TESTING TOP HAT LINERS AND ROBOTIC SYSTEMS FOR REPAIR OF LATERAL CONNECTIONS

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ABSTRACT

The objective of a IKT-Product-Test is, starting from the requirements of the sewage network operators, to examine canalisation technology products during the construction and operating stage. A comparative evaluation of the products gives the network operators a reliable basis for future investment decisions. Construction and operational experiences of the network operators as well as scientific perceptions by the IKT are the starting point of the tests. The IKT carried out the IKT-Product-Test "Repair methods for lateral connections" together with 26 network operators in 2003. Seven robotic systems and six top hat liners were tested and evaluated in comparison. The results of the tests, which were concluded in 2004, are represented as follows.

Concept of the IKT-Product-Test

The objective of the IKT-Product-Test is to provide network operators with reliable and independent information on the properties of commercial products. Such information has been almost completely missing for the pipeline construction and rehabilitation area until now. The clients attain information on product characteristics almost exclusively from advertisements and the offerers' brochures, who try to convince potential customers of the alleged quality of a product.

A central aspect of the IKT-Product-Test is the practical product quality evaluation, e.g. under operating conditions. The focus of the examinations is not the compliance with individual standards or bodies of rules and regulations, but the reliable fulfilment of network operator requirements during construction and operation. The service life under the expected conditions and loads, such as e.g. groundwater, earth pressures, volume of traffic or high-pressure cleaning, are the focus of attention. As a result the network operators are provided with independent, practice-related, and technically well-founded information concerning the strengths and weaknesses as well as areas of application and limits of the tested products.

IKT-Product-Test „Top hat liners and robotic systems“

Numerous procedures for repairing lateral connections are available on the market. However the quality of these technologies has not been comparatively tested until now. Sewage network operators are therefore frequently uncertain, which technologies are suitable for application in their sewer systems. This is why 26 sewage network operators from the cities Ahlen, Alsdorf, Beckum, Bergisch Gladbach, Braunschweig, Dinslaken, Dortmund, Düsseldorf, Espelkamp, Essen, Gladbeck, Hamburg, Hamm, Hemer, Hilden, Iserlohn, Kamen, Kempen, Monheim am Rhein, Neuss, Mönchengladbach, Recklinghausen, Rietberg, Troisdorf, Tönisvorst and Warendorf participated in the IKT-Product-Test "Repair methods for lateral connections" [1]. Seven robotic systems and six top hat liners were tested and comparatively evaluated.

Robotic systems:

- DSS-Flex, DiTom-Kanaltechnik GmbH
- Hächler grouting system, Hächler AG Umwelttechnik
- IMS injection method, IMS GmbH
- Janssen lateral rehabilitation system, Umwelttechnik Franz Janßen GmbH
- KA-TE formwork collar, KA-TE System AG
- Kasro injection sealing system, ProKasro Mechatronic GmbH
- Strobel concrete method, Umwelttechnik Strobel GmbH

Top hat liners:

- Houseliner top hat liner, KMG GmbH
- Top hat liner for DS CityLiner, D & S Rohrsanierung GmbH & Co. KG
- IMS-Top hat liner method, IMS GmbH
- Insituform top hat liner , Insituform Rohrsanierungstechniken GmbH
- Kasro laminated cap placement system, Prokasro Mechatronic GmbH
- Pyrolus system, PKT GmbH & Co. KG

The product test was closely followed by the 26 sewage network operators. A total of seven meetings took place, in which all test contents were co-ordinated, i.e. from the test programme to the evaluation. The main focus was on three tests: Process offerer quality assurance, system tests and construction site investigations.

Process offerer quality assurance

Basic requirement for the use or application of the repair procedure is a process description of the offerer, e.g. in a procedures manual. The process application and application possibilities should be described. The qualification of the implementing personnel can take place via training courses, in which theoretical fundamentals are discussed and the practical application of procedures in sewer sections is practised. The process offerer should ensure the quality of his method by practical examinations, e.g. a test application in sewers with following examination of the impermeability of the executed repairs. A construction supervision process approval by the Deutsche Institut für Bautechnik (DIBt) can ensure the quality. The repair methods should also be available on the market with a qualified external supervision.
Procedure manuals or descriptions are mostly available from the offerers of the tested robotic systems and top hat liners. Training courses are also carried out or offered by most of the offerers of the tested methods. A construction supervision approval by the DIBT was however not submitted for any of the robotic systems and only by one offerer of the top hat liners. The majority of the robotic system offerers

verified that their method is available on the market with external supervision; this verification was only furnished by one top hat liner offerer.

