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IKT - Institute for Underground Infrastructure

2010-2012

RESEARCH & TESTING

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Results with practical benefits

» Not only in Germany, but also in a large number of other countries, operators invest large amounts every year in public drain and sewer systems alone. Numerous suppliers of the most diverse range of processes and products all compete for this custom. Competition is tough, and not a few high-gloss brochures promise much more than is really possible.

The clients have become increasingly critical, however. More than ever before, they find themselves confronted with decisive questions: How do I locate the right product, in view of the large selection of suppliers and their contradictory arguments? How can I know which products really do what their salesmen promise? Reliable technical information - hard facts, not advertising slogans - are needed to permit correct decisions.

Exactly here is where the IKT can help, with its practically orientated tests. As an impartial, independent and non-profit-making research and test institution, we regularly test building products for drain and sewer systems to their utmost. The target is that of supplying reliable and well-founded aids to decision-making.

Unique in this context is our combination of science and practice. As a research institution, the IKT is constantly generating new knowledge. Research topics are defined “on site”, not at the conference table. Close contact is maintained with the system operators to ensure exactly this. They, ultimately, provide the impulses for IKT projects. And new research data is incorporated immediately into the work of the three IKT test bodies, viz.:

- the DIBt-accredited Building-Products Inspection Unit
- the nationally-accredited Test Unit for Flow Measurements and
- the DIBt-designated Test Unit for Water-Permeable Surfacings

In its Product Tests, the IKT goes one step further: every comparative test is supported by a group of system operators. Decisions concerning test contents, test procedures and test evaluations are made jointly by the group in a working committee. This ensures that the tests are closely practically orientated and that the test results are evaluated in line with the operators’ quality requirements.

Our IKT research and testing special off-print, compiled for the IFAT 2012, contains a selection of previously published and, in some cases, specially updated test and inspection results. It provides, by way of example, the prime emphases and the bandwidth of the examinations and product tests performed in recent years.

As a visitor to the IFAT, you yourself have the opportunity of observing the results of the IKT’s work while touring the exhibition; many of the products tested have been revised by their manufacturers and are now offered in an improved version. Indisputable benefits for the market – initiated by impartial and independent tests orientated entirely around working practice. «

Roland W. Waniek

Chief Executive Officer
IKT - Institute for Underground Infrastructure

Content

Large-diameter drains and sewers: installation, operation and maintenance

Experience from research, quality assurance and comparative product tests

Large-diameter pipes are the backbone of drain, sewer and other conduit systems. Their installation, operation and maintenance confront system operators with great challenges, however. IKT's application-orientated research projects and comparative testing of products and methods assist in achieving better comprehension of the complex interaction between quality requirements and cost-efficiency, in generating new knowledge, and in directly implementing the results in practice. Typical topics include open-trench and trenchless installation, cleaning, inspection, condition assessment and renovation.

Open-trench installation of large-diameter pipes

The installation of large-diameter pipes using open-trench methods makes high demands on work execution and on quality. In addition, reinforced-concrete and plastic components necessitate special knowledge, and profound understanding of specific material behaviour and the necessary quality assurance provisions.

A diverse range of questions arises when significant cracking occurs in large-diameter reinforced-concrete pipes:

- What crack dimensions are acceptable?
- What mechanisms are in fact acting?
- How can such damage be avoided in future?

Cracking is particularly critical if there is a danger of leakage or of consequential damage to the reinforcement. Repair is expensive, and frequently involves drawn out legal disputes between the parties. In order to provide clarity here, the IKT has developed its "Biaxial compression test", a special, highly authentic test for evaluation of the load-bearing and cracking behaviour of reinforced-concrete pipes [1]. The pipe is subjected during the test to the same loading strains as may be anticipated in practical service in the soil.

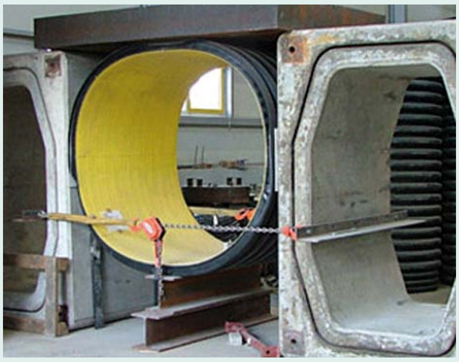
The test applies not only vertical, but also "supporting" horizontal loads. The internal stress patterns in the test cross-section (the crown of the pipe) then correspond exactly to in-situ conditions. It is then possible to evaluate the cracking behaviour of the "composite" material, reinforced concrete, without residual doubt. It would otherwise be necessary to anticipate deviations of up to 100% between the test and practice, even using the same crack-initiation stress in the concrete for the crack width observed.

Biaxial compression test (vertical/horizontal) for authentic testing of large-diameter pipes

As a result, it is possible not only to test and evaluate concrete tensile strength, but also crack propagation and the bonding behaviour between the steel and the concrete. The necessity for at least minimum reinforcement of the "large-diameter reinforced-concrete pipe" component, and the significant improvement in bond behaviour achieved by curing and sealing of the concrete were, for instance, confirmed in numerous tests. In addition, random-sampling testing also demonstrated that the design conditions normally selected for reinforced-concrete pipes need to be questioned in terms of concrete coverage and the spacing of the layers of reinforcement. On an overall view, the new test system provides additional safety for the optimisation and evaluation of large-diameter reinforced-concrete pipes.

Large-diameter plastic pipes are, in addition, also increasingly coming into use in drain/sewer construction. These types offer high flexibility, are relatively light, can, at least, be welded, and are generally resistant to aggressive media. Many operators encounter uncertainty when the flexibility of such easily deformed pipes gives rise to doubts concerning the stability of the structure in certain cases, however. The IKT has therefore also developed for these pipes practically orientated test concepts, which provide additional safety both in the laboratory and on the site [2].

It is thus now possible to investigate and evaluate the behaviour of large-diameter plastic pipes under exposure to deforming conditions in short-term (24 h) tests. In a similar manner to the testing of large-diameter reinforced-concrete pipes discussed above, not only vertical loads, but also horizontal bed reactions, are simulated in a special test apparatus. In this case, typical deformation states relevant in practice are induced in the pipe, and evaluated for the stability of the overall cross-section, the wall profiles and the welds. The crown and the bottom abutments can be equipped with load cells, and deformations maintained across a longer period, in a rigid load-application frame, where it is intended to register additionally the relaxation behaviour of the pipe under deformation, which is typical of plastics.



Large-diameter plastic pipe undergoing long-term relaxation testing

The methods for in-situ registration of pipe deformations have also been further developed, as the geometrical shape of the deformed pipe to be recorded is generally not known in advance, and the use of the necessary measuring technology always involves considerable work and complexity. The deformations are then visually and metrologically registered during a conduit inspection, evaluated with respect to external boundary conditions (live loads, bed material and surface buildings) and more extensive investigations proposed where appropriate (e.g. time-dependent deformation checks).

Studies performed up to now on large-diameter plastic pipes confirm the special significance of the quality of installation for the stability of the overall pipe/bed system. Not only cross-sectional deformations, but in many cases also horizontal/vertical displacements and, in a few instances, local deformations, are observed. In addition, the evaluation of stress-analysis calculations for completed projects also indicated that extremely optimistic assumptions had been made for soil conditions and degree of compaction. The available strength reserves are also generally fully utilised, particularly in the deformation and stability analyses. The importance of the formal acceptance inspection and of periodic inspection during operation thus becomes even greater. A combination of optical inspection and measurement of deformation is recommendable for the

In-situ measurement of deformation in large-diameter plastic pipes

detection and registration of abnormalities, in order to obtain informationally useful inspection results. Critical zones can then be delineated and shorter inspection intervals assigned for them.

No-dig installation: pipe jacking

Trenchless ("no dig") methods employing pipe jacking have proven suitable as an alternative to the installation of new large-diameter pipes using the open-trench procedure. Here, the pipes are subjected to special loads, particularly where the routing is not straight, and in case of difficult soil conditions. Inspection concepts developed up to now have, however, been restricted to the inspection of individual pipes and joints, and have ignored the curvature and bedding of the pipe string. A test system, using which pipe-jacking loads exerted on pipes and pipe joints can be simulated, complete with the resultant bed stresses, on a 1:1 scale, has been developed at the IKT, in the form of the IKT pipe-jacking simulator [3]. Recommendations for the optimisation of pipe joints, for the planning and control of pipe-jacking operations, and for on-site metrological support, have been derived from the test results.

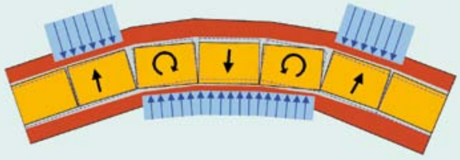
IKT DN 2000 pipe-jacking simulator: jacking pit 8 MN

The concept of the IKT pipe-jacking simulator augments the "passive" concept of measurement of a pipe exposed to external loads with an "active" observation element: when passing through curves , the longitudinal force necessary for jacking also generates a transverse movement of the unrestrained pipe string into the bed, with the result that corresponding bed reactions are activated. This special behaviour of the pipe string is simulated on a 1:1 scale in the IKT pipe-jacking simulator. Various means of force transmission into the pipe joint can be used, and various routing elements, such as curves and control movements, traversed repeatedly during simulation.

The geometrical and mechanical properties of the particular pipe-jointing technology demonstrated their special effect during the test. The magnitude of the bed reactions varied according to the routing and the selection of the (calculated) bore diameter oversize. The "ideal kinematics" of a curved pipe string generally assumed in the structural design, i.e., uniform distribution of pipe angling across all the pipes, were disproved. Individual groups of pipes have a tendency to "go straight on", with the result that greater degrees of angling must be expected at another point.

