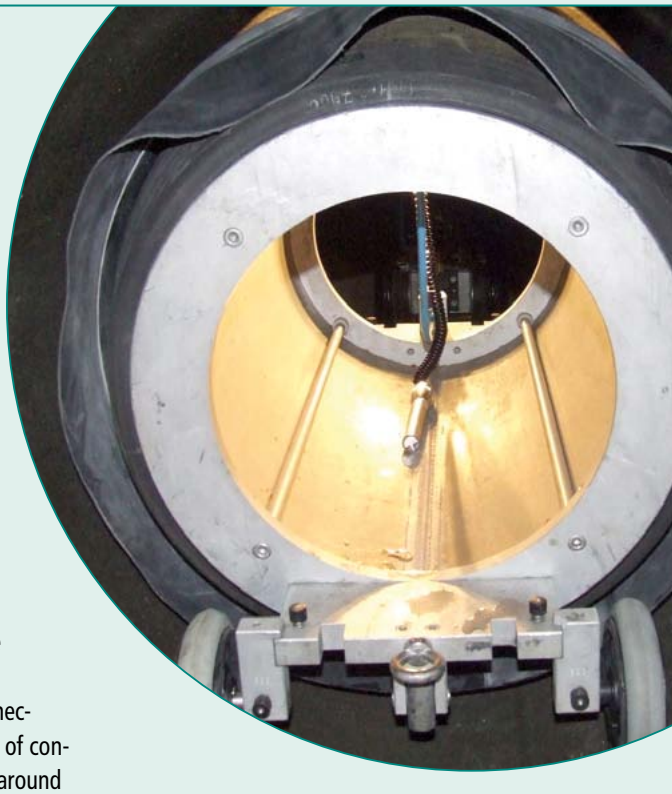
Repair of main drains and sewers

Experience from research and testing



Operators of waste-water systems at all times aim to achieve their refurbishing targets effectively and at the lowest possible cost. The advantage is with those who judiciously combine the various renovation and repair methods. New measuring systems now permit „before/after" comparisons, allowing the rational selection and combination of such methods. The necessary preparatory work is frequently neglected during on-site implementation, however. Repair procedures tested by IKT proved to be differingly immune to such application errors.

Background

There has, in the past, been significant uncertainty on the part of system operators concerning what the various repair methods can actually achieve, what quality can be attained, and what criteria need to be taken into account in tendering procedures, award of contract and on-site supervision. These techniques are used for the rapid, flexible and rational-cost repair of distributed damage, using a large bandwidth of procedures. The same also applies when renovation methods are implemented, since repair procedures are routinely used here for pre-sealing, reprofiling, connection of manholes and the integration of connecting lines. Throughout Germany, around 25 percent of drain/sewer damage is eliminated using specifically „repair" methods [2].

Figure 1: Repair methods in IKT projects: short-liners

The independent and impartial IKT - Institute for Underground Infrastructure has already tested repair methods, with the following focuses, in a large range of projects:

- Drain/sewer pipes: „Repair methods for DN 200 - DN 600 main drains" [15], Investigations into the adhesion properties of short-liners [16], Stability analysis of large-calibre drain/sewer sections [13], Investigations of behaviour under exposure to external water pressure/"infiltration tightness" [16, 11] (Figure 1)
- Waste-water manholes: Investigations of the repair of manhole covers [8, 9, 10] and into the repair of manhole structures using injection methods [12] (Figure 2)
- Laterals: Comparative product assessments in the IKT „Repair methods for sewer laterals" product test [14] (Figure 3)

The project results are examined below in more detail, with the focus on the repair of drain/sewer pipes in main drains and sewers. Questions concerning both walk-in and non-walk-in cross-sections, and concerning flexibility and service-lives are also discussed.

Figure 2: Repair methods in IKT projects: manhole sealing – injected polyurethane on the manhole exterior

Figure 3: Repair methods in IKT projects: Injection/pressure refurbishing on sewer laterals

Repair methods for DN 200 - DN 600 main drains and sewers in the IKT product test

Aims and methods examined

The aim of every IKT product test is that of achieving a comparative assessment of the quality of products and methods available on the market, of outlining potentials for improvement, and of simultaneously exerting corresponding market pressure, in order that the suppliers will actually make use of these potentials. The drain/sewer system operator, as the customer, specifies the quality requirements made on the products. A total of twenty-four system operators participated in the IKT "Repair methods for DN 200 - DN 600 main drains and sewers" comparative product test and provided intensive support in terms of subject matter and expertise.