System tests

The repair must significantly improve the operability of the defective lateral connection; the disposal reliability must be restored after the repair, resulting in an improved effluent drainage. Pipe and soil subsidence are prevented and there is no imminent danger of obstruction in the range of the lateral connection. The repair must seal the lateral connection; leakages may therefore not be caused by rising groundwater. A sufficient hardiness must be ensured opposite usual operational stresses - in particular high-pressure cleaning.
Sewer sections with defined applied damages were assembled on the grounds and on a large-scale test stand (6m x 6m x 15m) of the IKT (Figure 1) for the system tests. The network operators also selected different damage types and in part different pipe materials or pipe diameters for testing the robotic systems and top hat liners on account of the different areas of application of these two methods. The repair of so-called standard damages and so-called extreme damages were differentiated in principle. The top hat liners were examined exclusively as a "special test", i.e. as a repair method for lateral connections in a non-rehabilitated old pipe and not in main sewers rehabilitated by relining.

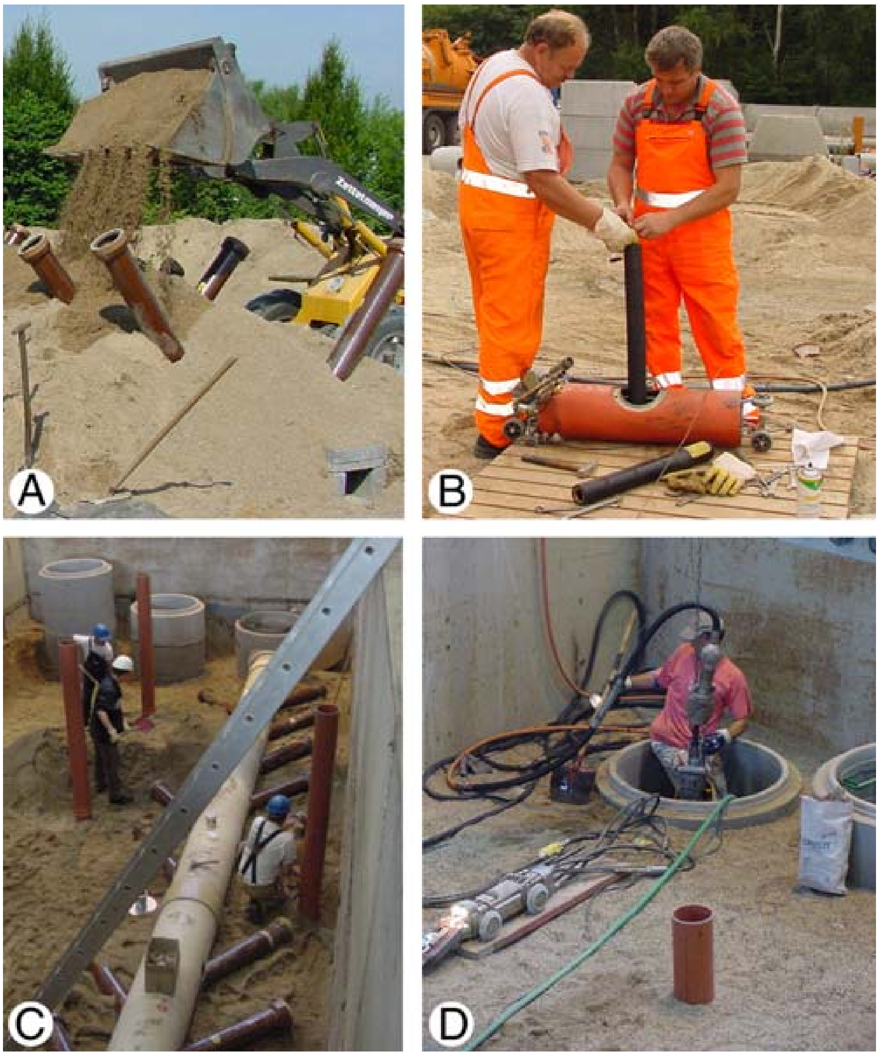

Figure 1. Test section construction and repair execution. **A** Construction of the outdoor sections. **B** Preparations for repairing the outdoor sections. **C** Test section construction on the large-scale test stand (6m x 6m x 15m). **D** Repair execution on the large-scale test stand.