Passage through curves must therefore be regarded as a critical pipe-jacking state in terms of the loads exerted on the individual pipe joints, since heterogeneous degrees of angling also result in heterogeneous bed reactions and in significant transverse-force effects. The pipe loads to be anticipated are then essentially determined by the (non-linear) properties of the means of force transmission. The following provisions for quality assurance are therefore proposed:

16 m pipe string consisting of five DN 2000 test pipes in a bed structure consisting of positionable steel rings with hydraulic cushions

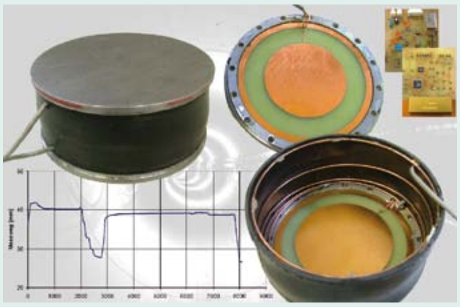


Pipe jacking, test result for passage through a curve: heterogeneous bed reactions with extreme angling between individual pipes

The materials characteristics data for the means of force transmission definitive for pipe-jacking should be determined at the planning stage and checked during pipe-jacking operations. Control specimens should be kept for the purpose of special tests in critical jacking situations. Quality Assurance for the jacking pipe can also be initiated prior to the start of production; the production conditions can be checked at the manufacturer's works and geometries and finished products measured at the works and on the site. Random-sampling-based quality tests under authentic loads (see modified vertical compression test) are also an available option, particularly in the case of special constructions and where increases in loads at a later time can be expected.

The pipe string should be visually inspected at suitable intervals during installation, in order to detect any abnormalities and permit the initiation of corrective action. Distributed metrological inspection of pipe joints during installation (using a slide gauge, for example) can also supply important information on the load exerted on the pipes and assist in locating critical zones, with a view, also, to the formal acceptance inspection. The IKT is, in addition, currently testing a measuring system integrated directly into the means of force transmission for measurement of joint-gap width, employing wireless transmission of the measured data. This eliminates the hindrance of on-site work by measuring instruments and cables, and significantly enlarges the number of joints measured.

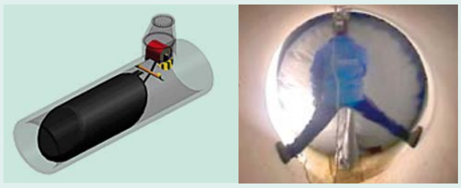
The research topic of "pipe jacking" continues to fascinate. There are, in practice, still numerous questions concerning planning, design, implementation and acceptance which require clarification. This is also true of the use of special cross-sections, such as rectangular-section pipes [4], which are also being tested in 1:1 scale experiments at the IKT.



On-line measurement of joint-gap width: measuring instrument

Use of the measuring instrument during pipe jacking

Rectangular jacking pipe: the insertion pit in the IKT large-scale test facility



Left: Surge-flushing using the flushing bag: system diagram (HST) Right: in use in the IKT test sewer

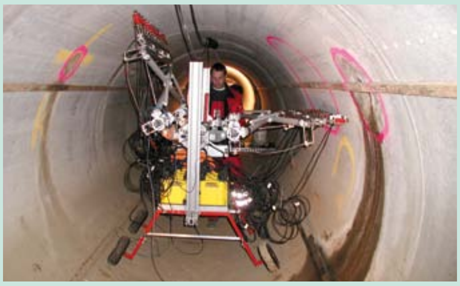
Cleaning and inspection

High-pressure flushing is the method most frequently used in practice for conduit cleaning. It runs up against its technical and economic application limits in the case of the cleaning of large conduits, however. Surge-flushing methods are an alternative, but have up to now required extensive civil-engineering provisions, and therefore the willingness on the part of system operators to invest large sums. In view of the ever-increasing economic pressure, still more solutions are needed, in order to achieve the necessary cleaning performance at rational cost.

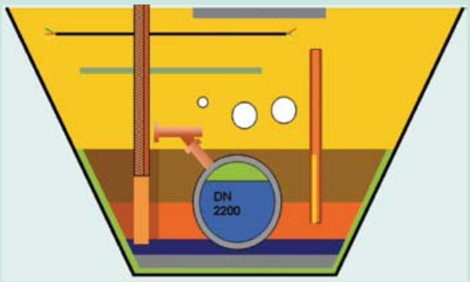
This opens the way for an innovative equipment development, known as the "flushing bag", and tested at the IKT [5]. For use of the "flushing bag", water is firstly dammed up, and then suddenly released into the conduit in the form of a "surge wave", to clean the conduit. The device can be integrated into existing manhole structures, with the result that no extensive new structural work is necessary.

Alternative inspection methods have also been investigated at the IKT. Large conduits, in particular, are frequently subjected to heavy loads, and continuously conduct large flows of sewage. For many system operators, the question arises, for these permanently partially filled sewers, of "How can such conduits be inspected in operational state?". The IKT has investigated various methods for inspection of partially filled large-diameter conduits in a pilot project [6]. The aim here was that of providing the responsible engineer with general information for the preparation of inspections and for the planning of future systems to take the necessity of inspections into account. The investigations involved both the selection of the most suitable inspection system or method, and the preparation of supplementary provisions to support the inspection procedure, such as drainage and conduit cleaning. More detailed information on the inspection of large-diameter conduits has been compiled by the major German system operators in Berlin, Hamburg, Munich and Cologne, and the Ruhr region's Emschergenossenschaft in co-operation with the IKT and has been published in special "Supplementary Technical Contractual Conditions" for "Inspection of large-diameter conduits > 1200 mm" (www.ikt.de/down/11_04_ztv-inspektion-grossprofile.pdf) (German version).

Geophysics in the large-diameter conduit:



Seismics under test



3D-mapped test length, diagram

Length prior to covering

Condition assessment and renovation

The selection of a cost-efficient method for the repair/renovation of large-diameter waste-water conduits and pipes necessitates the obtainment of further, comprehensive information on the condition of the pipe/soil system; such information cannot generally be supplied by means of visual inspection or distributed soundings alone. Geophysical measuring methods provide a rational augmentation here. Anomalies, bed defects and cavities in the vicinity of the conduit, and also defects in the pipe body, can be detected and integrated into the assessment, to permit appraisal of the stability and damage level of a structure.

Various geophysical methods, such as seismics, ground-penetrating radar, ultrasonics and impact-echo, have been scientifically investigated and tested under authentic conditions in a special IKT test length [7]. Seismic tomography, in particular, permits the derivation of extensive information on the condition of the soil between the terrain surface and the conduit. It is possible, in principle, to detect and locate cavities, non-homogeneous soil conditions and underground rubble, etc., in the vicinity of the conduit. Many measuring methods encounter their application limits when approaching the groundwater, however. In addition, the success of a measuring campaign using geophysical methods depends on the extent to which a measurable difference exists between the physical properties of a fault zone or anomaly and those of the other, comparatively undisturbed, zones. In the case of measurement in the interior of a waste-water conduit, the measured result can, in addition, also be significantly affected by the pipe material. On an overall view, the inspection of conduits using geophysical methods also necessitates special technical know-how, extending from planning and execution of the measurements, up to and including interpretation of the results.

As far as the actual civil-engineering renovation of large-diameter profiles is concerned, system operators are ultimately also obliged to substantiate their renovation decisions with reliable structural analyses. This becomes difficult when, in the case of older waste-water conduits, for example, scarcely any information is available on the original structural design, on soil quality in the vicinity of the pipe, and/or on the wall structure of the damaged waste-water conduit. Eau de Paris, in France, has therefore developed a non-destructive test method designated "MAC", which supplies, by means of force/deformation measurements, reliable information on the stiffness of the pipe/soil system, and thus provides the basis for reliable assessment of stability [8]. The IKT is currently further developing this system, with the result that direct structural assessment of large-diameter profiles will in future be practicable for nominal diameters of greater than DN 800. It will then be possible to register and evaluate both the original and the current condition of the renovated conduit in a kind of "before-and-after" appraisal.

The MAC system (Eau de Paris) for assessment of the stability of large-diameter profiles (photo: Eau de Paris)

International "Large Pipes and Sewers" network

Large-calibre pipes and waste-water drains form the "backbone" of the underground infrastructure. The construction, operation and maintenance of these systems confront system operators with great challenges, however. The "LARGE PIPES AND SEWERS" network organised by IKT now provides all operators of large-calibre conduits and pipes with a platform for interchange of knowledge and experience, the aim being that of preparing and substantiating even difficult investment and operational decisions on the basis of exchange of experience with other major operators. The participants' experience is to be systematically compiled, prepared, discussed and jointly evaluated for this purpose. Every participant will thus benefit from the knowledge and experience of the network as a whole. Workshops are to investigate and broaden conceptual solutions for typical engineering and operational questions, concerning, for example, tendering and award-of-contract procedures, and also quality assurance in the context of large-diameter pipe projects. The IKT is, in addition, also drafting market surveys and organising visits to sites and companies. Participants will thus obtain well-founded technical information from a neutral and impartial source. Further information: www.large-sewers.org