Twelve different methods from the three method groups of "Injection/grouting/pressure methods", "Short-liners" and "Internal sleeves" were used and comparatively tested in the test lengths under defined and repeatable boundary conditions (Figures 4 to 6). All the results were published in [15] and [16], and are available for free-of-charge download at www.ikt.de (German version only).

Test programme

The test programme had three central emphases: the method suppliers' Quality Assurance (QA) provisions, system testing of the methods in the test lengths, and on-site assessments.

The "Quality Assurance" item quantified the extent to which the particular supplier supported high-quality refurbishing in the use of his repair method by means of systematic QA provisions, such as a method manual, training provisions for users, potentials for outside supervision, and supplementary test certificates.

The system tests submitted the repair methods to a comprehensive programme of testing in the test lengths, the prime focus being on the tightness, correct functioning and operational safety and reliability of the drain/sewer lengths refurbished. Both clay and concrete test lengths were used, and load-exposure situations approximating closely to practical conditions simulated.

In the case of the tests on short-liners and internal sleeves, in which the soil does not play a part in the refurbishing result, the test lengths were supported on the floor of the IKT testing facility (Figure 7). A wrapping consisting of EPDM rubber mats and steel strapping, and calculated using FEM models, was applied here at and around the points of damage in the case of the "Intact pipe bedding" situation. The test lengths for the injection/grouting/pressure methods were installed in steel containers with sand overcover (Figure 8), since these procedures in some cases involve the systematic injection into the surrounding soil of resin, which then solidifies ("cures"), with the inclusion of portions of the soil.

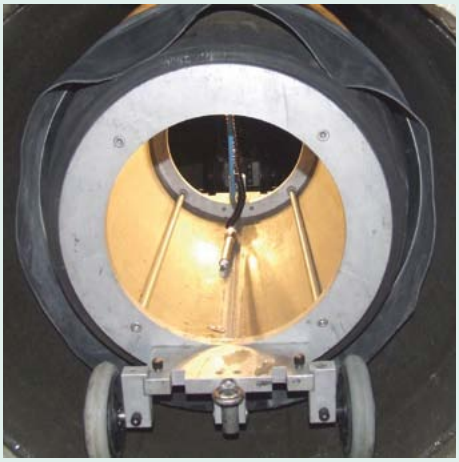


Figure 5: Internal sleeve under test: sleeve on the packer in the conduit

Figure 7: IKT Product Test „Repair methods for DN 200 - DN 600 main drains and sewers": Test apparatus for short-liners and internal sleeves

Figure 4: Pressure/grouting method under test: results of the grouting method

Figure 6: Pressure/grouting method under test: results of the grouting method

Figure 8: IKT Product Test „Repair methods for DN 200 - DN 600 main drains and sewers": Test apparatus for injection and grouting/pressure methods

High-pressure cleaning was selected as the critical operating load; all points of repair were exposed after completion to fifteen cleaning cycles.

The on-site tests served the purpose both of verifying the plausibility of the use of the repair methods in the test lengths and that of determining the practicability of these methods under on-site conditions (e.g. weather, time pressure).

Large spread of results

The overall picture of the repair results after completion of the refurbishing work was a positive one. Only very minor anomalies, which would have no significant influence on the correct functioning of the drain/sewer, were found. These included minimal losses of conduit cross-section resulting from the short-liner, sleeve and, in some cases, the injection processes themselves, and slight burring on the edges of the sleeves, with no flaring.

Traces of the cleaning action, ranging from only slight to significant, were apparent on many repaired points after high-pressure cleaning, however. In the case of the short-liners, the surface was generally slightly abraded (roughened), at least in the baseline area. In the case of individual short-liners, glass fibres were exposed on the surface, or spalling and/or cracking, primarily in the baseline area, had occurred. For the injection and grouting/pressure methods, spalling is generally of no consequence for the sealing action of the repair, but remnants of resin detached and/or projecting into the cross-section may also cause obstruction to fluid flow. The sleeves tested exhibited greatly differing results under exposure to HP flushing. In some cases, no deficiencies were observed, while in others the toothed racks of the locking wheels exhibited deficiencies with declining tensioning.

All the repaired points were tightness tested both immediately after completion and after simulation of operational loads with exposure to internal water pressure. The tightness tests relevant for the evaluation were conducted by means of visual inspection for the escape of water on the outer pipe side of the repaired point of damage after high-pressure flushing.