The following conditions and damages were defined by the network operators for the investigation of the robotic systems and top hat liners:

Robotic systems in the case of standard damage:
Unprofessionally installed lateral connection with strong borehole damage due to cracking and shard formation in a stoneware pipe DN 250 with stoneware connecting pipes DN 150 (see Figure 2 A).

Robotic systems in the case of extreme damage:
Unprofessionally installed lateral connection with strongly bent connecting pipe as well as a longitudinal crack in the connecting pipe and entering groundwater in a concrete pipe DN 300 with stoneware connecting pipes DN 150 (see Figure 4 A).

Top hat liners in the case of standard damage:
Unprofessionally installed lateral connection with strong borehole damage due to shard formation in a stoneware pipe DN 250 with stoneware connecting pipes DN 150 (see Figure 3 A).

Top hat liners in the case of extreme damage:
Unprofessionally installed lateral connection with bent connecting pipe as well as a longitudinal crack in the connecting pipe in a GRP-pipe DN 500 with stoneware connecting pipes DN 150 (see Figure 5 A).

The respective standard damages were used for the examination of the general application possibilities of the robotic systems and top hat liners; the respective extreme damages were used for the examination of the application under extreme conditions. The network operators also selected the GRP-pipe for the top hat liners because some of the test results can also possibly be used as reference points for the application of top hat liners in sewers rehabilitated with inliners.
The prepared damages were repaired in the appropriate test sections with the chosen methods. The participating network operators then assessed the re-establishment of the lateral connection operability by visual impression of the repairs. The respective standard damages were repaired visually satisfactory with the robotic systems and top hat liners (Figure 2 and Figure 3). Only three offerers could visually satisfactory repair the extreme damages foreseen for robotic systems (Figure 4). This can among other things be attributed to the applied technology. Some methods were e.g. not able to seal pipes connected in an acute angle with the inflatable piston or ballon for sealing the connecting pipe. The extreme damages for the top hat liners were only repaired visually satisfactorily by two offerers (Figure 5). Numerous repairs of the respective extreme damages were not visually satisfactory. The repair even worsened the condition of the lateral connections in some cases (Figure 6). In nearly all cases the top hat liner resin impregnation was only accomplished manually (Figure 7 A). A complete top hat liner surface impregnation cannot therefore be ensured. Only one offerer vacuum impregnated the top hat liner, thereby promoting complete impregnation (Figure 7 B).

Figure 2. Standard damage for robotic systems and example of a visually satisfactory repair result. **A** Initial situation. **B** View from the main pipe. **C** View into the connecting pipe.

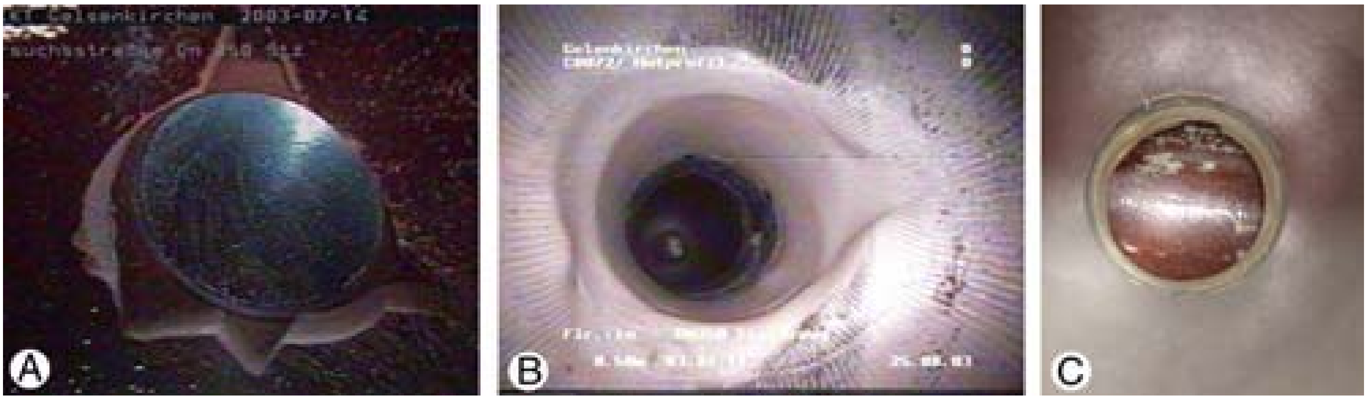

Figure 3. Standard damage for top hat liners and example of a visually satisfactory repair result. A Initial situation. B View from the main pipe. C View into the connecting pipe.