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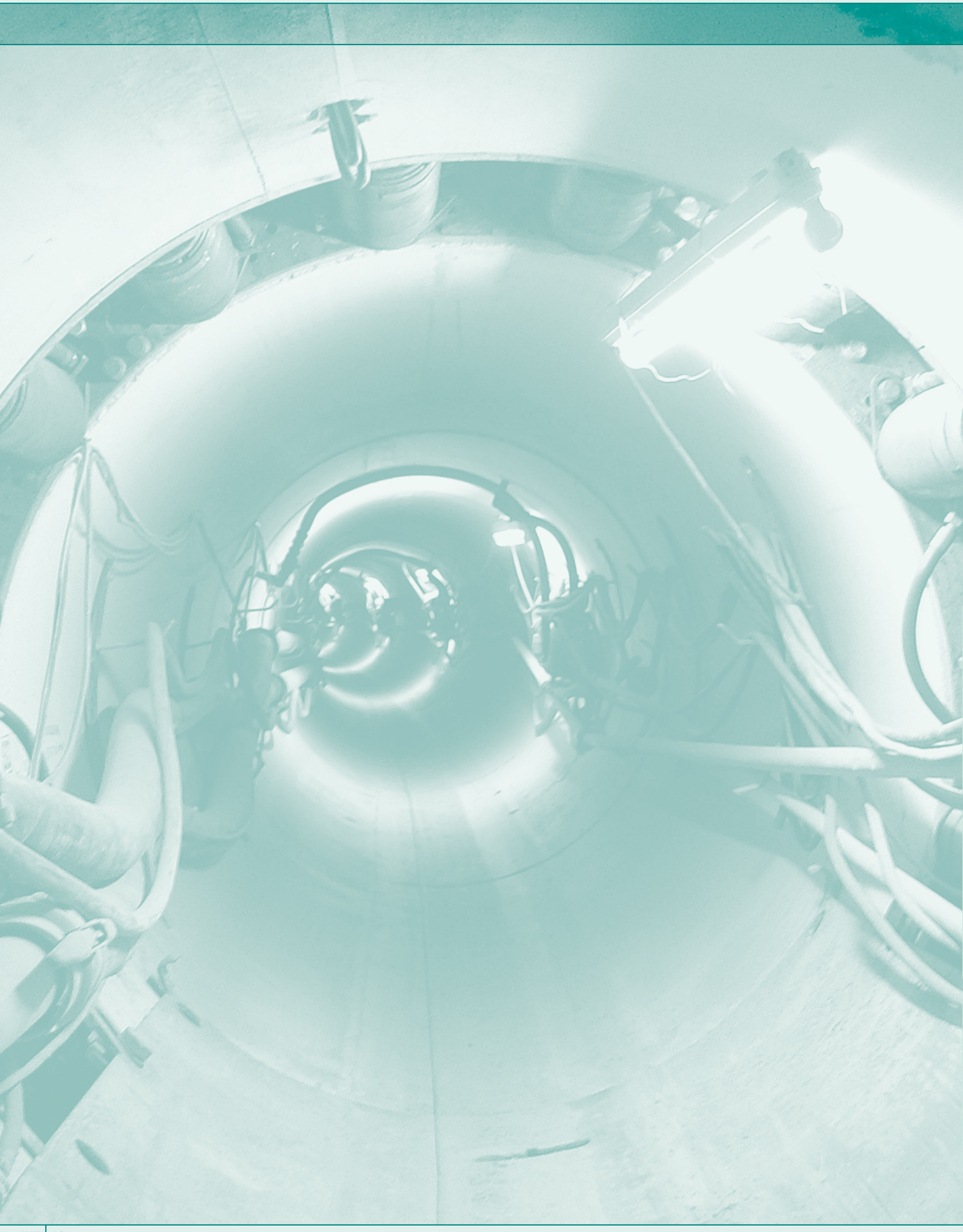


LARGE PIPES and SEWERS

International Exchange of Knowledge and Experience for Large Pipe and Sewer Operation, Maintenance and Rehabilitation

Large-diameter pipes form the backbone of drain, sewer and other conduit systems. The construction, maintenance and renovation of these structures are of great importance in assuring continuous safe operation. This task confronts system operators with great challenges, however.

The IKT - Institute for Underground Infrastructure will be focussing, as its main topic at the IFAT 2012 on the subject of “LARGE PIPES and SEWERS”, and will provide interested system operators with a platform for the interchange of experience and an accompanying programme covering all facets of “Large pipes and sewers”.

New developments and demonstrations at the IFAT 2012:

Large pipes and sewers

(IKT - Institute for Underground Infrastructure)

- Consulting, e.g. inspection of large-diameter conduits
- Quality Assurance, e.g. large-diameter reinforced-concrete and plastic pipes, pipe-jacking
- Appraisals, e.g. crack widths in reinforced-concrete pipes
- Testing, e.g. of pipe and fill materials

International Large Pipes and Sewers Network

(IKT - Institute for Underground Infrastructure)

The “LARGE PIPES and SEWERS” network provides operators of large-diameter drains, sewers and other conduits with a platform for the interchange of knowledge and experience. The aim of the network is that of concentrating knowledge and practical experience concerning the construction, maintenance and renovation of large-diameter conduits, and of processing and providing it for use by all participants.

The MAC method for assessment of stability

(Eau de Paris)

The “MAC” non-destructive inspection procedure is a method developed in France for assessment of the stability of large conduits requiring renovation. Pressure cylinders on the inspection unit generate and measure deformations in the conduit, and thus determine the stiffness of the pipe/soil system.

Measuring robots for control of pipe-jacking operations

(Emschergenossenschaft, IKT: Golden Manhole Cover 2011)

Measuring work during pipe-jacking of diameters imposes high physical burdens on the staff involved. An autonomous measuring robot has been developed to simplify pipe-jacking measurements - an idea which was rewarded with the IKT's "Golden Manhole Cover" for 2011. The measuring staff now no longer needs to enter the pipe string, and the time-savings achieved compared to conventional measurement amount to up to 75 percent, thus also reducing idling times on site.

Inspection of large-diameter conduits

(StEB Köln, Cologne Municipal Drainage Services)

The condition of large-diameter drains and sewers must be determined at regular intervals. For this purpose, a workgroup has formulated a so-called "Supplementary Technical Contractual Condition" (abbreviated ZTV in German), in which the requirements for assessment of the structural and operational condition of large-diameter conduits are specified (generally diameters of greater than DN 1200 mm).

PROGRAMME
MAY 7 TO 11, 2012

IKT staff will be available on the institute's stand throughout the exhibition for interchange of experience in the construction, operation and renovation of large-diameter drains, sewers and other conduits. The MAC method for the assessment of the stability of large-diameter pipes and sewers will also be shown.

Experts will be available on the IKT stand for discussion and for individual advice on the days listed on the right.

WE LOOK FORWARD TO YOUR VISIT!

IFAT	HALL B4
ENTSORGA	STAND 243

MONDAY, MAY 7, 2012

14:00 to 16:00 h — **International Large Pipes and Sewers Network**
Presentation, discussion and individual advice

16:00 to 18:00 h — **Inspection of large-diameter pipes**
Discussion on ZTV inspection of large-diameter conduits (StEB Köln)

TUESDAY, MAY 8, 2012

10:00 to 12:00 h — **Installation, Maintenance and Renovation of Large Pipes**
Results of research and testing

WEDNESDAY, MAY 9, 2012

12:00 to 14:00 h — **Quality Assurance for large-diameter plastic pipes**
Practical notes and individual advice

14:00 to 16:00 h — **Structural Assessment of large-diameter pipes**
Presentation of the MAC test system by Eau de Paris

16:00 to 18:00 h — **Installation, Maintenance and Renovation of Large Pipes**
Results of research and testing

THURSDAY, MAY 10, 2012

10:00 to 12:00 h — **Quality Assurance in pipe-jacking**
Measurement and force-transmission systems

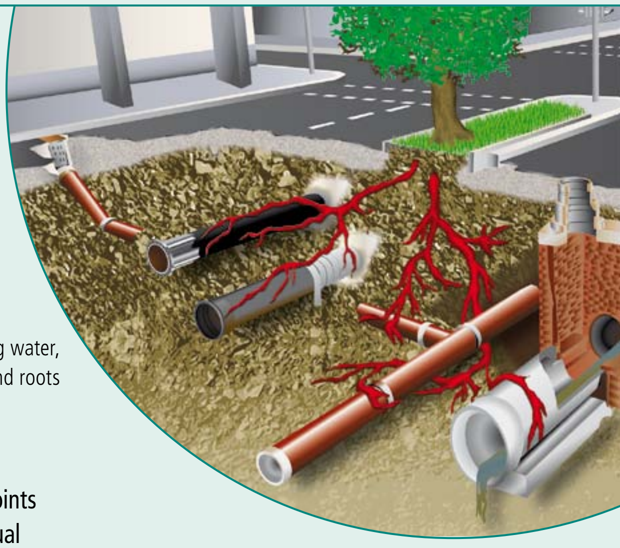
14:00 to 16:00 h — **Measuring robots for control measurement of pipe-jacking operations**
1st Prize, "Golden Manhole Cover 2011", Emschergenossenschaft

16:00 to 18:00 h — **Installation, Maintenance and Renovation of Large Pipes**
Results of research and testing

FRIDAY, MAY 11, 2012

10:00 to 12:00 h — **Measuring and process technology for construction, inspection and renovation**
including force-transmission systems and monitoring in pipe-jacking operations

Underground space: Utilisations in harmony



"tolerated chaos": gas, drinking water, sewage, stormwater and roots

Numerous utilisations in urban areas are reflected in the underground zone, in the form, for instance, of drains, sewers, cables, other conduits, foundations, road and street formations, root systems, transport routes and (water) storage facilities. A state of "tolerated chaos" prevails.

This "tolerated underground chaos" causes conflicts in the planning, construction, operation and renovation of systems, and restricts the adaptability of the infrastructure as a whole. Climate and demographic change, and also the need for space for energy and telecommunications links, necessitate permanent flexibility, however. The usual co-ordination of current construction projects is, alone, not sufficient here. Supra-sector long-term strategies for utilisation of underground space are needed, in order to ensure that, in the future, too, all infrastructural facilities have the space they need, possess the necessary adaptability, and contribute to the quality of human life in a manner that makes efficient use of the available resources. In short, harmonised solutions for the underground space must be found.

