6 - 6.0

Table 4. Results, Case 2: Lateral connection repair in a non-rehabilitated main sewer
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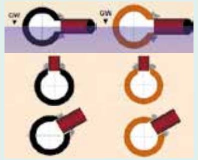

Rehabilitation task: Rehabilitation of three damage scenarios in each case in a non-rehabilitated concrete and non-rehabilitated vitrified-clay main sewer (DN 300)

- Damage Scenario I: "Defective (leaking) sewer connection" at the side zone of the main sewer (45° angle to/in the main sewer's longitudinal axis); DN 150 vitrified-clay pipe is presented up externally to the concrete/vitrified-clay pipe (main sewer). Groundwater influx at start of rehabilitation
- Damage Scenario II: "Defective (leaking) sewer connection" at the crown of the main sewer (90° angle to the main sewer's longitudinal axis); DN 150 vitrified-clay pipe is inserted to half the sewer's wall thickness into the concrete/vitrified-clay pipe (main sewer)
- Damage Scenario III: "Defective (leaking) sewer connection" between side zone and crown of the main sewer (45° angle outgoing perpendicular to the main sewer's longitudinal axis); DN 150 vitrified-clay pipe is inserted into the concrete/vitrified-clay pipe (main sewer); max. inward projection: 1 cm

Contractor	KATEC Kanaltechnik Müller & Wahl GmbH	Kuchem GmbH	PLITT-ROHRSANIERUNGS-GESELLSCHAFT mbH	Swietelsky-Faber GmbH Kanalsanierung	Geiger Kanaltechnik GmbH & Co.KG	IBG HydroTech GmbH[1]
Robot-based method using • Resin system	KA-TE PMO with • EPOXONIC Ex 1824 rapid • MC BAUCHEMIE Konodur Robopox 10	KA-TE PMO with • EPOXONIC Ex 1824 rapid	KA-TE PMO with • Sika Robotec 61	KASRO with • MC BAUCHEMIE KonudurRobopox CI	KA-TE PMO with • EPOXONIC Ex 1824 rapid	IBG HydroCut injection system with • resinnovation Harz 10
IKT test result	**GOOD (1.6)**	**GOOD (1.6)**	**GOOD (2.2)**	**SATISFACTORY (2.7)**	**SATISFACTORY (3.2)**	**ADEQUATE (4.5)**
System tests in test lengths (85 %)	**Good (1.7)**	**Good (1.7)**	**Good (2.4)**	**Satisfactory (2.8)**	**Satisfactory (3.5)**	**Deficient (4.7)**
Functionality[2] (50 %)	**2.4**	**2.0**	**1.9**	**2.2**	**3.1**	**3.6**
after completion (20 %)	2.3	1.9	1.9	2.1	3.0	3.5
after HP cleaning (80 %)	2.4	2.0	1.9	2.2	3.1	3.7
Tightness[3] (50 %)	**1.0**	**1.5**	**3.0**	**3.5**	**4.0**	**5.8**
Short-term groundwater exposure 2.0 m (20 %)	1.0	1.5	3.0	3.5	4.0	5.0
Long-term groundwater exposure 2.0 m (80 %)	1.0	1.5	3.0	3.5	4.0	6.0
Quality assurance[4] (15 %)	**Very Good (1.0)**	**Very Good (1.0)**	**Very Good (1.0)**	**Good (2.0)**	**Very Good (1.0)**	**Satisfactory (3.0)**
Process manual (20 %)	+	+	+	-	+	+
Operator training (20 %)	+	+	+	+	+	+
Test certificates for the materials used (20 %)	+	+	+	+	+	- (no DIBt approval)
Third-party supervision (20 %)	+	+	+	+	+	-
No particular problems (20 %)	+	+	+	+	+	+
Additional information: Impression from on-site investigations	Practically-orientated implementation	Practically-orientated implementation	Practically-orientated implementation	Practically-orientated implementation	Practically-orientated implementation	No date stated
Internal-pressure test at 0.5 bar after completion of the test programme and opening	6x tight	6x tight	4x tight, 2x not tight	5x tight, 1x not tight	5x tight, 1x not tight	2x tight, 4x not tight
Year of manufacture of robot	approx. 2008	approx. 1997	Not known	2012	approx. 2003	approx. 2013
Days of use on site	4 days	2 days	3 days	2 days	2 days	4 days
Time needed for rehabilitation (cutting) of 6 lateral connections (ca.)	7.8 hours (3.2 hours)[5]	5.4 hours (2.6 hours)	11.3 hours (5.0 hours)	13.8 hours (8 hours)[6]	9.2 hours (3.7 hours)[6]	11 hours (4.6 hours)[7]
Material consumption for 6 lateral connections (ca.)	24 kg	16 kg	48 kg	55 kg	28 kg	22 kg
Costs per lateral connection (net)/ depot (ca.)	720 €/ NRW	670 €/ NRW	700 €/ Lower Saxony	920 €/ NRW	830 €/ NRW	440 €/ Hesse

1 The complete repair scope was performed by IBG. Use was made of equipment supplied by the Horst Drzysga company only for the cutting work.
2 Evaluation based on visual assessment by municipalities by means of award of grades (1-6). Decimal places permissible (20 % weighting after completion; 80 % weighting after HP cleaning)
3 Evaluation on the basis of external water-pressure exposure. Grades awarded by points: No infiltration 0/green; Problems – 0.5/yellow; Perceptible infiltration – 1.5/red. 0 points = 1.0; 1 point = 2.0; 2 points = 3.0; 3 points = 4.0; 4 points = 5.0; above 5 points = 6.0
4 Evaluation: "+"= demonstrated; "-"= deficient; Approval/Certificates/Analyses must apply to the materials used in the test
5 One lateral connection was injected a second time
6 Two lateral connections were injected a second time
7 Five lateral connections were injected a second time

Evaluation key for test results: Very Good = 1.0 - 1.5. Good = 1.6 - 2.5. Satisfactory = 2.6 - 3.5. Adequate = 3.6 - 4.5. Deficient = 4.6 - 5.5. Inadequate = 5.6 - 6.0.

neutral
independent
non-profit institute

IKT - Institute for Underground Infrastructure

ABOUT IKT

IKT - Institute for Underground Infrastructure is a research, consultancy and testing institute specialized in the field of sewers. It is neutral and independent and operates on a non-profit basis. It is oriented towards practical applications and works on issues surrounding underground pipe construction. Its key focus is centred on sewage systems. IKT provides scientifically backed analysis and advice.

IKT has been established in 1994 as a spin-off from Bochum University, Germany.

The initial funding for setting up the institute has been provided by the Ministry for the Environment of the State of North-Rhine Westphalia, Germany's largest federal state.

However, IKT is not owned by the Government. Its owners are two associations which are again non-profit organizations of their own:

a) IKT-Association of Network Operators:
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b) IKT-Association of Industry and Service:
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You can find information on projects and services at:
www.ikt-online.org

IKT – Institute for Underground Infrastructure

Exterbruch 1
45886 Gelsenkirchen
Germany

phone: +49 209 178060
fax: +49 209 17806-88
email: info@ikt.de

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ca. 30 min. off Düsseldorf
International Airport.

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