These methods manifested a large spread of results, depending on the product used. The effects of HP cleaning on the tightness of the repairs could, in all cases, be considered slight, however.

Suitability for practical use confirmed

The on-site tests in all cases confirmed the practicability of the methods tested. It was, however, also apparent that the work performed on site deviated in some cases from the method manuals. This can occur for time and cost reasons, due to differing quality standards set by the refurbishing contractors, or also as a result of work not specified - and therefore not paid for - by the client. This applies, in particular, to preparatory and support provisions, such as high-pressure flushing and mechanical deglazing, the non-performance of which is not immediately apparent when the result of repair is acceptance inspected.

Good standard of repair quality, depending on method

A high-quality repair result can, in principle, be achieved with either an injection or grouting/pressure method, or with a short-liner or an internal sleeve. The test also demonstrated that quality can fluctuate significantly between the individual methods of a particular group, however. Methods which were awarded the grades "Good" to "Sufficient" can be found in all the groups. The three methods which received only "Sufficient" were, however, also scarcely recommendable for practical use in the development status in which they were tested. The manufacturers in question themselves reacted immediately to the test results, with the consequence that these methods are no longer available in the form tested at IKT and/or that, according to information from the manufacturer, corresponding further development has been initiated.

Of particular technical informational value was the fact that refurbishing frequently generates extremely complex systems, consisting of the original pipe, the repair/refurbishing element, and the soil, with potential interactions between them. In addition, there is also a possibility of an alteration or even a spread of the damage under the influence of internal packer and/or sleeve pressures. Repairs must always be anchored in undamaged areas of the pipe. It appears recommendable to extend the repair beyond the adjoining bell sockets, particularly in the case of cracking in clay pipes and the danger of further crack propagation under exposure to internal pressure. The use of a short-liner of an appropriate length may therefore be a good option, particularly in the case of extensive ramified cracking. Where more extensive spalling has occurred, a sleeve or an injection/pressure method, or possibly also a combination of injection/pressure and short-liner, may be more suitable for the avoidance of bulging or leaks in the laminate as a result of inadequate counterpressure during curing.

Varying method robustness (surface preparation)

On-site implementation, and thus also relative immunity to execution errors, is the definitive factor in the quality of all these methods. There is in all repair methods the danger in principle that important operations may be shortened or even completely omitted on site, particularly preparatory and supporting work, such as HP flushing and mechanical deglazing, and allowance of the necessary, or maximum, curing times.

In all the methods based on repair resin products, the sealing function depends essentially on bonding between the resin and the pipe wall and its resistance to abrasion. The extent to which mechanical deglazing exerts a significant influence on the adhesion, tightness, operational reliability and durability of short-liners, and can thus be regarded as preparatory work necessary and therefore to be included in tendering documentation (see [5]) has been examined in detail in more extensive investigations [16], with the following conclusions being drawn:

- Removal of glaze from clay piping: The necessary tensile adhesions were generally not achieved on glazed clay surfaces, whereas extremely high adhesion data were attained on mechanically deglazed clay surfaces.
- Necessity of thorough cleaning and removal of corroded concrete: Residual grease has been proven to have a potentially significant influence on tensile adhesion in short-liner procedures, and must therefore be removed by means of thorough cleaning. Adequate tensile adhesion can be attained in corroded pipes only provided the defective concrete is removed until only undamaged concrete is left.
- Differences in the immunity ("robustness") of the methods/products: The tensile adhesion of the individual products, and their immunity to fluctuations in surface preparation, in particular, exhibited significant variations. Adequate tensile adhesions may be anticipated from all these products provided cleaning and surface preparation are sufficiently thorough, however.

These tests also confirmed the immunity of the methods to execution errors (in surface preparation, in this case) as a particular quality criterion. Similar circumstances are also known from manhole refurbishing, see [12].

Large-calibre conduits necessitate structure-analytical evaluation

Repair methods and structural analysis

Specific standardised calculation methods such as are known for renovation procedures, for example, are lacking in the case of repair methods (see [4]); deductions based on analogy, on the other hand, require special expertise (see [7]). As a consequence, a structure-analytical calculation is generally omitted in practice, or is not even expected (in the case of pipe joints, for example). Structure-analytical evaluation can, however, become a central concern and play a critical role in the refurbishing task and the selection of suitable methods, precisely in the case of large-diameter drains and sewers.