The "Underground Space" research alliance

The IKT - Institute for Underground Infrastructure, in co-operation with its long-established partner institutions from a range of disciplines, has now founded the "Underground Space" research alliance. The principal aim of this interdisciplinary organisation is that of identifying interactions and synergies in the context of utilisation of the underground space, and of promoting and enhancing understanding of the relevant correlations on a supradisciplinary basis. The research alliance identifies specific needs for research/development and then initiates joints projects, with the aim of drafting conceptual solutions, strategies and products for utilisation of the underground space. The alliance flourishes from its holistic and interdisciplinary orientation; the IKT is responsible for the co-ordination, chairmanship and strategic alignment of the research alliance. The following scientific institutions are participants in the "Underground Space" research alliance:

- IKT – Institute for Underground Infrastructure, Gelsenkirchen
- The Ruhr University, Bochum, Faculty of Civil and Environmental Engineering – Chair of tunnel construction, pipeline construction and construction management
- The Ruhr University, Bochum, Faculty of Civil and Environmental Engineering – Chair of Urban Water Management and Environmental Engineering
- The Ruhr University, Bochum, Faculty of Biology and Biotechnology – Chair of Evolution and Biodiversity of Plants
- Leibniz University of Hanover, Institute for Geotechnical Engineering (IGtH)
- Technical University of Kaiserslautern, Department of Construction Management
- Bergische University of Wuppertal, Department of Soil and Water Management, Wuppertal
- Bauhaus University of Weimar, Department of Urban Water Management and Sanitation, Weimar
- Ruhr West University of Applied Sciences, Institute of Economics, Mülheim/Ruhr
- Bundeswehr University, Munich, Institute of Hydro Sciences, Chair of Sanitary Engineering and Waste Management

The work of the research alliance receives significant support from the IKT-Association of Network Operators – a group of more than one hundred and thirty towns/cities, municipalities, municipal service organisations and water boards - and from the Municipal Network for Private Sewerage Systems, with its sixty-five members, in order to assure, in particular, the practical orientation of this work. The IKT-Association of Industry and Service – a grouping of innovative companies from the building and other industries – is also a strategic partner, contributing content, providing products for solutions, and pursuing product developments where necessary.

The strategic and thematic orientation is linked, at all times, with higher-level (urban) civil-engineering and environmental policy questions. For this reason, the research alliance maintains close contacts with representatives of the German "Bundesstiftung Umwelt" environmental foundation, and with the Federal Office for Building and Regional Planning.

Root penetration in a pipe

Underground space

Initial framework-defining research project planned

A number of members of the "Underground Space" research alliance are now planning a major interdisciplinary research project on the subject of "UNTERRA: Underground space - harmonised utilisations", to be conducted under the overall leadership of the IKT.

This planned joint project focuses on essential aims of the research alliance, exploring them in more detail:

- Detection of interactions and conflicts;
- Attainment of transparency and
- Drafting of technological, conceptual and organisational proposals for solutions.

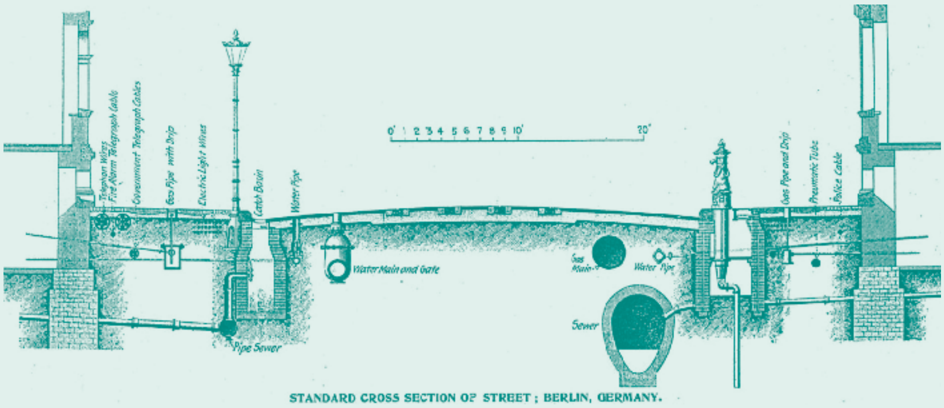
A total of thirteen institutions active in the fields of science, administration and business are participating in the UNTERRA joint project, which simultaneously provides the framework for further R&D projects by the "Underground Space" research alliance; technical and conceptual sub-questions identified in the context of the framework project are, for instance, to be investigated by workgroups.

A corresponding project proposal for the framework project has been drafted in co-ordination with the participating institutions, and has already been submitted to an initial source of subsidies. Further such sponsors will be contacted if necessary, in order, also taking account of specific sub-aspects, to secure appropriate sources of financing.

Interdisciplinary solution concepts

A cross-section of a Berlin street in 1896 proves the point: conditions in the underground infrastructure were a topic even in those days. It was necessary, for example, to find space for gas and water supply conduits, waste-water drains, and a range of different telegraph and electrical cables in the cross-section under the street.

Technical progress, increasing urbanisation, an ever greater need for space underground, and future challenges, such as climate and demographic change, and also the necessity to protect the soil and the groundwater, underline yet again the necessity of mutual consultation and co-ordination in underground matters.



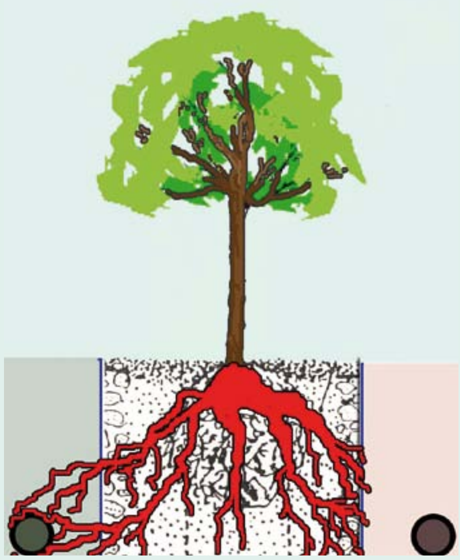
Cross-section through a Berlin street in 1896
Bild: www.sewerhistory.org

Not only the classical supply and disposal conduits, but also other infrastructural facilities, need adequate space underground, including, for example, new conduits for the separate conveyance of rainwater and sewage, storm drains, energy and fibre-optics cables, community-heating transmission pipes and also conduits for the use and/or distribution of geothermal heat and heat recovered from waste-water.

New and topical questions, many not a subject of discussion in the technical world only a few years ago, also arise concerning the interaction between vegetation and infrastructural facilities in the urban underground.

One example: root growth and its interactions with, for example, waste-water conduits and sewers. Interdisciplinary research projects have made it possible in recent years to gain important knowledge concerning the causes of the ingrowth of roots into sewers, etc., and concerning possible preventative provisions. The IKT played an important role in research into these causes.

It also became apparent, however, that suitable solutions for the joint use of underground space by both trees and underground conduits, etc., can be drafted only on the basis of consultation with all those persons affected. In 2006, the topic was taken up again on the basis of new discoveries, and placed on a broader foundation, with the setting-up of the supra-association "Tree sites, sewers and other conduits", by the DVGW (German Technical and Scientific Association for Gas and Water), DWA (German Association for Water, Wastewater and Waste) and FGSV (German Road and Transportation Research Association). All the disciplines affected, such as supply and disposal technology, underground civil-engineering, landscape development, landscaping, biology and parks and amenities planning were involved in the drafting of the new DWA M code 162, The "Trees, underground conduits and sewers" code is a brilliant example of successful interdisciplinary co-operation for the attainment of conceptual solutions capable of achieving supradisciplinary consensus.



Root growth in a pipe trench.
right: root-proof bed,
left: root infiltration in the bed material

Prospects

The complex structures of the urban underground necessitate new and generally interdisciplinary conceptual solutions. Current examples include:

- the use of multifunctional soils as a load-bearing soil-mechanical structure, hydrogeological conductor/reservoir, ecological buffer medium, substrate for vegetation and thermal conductor/barrier;
- modification of conduit (etc.) structures (e.g. pipe and cable ducts for compact installation and management of supply and disposal conduits, cables enclosed in sewers, etc.);
- functional conversion of existing structures (e.g. combined system intercepting sewers used as seepage water drains);
- the use of new infrastructural elements for sustainable rainwater management (e.g. blind drains, seepage-capable paving systems);
- the use of conceptual and organisational control models and tools for supra-disciplinary co-ordination during the planning, construction, operation and renovation of the underground infrastructure.

Supra-disciplinary and harmonised solutions are needed for the underground space, in order to master the challenges of the future.

The "Underground Space" research alliance focuses on these topics, identifies the need for Research & Development on a practically orientated basis, and endeavours to accelerate the pace of innovation.

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Rehabilitation of waste-water manholes: Large-scale tests and in-situ studies

Manholes in IKT's large-scale test facility

IKT's recently completed research report on the "Rehabilitation of waste-water manholes" focuses on two central topics: the sealing of the manhole structure and in- and outlets, and coating using mineral and polymeric systems.

Sealing and coating of manholes

There are around ten million waste-water manholes located in public traffic surfaces in Germany. Leaking manholes result not only in exfiltration of waste-water; if the groundwater table is in contact, significant quantities of infiltration can also enter, thus impairing the cleaning performance of treatment plants and storm water tanks. In addition, waste-water manholes are in many cases the citizen's only visible "interface" with the drain and sewer system. Defects here can cause hazards for traffic.

Manhole cover: the visible interface with the drain and sewer system photo: unikation, photocase.com

In co-operation with municipal system operators, IKT has developed the "Waste-water manholes" research focus, which receives decisive support from the NRW ministry of the environment. Two essential questions of this research focus have been studied intensively in the recently completed "Rehabilitation of waste-water manholes" [1] sub-project: sealing of the manhole structure and the in- and outlets, and coating using mineral and polymeric systems. The prime emphasis here was on the robustness of the methods and materials used in practical service, and performance under external water pressure during infiltration rehabilitation.

The project was monitored by a steering committee representing thirty-five system operators, and continuously orientated around their practical requirements. Selected products and procedures were analysed in the context of in-situ projects, 1:1 scale tests and supplementary detailed analyses.

All results can be downloaded from the Internet at: www.ikt.de (German Version)

Project target

The prime target of the project was that of obtaining substantiated knowledge concerning the factors influencing quality in sealing and coating projects, in order that this knowledge could then used by the system operators as a guide for further decision-making. This applied to the complete procedure, from the tendering and award-of-contract stage, up to and including acceptance inspection of rehabilitation work, including Quality Assurance provisions.

Suitable coatings already applied were firstly examined and submitted to numerous quality tests, in order to determine the effects of multiple years of exposure to operating conditions. In addition, sealing work on manhole structures and pipe joints were observed on site. The results of this, and perceptions gained from earlier research projects [2], were then used for the selection of suitable materials, methods and boundary conditions for the subsequent large-scale tests and supplementary laboratory analyses.