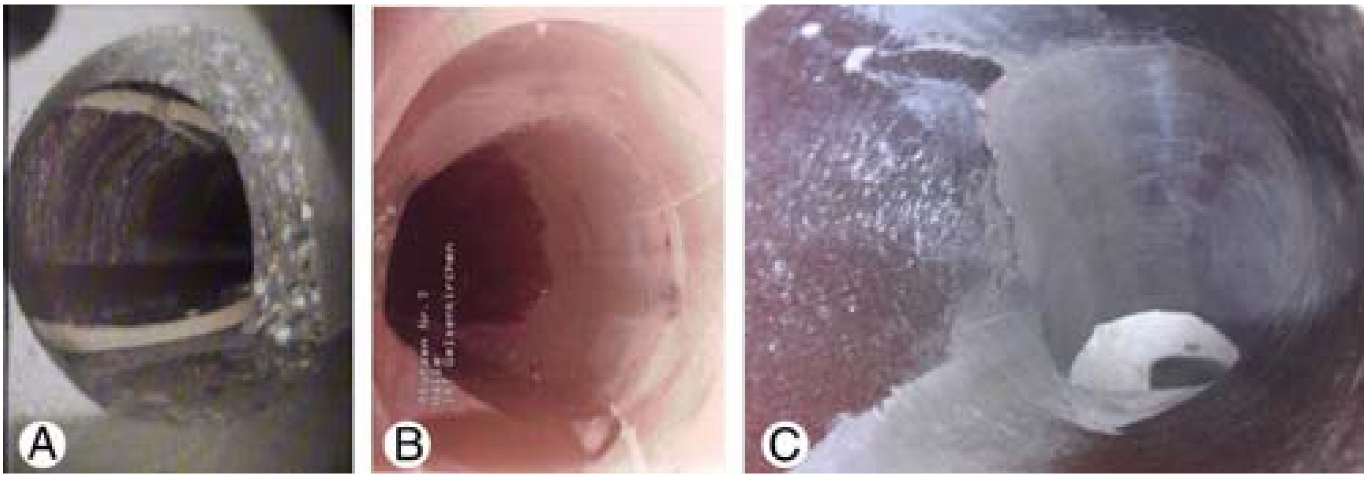

Figure 4. Extreme damage for robotic systems and example of a visually satisfactory repair result. **A** Initial situation. **B** View from the main pipe. **C** View into the connecting pipe.