The situation becomes even more critical where the fact of "no proof" is interpreted as "no contribution" to stability at the competition stage: this fails to take account of the performance of injection methods, for example. In combination with renovation procedures, in particular, such repair methods can make a special contribution, since stability is determined not by the conduit alone, but instead, in every case, by the entire conduit/soil system. Typical interactions in the pipe trench, such as silo effects, vertical load division, support stresses and horizontal (bedding) reaction pressure, impressively reflect this.

The soil must then be regarded as part of the system fabric, and injection methods, in particular, can thus make a significant contribution to subsequent renovation work (such as sealing using a liner, for example), actually meeting the definition of "renovation" [6] – i.e., "Provisions for the improvement of the current functioning of waste-water conduits and drains involving the complete or partial inclusion of their original fabric".

Particular importance therefore attaches to the inclusion of the soil in overall planning and in any combination of repair and renovation methods. Both the original and the refurbished condition of the conduit/soil system should be recorded and evaluated, in order to permit a "before-and-after" assessment. New developments in structure-analytical evaluation are now available for this purpose.

New concepts for structure-analytical evaluation

Further development work is currently going on at IKT on a non-destructive test procedure, known as "MAC" and introduced by Eau de Paris, in order to close the gap in structure-analytical proofs prevailing up to now by means of systematic before-and-after tests. This procedure provides, by means of direct force/deformation measurements, substantiated information on the stiffness of the conduit/soil system, and thus the basis for a reliable assessment of stability and for checking of success, in the case, for example, of the use of injection methods (Figure 9). The technical concept and the applications for this procedure are described in detail in [1].

The main application for this procedure is for the identification of zones featuring defects or weakening of the supporting system consisting of the conduit and the surrounding soil. A special calculation algorithm, which has been tested on numerous practical examples, makes it possible to determine the extent to which the conduit, on the one hand, or the soil, on the other hand, contributes to overall stiffness or, conversely, exhibits weaknesses - thus a decisive contribution to the selection and combination of repair and renovation methods.

Figure 9: The MAC method: measurements of the system stiffness of the main drain/soil system

Flexibility vs. long-term solutions

The term "intergenerational equity" can, for our case, also be interpreted as: We should construct, operate and maintain our facilities and systems in such a way that the coming generation will have no problems with the consequences; our descendants should not find these consequences a burden, either in a technical or a financial sense. Repair methods can manifest special advantages in this context: clarity in the means used, systematic restorative action on the local damage scenario, and a residual flexibility to accommodate future developments. Judicious combination of renovation and repair methods then makes it possible to attain, cost-efficiently and with certainty, the technical targets, i.e., long-lasting stability, tightness and operational safety and reliability. In addition, repair methods, in particular, provide opportunities, even in case of the endangerment of these targets, to initiate appropriate immediate action during the planned period of service, while at the same time retaining the scheduled (re-)investment cycles at overall network and section level.

Conclusions

On an overall view, we are obviously confronted less with a problem of choosing between repair and renovation, or even with a contradiction between the two approaches, and more with the task of achieving the refurbishing aim effectively and at rational cost using a judicious combination of the various methods. Here, repair procedures make a decisive contribution, some with possible additional benefits for stability. In this context, we should note by way of summary:

Quality is decisive in practice: Installation necessitates high-quality preparatory work, such as mechanical deglazing and cleaning. In this respect, the methods and materials exhibit significant differences in their immunity to execution errors, with respect, for example, to the tensile adhesions achieved.

Recognition and registration of the structure-analytical contribution: Stability is a function of the behaviour of the entire conduit/soil system. Injection methods are capable of making a significant contribution to the structure-analytical improvement of this overall system. New measuring systems, such as "MAC", offer perspectives for before-and-after comparative assessments, and therefore for the economically rational selection and combination of refurbishing methods, particularly in the case of large-diameter conduits.

The criterion of flexibility: Cost appraisals have up to now generally only taken account of cash flows. The value of flexible selection of the time and place of refurbishing is generally not formally considered. This is where strategic planning for future generations is needed, and repair procedures are capable of making an interesting contribution.

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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:
Members are more than 120 cities, among them Berlin, Hamburg, Cologne and London (Thames Water). They hold together 66.6% of IKT.

b) IKT-Association of Industry and Service:
Members are more than 60 companies. They hold together 33.3% of IKT.

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