Sealing work in practice: cementitious waterproof plugging compound

The large-scale (1:1) tests investigated, in particular, the performance and robustness of sealing and coating methods under defined boundary conditions, which were identical for all the rehabilitation work. Special time-compression effects were applied across a period of five months, in order to permit study of the long-term behaviour of the renovated waste-water manholes under exposure to external water pressure.

Further specific questions, such as the mechanical load-bearing capacity of repaired pipe joints, the behaviour of cavities under exposure to external water pressure, and the effectiveness of repair products for mineral coating systems, were answered on the basis of supplementary laboratory analyses. Activities were rounded off by a cost-effectiveness analysis, the use of innovative inspection procedures and practically orientated notes for planning, recommendations and training programmes.

Waste-water manholes: civil-engineering characteristics

Renovated waste-water manholes are complex civil-engineering systems. The assignment of specific damage and defects in renovation quality to causal damage/defect effects on the basis solely of in-situ observations is correspondingly scarcely possible. Previous research projects [2] had already shown that there are diverse factors capable of influencing the robustness and quality of the "renovation result", including, for example, deficiencies in preparation and performance of the renovation, and also failure to take account of structural loads and/or civil-engineering boundary conditions. Particular importance therefore attaches to understanding of the civil-engineering (system) characteristics of a renovated waste-water manhole; this applies, in detail, to the following:

Loads

Every civil-engineering system is affected by the loads acting on it. These may be of a purely mechanical, or also of a (bio)chemical nature. The soil load exerted on the structure, the level of the groundwater table and the dynamic traffic loads acting on the structure may be mentioned here, by way of example, for manhole structures. Exposure to chemical loads exerted by the conveyed fluid also play a role.

Material properties

The properties of the materials used both for the manhole structure itself and for the sealing/coating system are of great importance for the character and performance of the structure as a whole and, in particular, for its mechanical strength, surface quality and chemical resistance.

Component and structural geometry

Waste-water manholes generally take the form of single-shell cylindrical elements with side in- and outlets. This geometry may be significantly modified by sealing or coating work. Sealing operations using injection methods, for example, generate voluminous foreign bodies in the surrounding soil, thus decisively altering the geometry outside the manhole structure itself. Coatings are intended to bond permanently with the substrate material, and thus modify the wall thickness and structure. Significant changes can also occur here in the course of time, as a result, for example, of the detachment of the coating, associated also with blistering caused by external water pressure, and/or the detachment of injection foreign bodies due to fluctuating groundwater tables.

External interactions / boundary conditions

Loads, material properties and structural geometry may also interact closely with other influencing factors and boundary conditions. Examples of this can be found in the compaction of the surrounding soil, and in alterations to the road formation and the underground zone.

As-completed/renovated manhole conditions

The relevant loads, material properties and geometry of a waste-water manhole are subject to changes over time as a result of the construction and/or renovation process, and the subsequent operating phase. The materials used are generally subjected as early as their development phase to comprehensive laboratory testing in order to determine their (time-dependent) material properties under exposure to mechanical and chemical loads (see [3]). The central focus of observations is therefore on process-engineering influencing factors, application-specific loads (and the groundwater, in particular), and the geometrical characteristics of the renovated systems.

The as-completed/renovated manhole conditions observed in the in-situ and laboratory studies can be differentiated as follows, using the example of the coating processes:

A system operator's manholes are inspected in the context of a condition survey, and the need for renovation is determined. It focuses, in general, on leaking masonry or concrete manholes, usually with a circular cross-section and various points of damage, including, for example, isolated and larger-area superficial damage, leaks in the pipe wall, and leaking inlets. The ingress of water may vary greatly, depending on the continuously fluctuating groundwater table. It must also be remembered that the connecting pipes may consist of different materials; in addition, considerable levels of moisture and of wall fouling must also be anticipated in a waste-water manhole.

Manhole renovation in practice

On the basis of this scenario, sealing provisions will now be performed, in order to temporarily restore the manhole's tightness. The visible leaks in the manhole will be systematically sealed using the most diverse range of materials and methods up to the level of the current groundwater table in order to achieve this. Mineral- and polymer-based materials are used for this purpose, and are either applied manually to the inner walls of the manhole, or injected into the manhole surroundings using injection packers and pumps. The geometry of the structure is generally significantly modified during these processes. Such work is normally performed during the summer months, when groundwater tables are low.

After successful sealing of the manhole, the manhole walls are firstly submitted to intensive substrate preparation, in order to make them suitable for coating. The aim of such preparation is, on the one hand, the removal of fouling, such as grease and loosely adhering deposits, from the substrate while, on the other hand, it is necessary to create a surface which will enable the coating to bond permanently with the substrate. For this purpose, the aggregate particles in concrete manholes should be visibly exposed, in order to provide the largest possible surface area for bonding. Reprofiling may also be necessary if significant surface irregularities, cavities and/or spalling have occurred. A specific substrate moisture level, depending on the coating material, must then be achieved by drying (in the case of polymeric coatings) or of moisturising (in the case of mineral coatings).

The structure is restored to its "freshly renovated" state by means of the coating and the finishing work. The coating may be applied to the manhole walls either manually or mechanically, or both. The interaction of the material and the method used are of particular importance in this context. Mechanical application, for example, necessitates material properties different to those required in manual coating using a pointing trowel and a smoothing trowel. Particular care is necessary on the ladder irons and at the in- and outlets. After-treatment of mineral coatings is generally necessary, in order to prevent cracking and assure optimum adhesion.

Complete curing (hardening) of the materials applied, completion of all finishing work and after-treatments is followed by acceptance inspection. This will involve visual inspection of the coating, tapping of it to detect any cavities, and the determination of tensile adhesion data for the bond with the substrate.


Acceptance inspection: visual assessment of the coating

By the time of the guarantee inspection after around five years, short-term operational influencing factors will have affected the coating. The groundwater, for example, may well have risen above the level of the temporary seals. It is also possible that the sealing action of the temporary sealing provisions was not lasting. The coating must then also assure sealing against the contacting groundwater.

Ultimately, the service-life will be achieved during operation, as a result of long-term operating influencing factors. The time leading up to this point will be characterised by years of exposure to fluctuating groundwater table loads, for example, and/or (bio)chemical loads. Further condition surveys will now be implemented at regular intervals, and may ultimately again indicate a need for renovation, or even renewal.

In-situ analyses

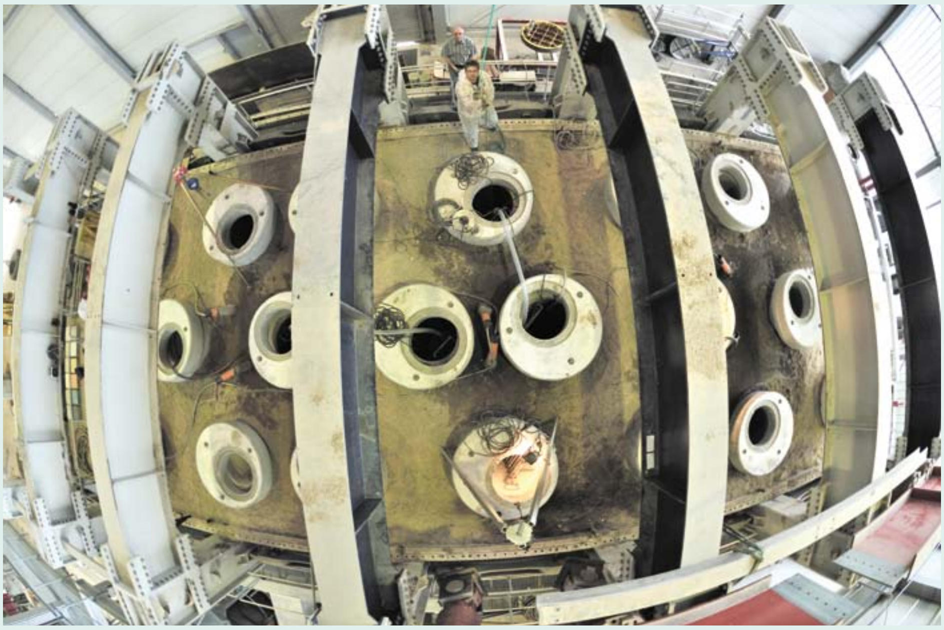
Twenty existing in-situ coatings ranging in age from around three to fourteen years were firstly examined in the context of the in-situ inspections, and also submitted to numerous quality tests, in order to determine the effects of years of exposure to operating loads.

In summary, the thirteen mortar coatings inspected demonstrated that satisfactory renovation results can be achieved even for an operating period of up to fourteen years. Careful preliminary sealing is necessary in the case of mortar coatings, in order that the hardening process is not impaired by any influx of groundwater. Uniform adhesion appears to be more important than only locally high tensile adhesion ratings. It was ultimately apparent that any damage had, predominantly, already been detectable as early as the acceptance inspection performed after one to six months. Further observations then served the purpose of assessment of the progress of the damage.

Significant deterioration was observed in five of the seven polymeric coatings inspected, on the other hand. The extent of cavities present immediately after coating constituted, in particular, a major problem in some cases, despite locally high tensile adhesion ratings. Uniformly good bonding appears to be of particularly great significance here. In view of the progress of the damage with time, special attention must be devoted to the guarantee inspection in the case of polymeric coatings.

Further on-site monitoring of sealing work performed on manhole structures and pipe-joint zones primarily served the purpose of selecting materials and procedures for subsequent large-scale and laboratory tests, and of obtaining orientation data for the boundary conditions of the large-scale tests. The conclusion of the renovation monitoring activities demonstrated clearly that sealing work on waste-water manholes necessitates a high time, labour and material input. In addition, the desired long-term success is not always achieved; the renovation task appears, in some cases, simply to be too demanding.

Monitoring of the construction of new manholes permitted the more detailed and profound recording of subsidiary construction costs and of follow-up costs, as the basis for a cost-effectiveness analysis of coating systems vs. new manholes.