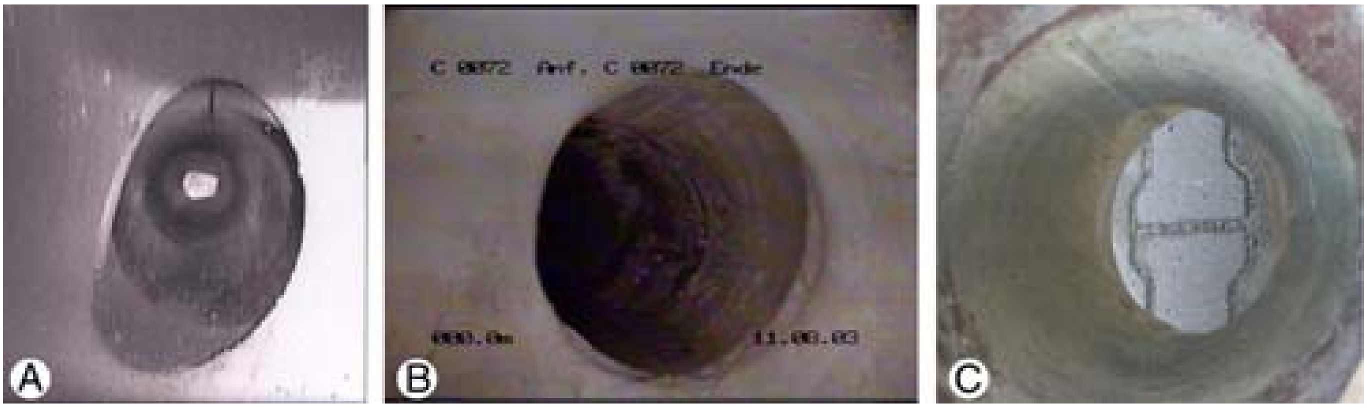

Figure 5. Extreme damage for top hat liners and example of a visually satisfactory repair result. **A** Initial situation. **B** View from the main pipe. **C** View into the connecting pipe (after disassembly).

Figure 6. Examples of visually unsatisfactory repair results on extreme damages **A** Robotic system - view from the main pipe. **B** Top hat liner - view from the main pipe. **C** Top hat liner - view into the connecting pipe (after disassembly).

Figure 7. Top hat liner resin impregnation **A** Only manual resin impregnation. **B** Vacuum resin impregnation.

High-pressure flushing was carried out after repair to simulate operational stresses. The exposure to high-pressure flushing with added granulates resulted in strong abrasion and in part to the separation of material from the old pipe at numerous repair locations. The collar of numerous top hat liners, which is located against the inner wall of the main pipe, was damaged. The connection between top hat liner and old pipe was impaired in part, so that the collar was detached from the inner wall of the pipe. High-pressure cleaning often caused injection body parts situated in the main pipe to flake in the case of lateral connections which had been repaired with robotic systems. Larger breakages were also partly ascertained.

Waterproof testing with exterior and interior water pressure was carried out immediately after the repair. A renewed examination of the leak was carried out with interior water pressure after high-pressure flushing stress. Figure 8 summarises these leak test results. Altogether 21 standard or extreme damages were repaired with robotic systems and 12 and/or 15 damages were repaired with top hat liners. In the case of robotic systems applied to repair extreme damages only 17 of 21 leak tests were considered in the final evaluation because an influence of later repairs at other locations could not be excluded with regard on four connections.

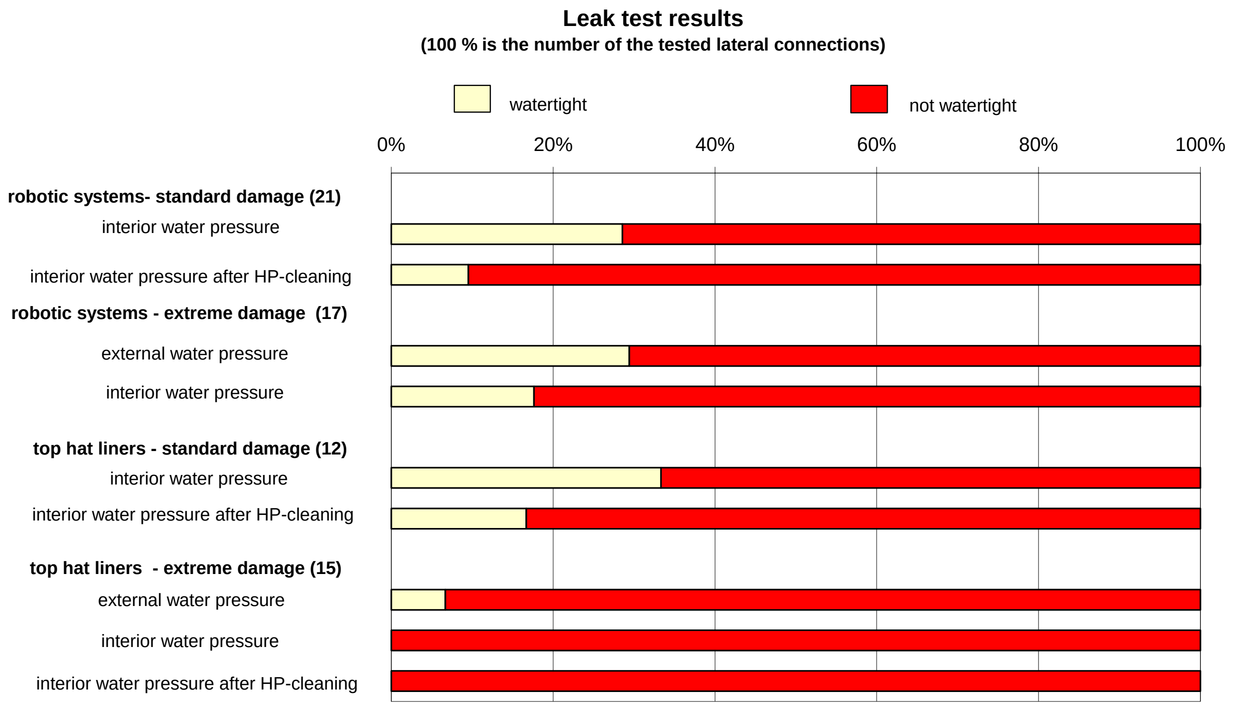

Figure 8. Leak test results

The majority of the repairs leaked during the external and/or internal water pressure leak tests. Leakages were ascertained in over 70% of the standard damage lateral connections repaired with robotic systems and in almost 70% of the standard damage lateral connections repaired with top hat liners at an interior water pressure of 0,1 bar. Over 70% of the extreme damage lateral connections repaired with robotic systems leaked at an external water pressure at pipe crown level; over 80% of the connections leaked during application of interior water pressure. Over 90% of the top hat liners, with which extreme damages were repaired, leaked under external water pressure (50 cm over pipe crown) and 100% with application of interior water pressure. The high-pressure flushing of the repair locations resulted in leaking lateral connections, even though they were impermeable immediately after repair.

Construction site investigations

The application of all repair methods of the test in present sewage systems was accompanied on construction sites. The construction site investigations recorded the manageability of the method under in-situ-conditions (traffic, weather, time pressure).

The general impression when carrying out repairs during the construction site investigations was basically positive. The construction site method application was trouble-free, apart from some occurring technical difficulties, which were remedied on-site. This is also due to the overall high qualification of the implementing personnel. This impression corresponds with the statements of the questioned technicians,

who normally confirmed comprehensive training courses and many years of experience with regard to the respective method.
The top hat liners installed on construction sites were mostly foreseen to connect connecting pipes to main pipes already rehabilitated with inliners. Only two top hat liners were used to repair lateral connections in non-rehabilitated old pipes. The top hat liner resin impregnation method was also carried out nearly completely manually on the construction sites. Most of the robotic systems were used to repair lateral connections in non-rehabilitated old pipes. Some robotic systems were however used to connect connecting pipes to main pipes, which had been rehabilitated with inliners or part liners.
The visual impression of the repair results during construction site investigations was considered to be overall positive. This permits the conclusion that the operability (e.g. no imminent danger of obstruction) of the lateral connections was clearly improved by the respective repair measure, whereby this evaluation refers to the results evident during camera passage through the main pipe. The repaired lateral connections were normally not checked for impermeability.

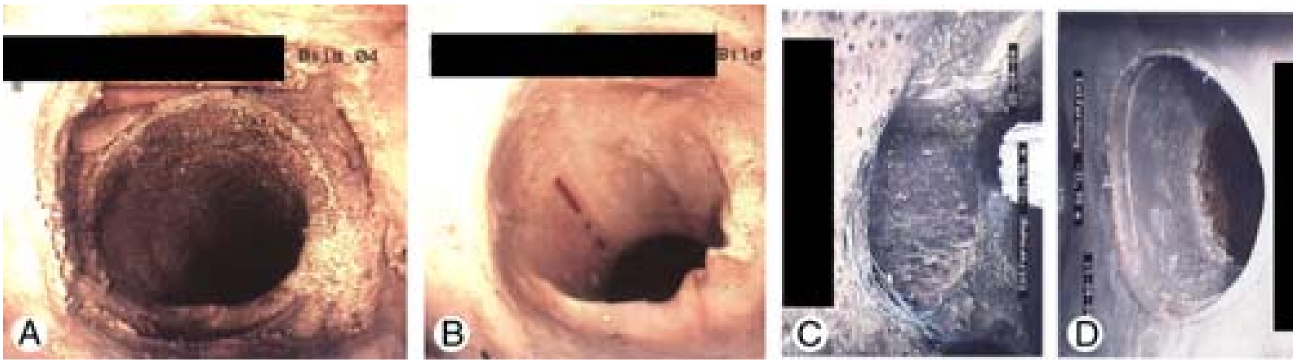

Figure 9. Repair results of construction site investigations. **A** Initial situation before repairing with a top hat liner. **B** Repair result with top hat liner. **C** Initial situation before repairing with a robotic system. **D** Repair result after repairing with a robotic system.