Manholes in IKT's large-scale test facility

Installation of the manholes in the large-scale test facility

Large-scale (1:1) tests

The tests conducted at IKT's large-scale test facility investigated, in particular, the performance and robustness of the various methods under identical boundary conditions. The main focus was on variation of geometrical and process-engineering characteristics data and external loads, such as the formation of defects, for example, large-area fouling of manhole walls, and the level of groundwater tables as a function of the renovation conditions under examination. A total of twenty manhole structures consisting of prefabricated concrete elements were installed in a mixture of gravel and sand with a maximum particle size of 8 mm in the IKT large-scale test facility. The manholes had an internal diameter of 1000 mm (DN 1000) and a total structure height of around 5.6 m. Conduits and manhole linings of DN 300 were installed in the lower manhole sections. Stoneware and PVC-KG pipes were connected to the manhole linings installed.

Various geometrical faults were incorporated into the shaft rings and lower sections prior to and during installation of the prefabricated concrete elements. These simulated local and widespread leaks, and also leaking shaft ring joints, and took the form, essentially, of varying numbers of drilled holes of various sizes. A mould release agent for intentional weakening of the bond was applied to the "large-area leak" point of damage after completion of substrate preparation, but prior to coating.

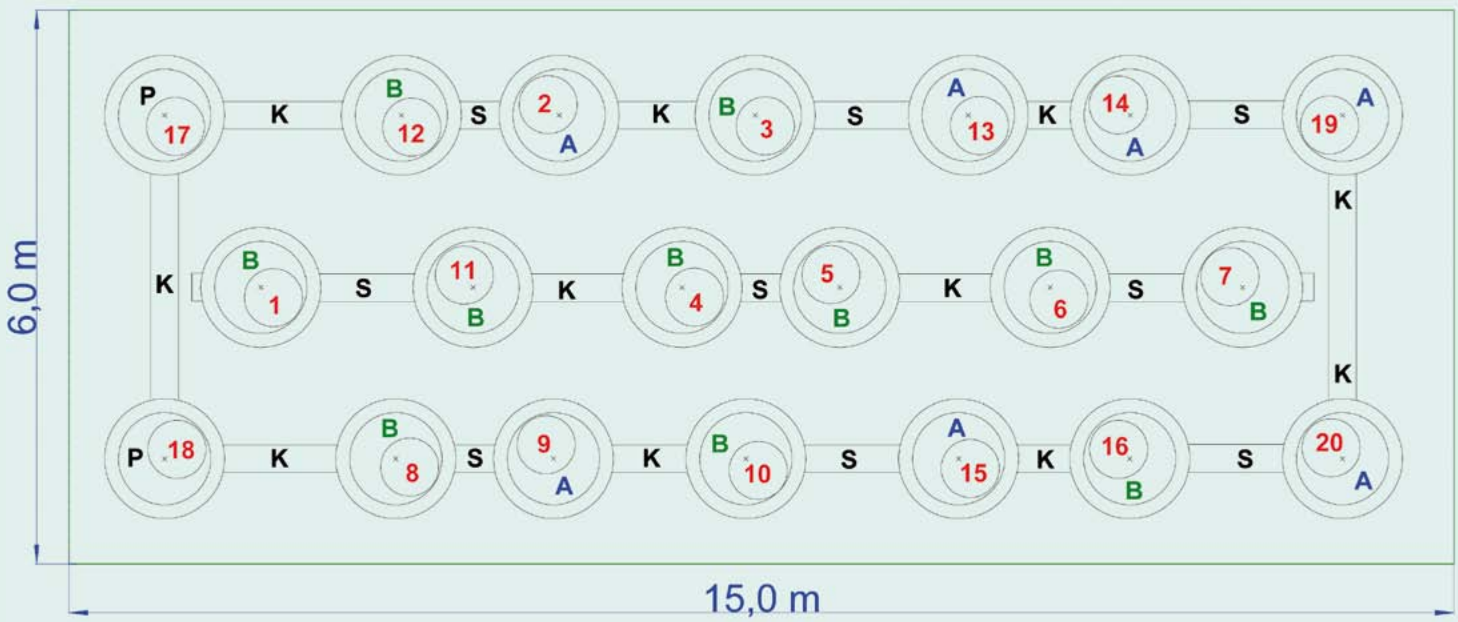
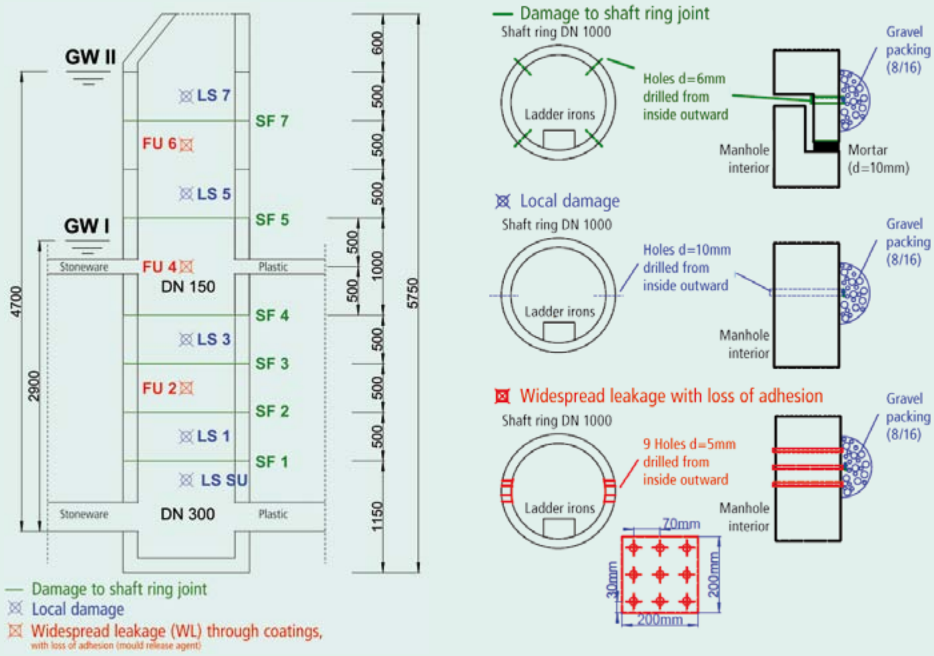


Diagram (plan view) of the manhole structure in the large-scale test facility
A: Manhole for sealing provisions; B: Manhole for coating provisions;
P: Pump shaft; K: PVC pipe; S: Stoneware pipe



Faults deliberately incorporated into manholes intended for coating:
side view of the manhole structure (left) and damage patterns (right)

In addition to the geometrical damage to the manhole structures described above, the pipe joint zones intended for use of sealing methods were also deliberately damaged in advance. The seals in the pipe joint zones under observation were partially removed here.

The test procedure was characterised by the fact that the renovation operations customary on site - sealing, followed by coating - were separated from one another. In the case of the coating methods, this meant that the manholes prepared with defects (leaks) were firstly coated using various materials and systems but without prior sealing and with no groundwater in contact, and the water level only then raised. This water pressure then acted directly on the coating applied. A load such as this occurs in situ only in cases in which the prior sealing of the manhole structure fails or the groundwater rises above the sealed zones.

After curing of the coating materials, various methods and materials for sealing of the manhole structures and the in- and outlets were applied in other manholes, with influx of groundwater.

The coated manholes were visually inspected, and their condition documented, in parallel to this sealing work. The maximum groundwater table of 4.7 m above the lower pipe sole was maintained for a period of twenty weeks. The seals and coatings were inspected at regular intervals during this period; any changes in condition were documented, and any water ingress measured on a random-sample basis.
The procedure described above made it possible to apply the following time-compression effects, in order to accelerate possible failure of the renovated components:

Early application of maximum load to the component:
The maximum groundwater table was applied within a few days; a rise in groundwater can be anticipated in situ across a number of weeks or even months.

Early exposure of the renovation product:
Since coating was performed in dry state, with no prior sealing, the coatings were directly exposed to the contacting groundwater when the test facility was filled. The period normally required up to failure of a preliminary sealing and/or up to the rise in the groundwater table above sealing height was thus eliminated.

Foreshortening of exposure to maximum load:
The maximum groundwater table was applied in the test period for twenty weeks. In situ, it is generally necessary to anticipate fluctuating groundwater tables, with the result that a comparable exposure time and loading on the renovation product can be expected only across longer observation periods.

Continuous load-exposure / creep effects:
Plastics, in particular, exhibit significant creep when exposed to continuous load. Fluctuating groundwater tables in situ result in repeated relief and reversal of creep effects, whereas it was possible in the test to achieve comparatively continuous load scenarios, with corresponding creep phenomena.

At the end of the observation period, the water was drained from the test facility, and tensile adhesion tests performed on the coatings. Exposure of the manhole components also made it possible to inspect from the outside the injection bodies created during the sealing operations.

Polyurethane injection body on the exterior of a manhole

Results

An overall view of the project results makes it possible to summarise a number of basic perceptions which can be used by the system operators as a guide for further decision-making and action. These apply to the complete procedure, from the tendering and award-of-contract phase, up to and including acceptance of renovation work and supplementary Quality Assurance provisions.

Sealing suitable as a preparatory measure

➔ but long-term effectiveness remains dubious

Under exposure to external water pressure for a number of days in the large-scale test, resins and gels achieved good sealing of the damaged manholes. They are, therefore, also suitable as a preparatory measure for coating. Virtually all the resins and gels exhibited significant leaks after more prolonged exposure to external water pressure (around five months). Cementitious waterproof plugging compounds, on the other hand, exhibited a significantly poorer sealing action, even in the short term; their use is recommendable primarily for initial sealing of severe influxes of water, by way of preparation, for example, for more extensive injection sealing. Injection of a cement paste involved fundamental difficulties, due to the comparatively slight cavity/pore size of the well compacted surrounding gravel/sand soil used in the test.

Sealing of smaller-diameter (DN 150) pipe joints proved to be poorly reliable, even where resins/gels were used. The reasons can probably be found in the geometry of the manhole linings to be refurbished. The annular cavities for injection are significantly smaller in these instances than in the case of larger pipe joints (DN 300), with the result that the injection packers cannot be applied directly into the annular space, but must, instead, be applied into the manhole wall. The number and positioning of the packers may need to be matched to this circumstance.

The surface use of a crystallising mortar for sealing of the manhole structure achieved a special ranking. Specific applications have here not yet been clarified. The sealing action in the test was supported, but no contribution to load-bearing capacity or protective action (corrosion) was apparent. The extent to which this material's surface conditions (particulate, loose) can be improved by means of further provisions to make a protective action or improvement of load-bearing capacity possible by means, for example, of further coating with other materials, also remains open.

Mortars are durable, but frequently exhibited visual defects

➔ scarcely any risk of infiltration, even in case of bonding defects and shrinkage cracking

Cracking and moisture stains on the manhole wall, but no leaks involving measurable influx of water, were apparent in around 50 percent of the mineral coating systems. This also applied to those points at which the bond had been deliberately weakened using release solvents. IKT applied the mould release agent at these points prior to coating, in order to obtain initial indications concerning the "robustness" of the repair system vis-à-vis unexpected bond weaknesses, such as can occur in practice in case of lack of substrate pre-treatment. No wall breakage as a result of external water pressure was observed. This fact was attributed largely to the geometrical conditions, i.e., the large wall thickness (and thus stiffness), and the stabilising circular geometry of the coating. In interaction with the existing manhole, the external water pressure is then transmitted via compressive stresses in the mineral coating.

In-situ observations of mineral coatings of an average age of five to six years indicated that no infiltration-relevant deterioration of overall condition, and no perceptible corrosion damage, occurred during this period. The main focus of acceptance inspection should therefore be on the actual official acceptance inspection, with detailed documentation of possible conspicuous abnormalities. A check should then be made at the guarantee acceptance inspection to determine whether further spreading of any existing cavities and cracks can be excluded or not.

Random-sampling-based laboratory tests did not indicate any benefits from the use of repair products. Cases in which sealing of the surface prevents necessary water influx may be considered critical.

Plastic highly promising, with great demands on technology and execution

➔ only enduringly tight if preparation good

Polymeric coatings achieved good results, provided substrate quality was satisfactory, and execution careful. Punctiform damage, e.g. pinholes, occurred here only in the case of isolated products. These are irregularities of the size of a pinhead in the coating, and may also cause leaks. Blisters occurred in some cases as a result of external water pressure, where the bond had been deliberately weakened for the test, however. In a number of cases, these blisters spread to such an extent that they also impinged on areas of high tensile adhesion ratings.

All in all, polymeric coatings achieve a good coating result with high demands made on the technology used and the care exercised in application. More intensive study of these coatings during the guarantee acceptance inspection is recommendable, due to the great dependence of any faults on time, as was also observed in situ.

Full-surface bonding decisive for quality

➔ tensile adhesion data provide only additional safety

Full-surface bonding is more important than high tensile adhesion ratings in specific areas, particularly in the case of polymeric coatings. Even values of greater than 1.5 N/mm^2 do not provide protection against the spread of any blisters/detached points already present. No faults were observed where bonding was full-surface.

The mineral coatings investigated in the 1:1 scale laboratory tests exhibited average tensile adhesion ratings in the 0.5 to 1.3 N/mm^2 range, on the other hand. More intensive cracking and moisture stains were, it is true, observed for comparatively low values, but with only slight effects on sealing action, even at cavities.

Infiltration risk: seepage at ladder irons

Seepage at ladder irons is a significant weak point, with perceptible risks of infiltration, in both mineral and polymeric coatings. It should, in principle, be determined whether ladder irons or step irons can be removed, and replaced by means of suitable internals (ladders) in the context of coating projects.

Method selection determined by renovation target

The renovation targets determine method selection; it is necessary here to decide the extent to which the renovation project is intended to contribute to load-bearing capacity, to protective action and/or to the sealing action across the targeted service-life.

To restore load-bearing capacity, the material used must be capable of making good an advanced loss of structural fabric. High tensile adhesion ratings with the substrate illustrate, in the case of mortars, for example, the extent to which new and old material can be regarded as a joint load-bearing system. A protective action by the material may be required in the form of corrosion protection against the fluid conveyed in the drain/sewer system, with the result that material resistance must then be measured by this standard. It is necessary, with respect to sealing action, to differentiate between the effectiveness of the overall structure vis-à-vis internal pressure and vis-à-vis external groundwater pressure. In terms of robustness, the question arises, in particular, of the resistance of the above-mentioned load-bearing, protective and sealing actions under exposure to mechanical, biological and/or chemical attack.

It thus becomes apparent that the renovation target and the specific requirement profile for each and every coating project must be individually defined, and that it may decisively influence method selection. The use of mineral coatings may thus be a solution for making good loss of structural fabric under exposure to groundwater pressure, with no further danger of corrosion. Polymeric coatings, on the other hand, exhibit their best performance in the presence, for example, of aggressive fluids and where there are high demands for sealing against internal pressure. A combination of mineral and polymeric coatings may therefore constitute a technically rational solution in specific cases.

Preparatory work depends on manhole condition

The use of coating methods generally presupposes a clean and largely dry substrate capable across its entire area of bearing loads. The preparatory work then necessary will depend primarily on the condition of the manhole structure and only secondarily on the coating material to be used. Fouling must, for instance, always be removed, using high-pressure jets of hot water (for removal of grease and loose particles), for example. Where corrosion has occurred, the damaged substrate must under all circumstances be removed, by means of ultra-high-pressure or solids blasting (for roughening of the remaining surface and exposure of the particulate structure). Where infiltration has occurred, the structure must in all cases be sealed, by means of injection, for example, prior to coating.

Renovation record the precondition for acceptance

A comprehensive renovation record is the precondition for any official acceptance inspection. This documentation should be taken into account as early as the tendering stage, and should include the entire refurbishing process, from condition surveying, via sealing provisions, substrate preparation, coating and after-treatment, up to and including acceptance inspection of the renovation project. The quality requirements resulting from the renovation targets should be noted for orientation purposes. The location and scope of any damage to be repaired, and the preparatory work performed in the manhole structure, should then, in particular, be recorded, as the basis for subsequent checking of any weak points. The times for the official acceptance inspection and guarantee acceptance inspection should be scheduled as a function of the particular method selected.

"Manhole renovation" training programme

A training programme intended to contribute to the improvement of quality and enhancement of efficiency of manhole renovation projects has been developed on the basis of the research results examined above. The scientific contents are augmented by the up-to-date practical experience of the system operators and the IKT test facilities. Contents are orientated around practical implementation of notes for planning and recommendations for manhole renovation. The methodological instruments for inculcation of the taught material take the form of exhibits from the research project, specimen renovation projects, talks with and by experts, technical papers and workgroups.

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Dipl.-Ing. Martin Liebscher
IKT - Institute for Underground Infrastructure

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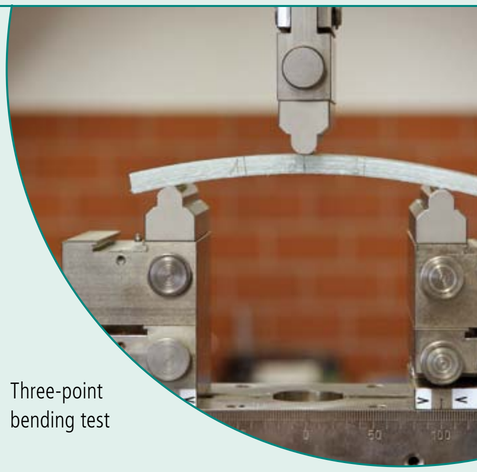
Tube liner quality reaches celebratory high level!



Three-point bending test

The tube liner's 40th anniversary found the process in top form; the test results for 2011 are a significant improvement over the previous year's level.

2011 was a red-letter year for the tube lining process - one in which it celebrated its 40th anniversary. This "round-figure birthday" was honoured in detail in numerous celebratory addresses and publications, in which the "tube liner family" proudly highlighted its method as the leading renovation technology for damaged waste-water conduits.

The degree to which claims and reality accorded in this anniversary year is illustrated by the eighth IKT – Institute for Underground Infrastructure LinerReport, presented here. This report is based on some 2,100 tube liner samples taken from sites during 2011 and analysed at the IKT tube liner test centre.

Table 1: Contractors and liner systems

Contractors	Liner systems	Liner type	Number of samples	IKT test commissioned by	
				Contractor %	Client %
AKS Umwelttechnik GmbH	Saertex Liner	GRP	51	0	100
Arkil Inpipe GmbH	Berolina Liner	GRP	117	0	100
Arkil Inpipe GmbH	Inpipe Liner	GRP	45	4	96
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	Alphaliner	GRP	84	14	86
Erles Umweltservice GmbH	Impreg Liner	GRP	61	23	77
Fleer-Tech GmbH	RS-CityLiner	NF	48	0	100
Geiger Kanaltechnik GmbH & Co. KG	Berolina Liner	GRP	26	12	88
Hamers Leidingtechniek B.V. (NL)	Alphaliner	GRP	27	100	0
Hertha Ehnes GmbH	Brandenburger Liner	GRP	34*	79	21
Insituform Rohrsanierungstechniken GmbH	Impreg Liner	GRP	115	9	91
Insituform Rohrsanierungstechniken GmbH	Insituform Schlauchliner	NF	181	3	97
Jeschke Umwelttechnik GmbH	Alphaliner	GRP	89	29	71
Jeschke Umwelttechnik GmbH	Brandenburger Liner	GRP	72	0	100
Kanaltechnik Agricola GmbH	Impreg Liner	GRP	42	81	19
Karl Weiss GmbH & Co. KG	Brandenburger Liner	GRP	51	47	53
KATEC Kanaltechnik Müller & Wahl GmbH	Alphaliner	GRP	41	80	20
KMG Pipe Technologies GmbH	Brandenburger Liner	GRP	44*	0	100
KMG Pipe Technologies GmbH	Saertex Liner	GRP	86	0	100
KTF GmbH	Impreg Liner	GRP	26	100	0
Max Bögl Bauservice GmbH & Co. KG	Brandenburger Liner	GRP	91	4	96
Rainer Kiel Kanalsanierung GmbH	Saertex Liner	GRP	146	31	69
Rohr Fuchs Rohrreinigungs GmbH	Impreg Liner	GRP	62	19	81
Rohrsanierung Jensen GmbH & Co. KG	Alphaliner	GRP	36	78	22
Swietelsky-Faber GmbH Kanalsanierung	Brandenburger Liner	GRP	100	0	100
TKT Jens und Lutz Meißner GbR	Alphaliner	GRP	233	9	91
Umwelttechnik und Wasserbau GmbH	Alphaliner	GRP	149	52	48
Van der Velden Rioleringsbeheer (NL)	Impreg Liner	GRP	34	97	3
Win-Line GmbH	Brandenburger Liner	GRP	25	44	56
Total			**2,116**	**22**	**78**