Evaluation of the methods

A comparative evaluation of the methods was carried out on the basis of the test results and test findings were formulated. The formulation of the test findings took place using the quality assurance of the process offerers and system tests as investigation priorities. The quality assurance of the process offerers was evaluated by means of the four characteristics "Procedures manual and/or description", "Training courses", "Test certificates" and "External supervision". The characteristics "Repair of standard damages" and/or "Repair of extreme damages" and "Stress due to high-pressure flushing" were used to evaluate the system tests. The criteria "Operability (visual condition)" and "Impermeability" were each considered during these evaluations. The construction site investigation results were not taken into consideration for the test findings, since construction site conditions are not comparable.
All detailed results are represented in [1] and can be downloaded together with the score cards on the tested methods from **www.ikt.de**.

Conclusion

The IKT-Product-Test "Repair methods for lateral connections" permits the following basic conclusions:

- The repair results are normally not comparable to those of a new construction. Many of the tested methods do not fulfil the test requirements. The lateral connections were mostly permeable immediately after the repair, and nearly always after high-pressure flushing. High-pressure flushing stress with added granulate partly resulted in substantial damage to the repairs. The repair could often not restore the disposal reliability of the lateral connection, particularly in the case of so-called extreme damages and/or the repair even worsened the condition (e.g. imminent danger of obstruction by formation of wrinkles and edges).

- The impermeability of the repaired lateral connections can under no circumstances only be ascertained by visual impression. Numerous repairs leaked during the test despite a visually satisfying condition. Leak tests can however only be carried out in sewage systems with substantial expenditure. The significance of the tests is furthermore reduced, due to sources of error, e.g. discharge of the test media through the seals. The further development of impermeability test methods is therefore necessary.
- The repair result not only depends on the type of damage, but also on the adhesive characteristics of the used repair materials with the given pipe materials (concrete, stoneware etc.). Some robotic systems e.g. demonstrate better results when repairing extreme damages in concrete pipes than when repairing standard damages in stoneware pipes. This can be attributed to the adhesive characteristics of the used materials with regard to the respective pipe material.
- The process engineering conditions for the repair of defective lateral connections in closed constructions are basically given. The applied methods concerning so-called extreme damages demonstrated however the limits of the repair methods during the test. Both the qualification of the implementing technician and also the accomplished pre- and reworking (e.g. milling, high-pressure cleaning) have a substantial influence on the repair result.

The IKT-Product-Test "Repair methods for lateral connections" represents a comparative method evaluation by test findings. These test findings demonstrate the need for substantial repair method improvements. The test finding GOOD was only awarded once; the methods were predominantly evaluated with SATISFYING, SUFFICIENT and even DEFECTIVE (see [1]).

Final conclusion

The results the IKT-Product-Tests completed up to now [1, 2] confirm the need for evaluation of the offered sewer technology products in the context of comparative quality tests. The network operators are quickly and comprehensively informed on product quality by means of an understandable evaluation scheme and a test seal (see Figure 10). The most suitable method for the respective purpose can be selected from the many offers, thus reducing the investment risk.

The practical experiences of the network operators are vital for development of product tests. Exclusive conventional component tests are not sufficient, in order to verify the lasting quality of products, which will be used in the sewer for decades. Product tests can therefore result in a “Closed loop of product improvement”, which is in the interest of the network operators, if improvement potentials of the respective products are identified and documented for the manufacturer.

The complete edition of the final report on the IKT-Product-Test "Repair methods for lateral connections" can be downloaded from www.ikt.de free of charge.

Figure 10: Test seal

[1] Bosseler, B.; Kaltenhäuser, G.: IKT-Product-Test "Repair methods for lateral connections", IKT - Institute for Underground Infrastructure, by order of 26 network operators, 06/2004, download on www.ikt.de (in German).

[2] Bosseler, B; Kaltenhäuser, G; Puhl, R: IKT-Product-Test "Lateral connections", IKT - Institute for Underground Infrastructure, by order of 14 network operators, 06/2001, download on www.ikt.de (in German).