GRP: Glass-fibre backing material | NF: Needle-felt support material | *from four sites

Overview of test and inspection criteria

Modulus of elasticity (short-term flexural modulus)	Wall thickness (mean combined thickness)
• Tube liners must be capable of withstanding loads such as those arising from groundwater, road traffic and soil pressure • The modulus of elasticity is an indicator of load-bearing capability • Stability may be endangered if modulus of elasticity is too low • Test method: Three-point bending test as per DIN EN ISO 178 and DIN EN 13 566, Part 4* Results: see Table 2	• Minimum value is specified in the stress-analysis calculation • Wall thickness and modulus of elasticity jointly determine the stiffness of the liners • Excessively low wall thickness can endanger stability • Test method: Mean combined thickness is measured in accordance with DIN EN 13 566, Part 4**, using a precision slide gauge Results: see Table 4
Flexural strength (bending stress at rupture = short term-σ_{fb})	**Water tightness**
• This indicates the point at which the liner fails due to excessively high stress • If flexural strength is too low, the liner may rupture before the permissible deformation is reached • Test method: Increase of load up to failure in the three-point bending test; in accordance with DIN EN ISO 178 and DIN EN 13 566, Part 4* (short-term flexural strength) Results: see Table 3	• A cut is made into the inner film if the latter is not an integral component of the liners; the outer film (if any) is removed • Water containing a red dye is applied internally • A 0.5 bar partial vacuum is applied externally • The liner is „Not tight" if water penetrates through • Test period: 30 min. Results: see Table 5

* DIN EN ISO 11296, Part 4 superseded DIN EN 13566, Part 4 with effect from July 2011. The test results were evaluated on the basis of DIN EN 13566, Part 4, however, since the mechanical characteristics data (general building-supervision approvals) were determined on the basis of DIN EN 13566, Part 4.

** The procedure for determination of combined thickness has not been modified in DIN EN ISO 11296, Part 4, vis-à-vis DIN EN 13566, Part 4.

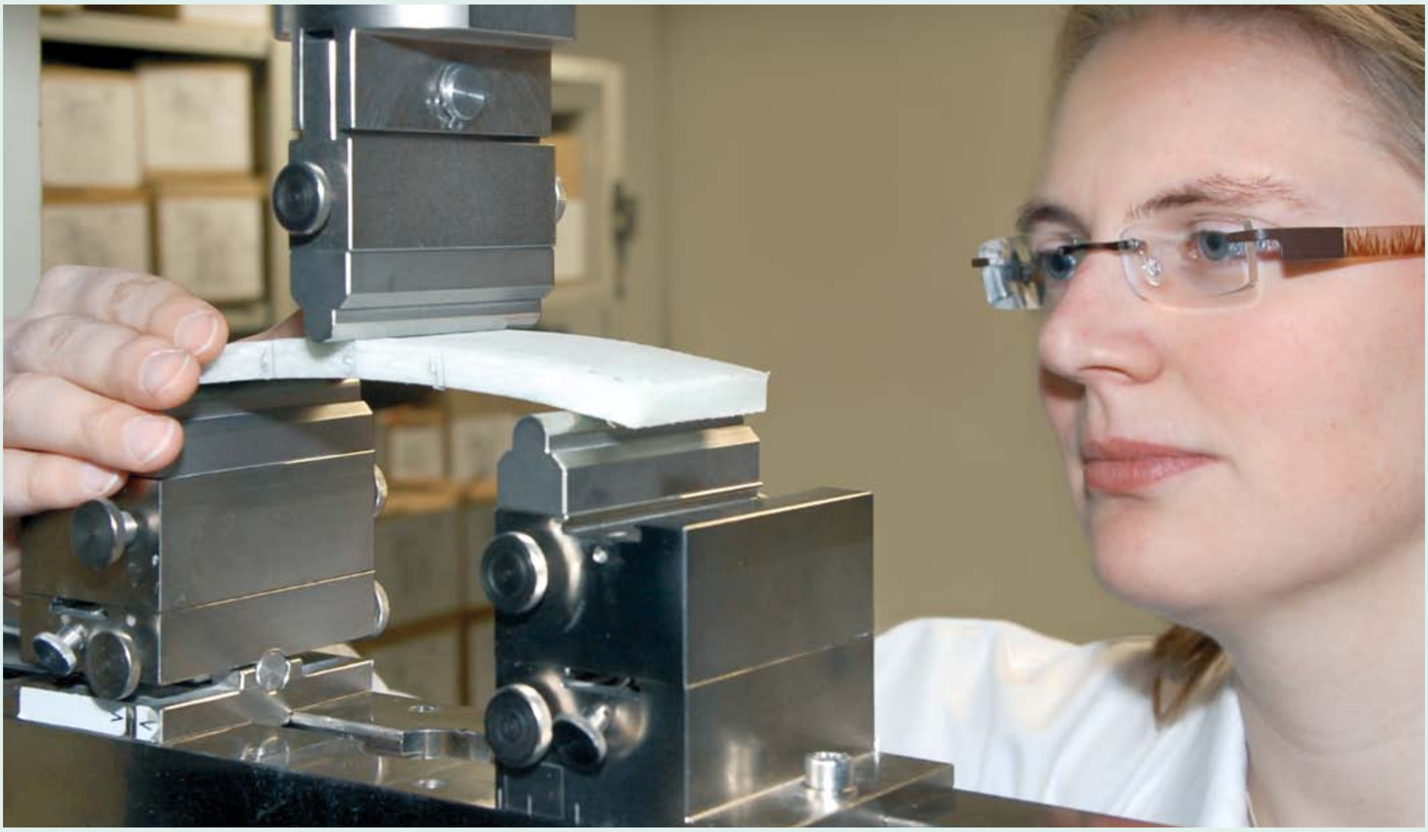
Data-base

The results obtained by those repair contractors from whom the IKT analysed not less than twenty-five liner samples obtained from five different sites are presented here. This requirement was fulfilled by twenty-four contractors, six more than in the previous year. Two of the contractors work only in the Netherlands, and are indicated by (NL) in the tables.

In 78% of cases, the clients (or their engineering consultancies) commissioned IKT directly for laboratory testing of liner samples, which were taken on site. 22% of the commissions originated from the repair contractors themselves (see Table 1).

Target/Actual analysis

The characteristics of modulus of elasticity, flexural strength, wall thickness and water-tightness of the tube liner samples taken from construction sites were analysed. The Actual values are compared against the Target data contained in the DIBt (German Institute for Building Technology) approvals, and against any divergent target data provided by the client. The target values for wall thicknesses are specified by means of statics calculations or by the client.



Three-point bending test on a tube liner

Table 2: Test results for modulus of elasticity (Short-term flexural modulus)

Contractors	2011		2010	Trend
	No. of samples	Target* achieved in % of tests	Target* achieved in % of tests	
Diringer & Scheidel Rohrsanierung GmbH	84		94.7	↑**
Erles Umweltservice GmbH	61		100.0	↔
Geiger Kanaltechnik GmbH & Co. KG	26		–	–
Hamers Leidingtechniek B.V. (NL)	27		–	–
Insituform Rohrsanierungstechniken GmbH using the Impreg Liner	115		100.0	↔
Jeschke Umwelttechnik GmbH using the Brandenburger Liner	72		–	–
Kanaltechnik Agricola GmbH	42		–	–
Karl Weiss GmbH & Co. KG	51		100.0	↔
KATEC Kanaltechnik Müller & Wahl GmbH	41	100.0	–	–
KTF GmbH	25		100.0	↔
Max Bögl Bauservice GmbH & Co. KG	72		–	–
Rohr Fuchs Rohrreinigung GmbH	62		98.4	↑
Rohrsanierung Jensen GmbH & Co. KG	36		–	–
Swietelsky-Faber GmbH Kanalsanierung	99		98.1	↑**
Umwelttechnik und Wasserbau GmbH	149		98.7	↑**
Van der Velden Rioleringsbeheer (NL)	34		–	–
Win-Line GmbH	25		–	–
Arkil Inpipe GmbH using the Berolina Liner	117	99.1	100.0	↓
Jeschke Umwelttechnik GmbH using the Alphaliner	89	98.9	100.0	↓
KMG Pipe Technologies GmbH using the Saertex Liner	86	98.8	90.0	↑
TKT Jens und Lutz Meißner GbR	233	98.7	100.0	↓
Average		**98.2**	**96.8**	↑
AKS Umwelttechnik GmbH	51	98.0	91.8	↑
KMG Pipe Technologies GmbH using the Brandenburger Liner	44	97.7	–	–
Rainer Kiel Kanalsanierung GmbH	118	97.5	99.1	↓
Hertha Ehnes GmbH	34	97.1	–	–
Arkil Inpipe GmbH using the Inpipe Liner	45	93.3	–	–
Fleer-Tech GmbH	48	91.7	–	–
Insituform Rohrsanierungstechniken GmbH using the Insituform-Schlauchliner	181	90.1	97.0	↓

* Target values as per client's data (statics / traveller card) | ** Different liner system used in 2010 than in 2011 | – Not evaluated, too few liner samples

There are two procedures for testing for water-tightness of needle-felt liners: with and without cutting of the inner film. The latter procedure is used in the case of liners for which the DIBt approval confirms that the inner film is an integral element relevant to tightness. On all other needle-felt liners, the inner film is cut.

GRP liners are in all cases tested without cutting, since they do not feature any inner film which remains in the conduit.

Table 3: Test results for flexural strength (Short-term-σ_{fb})

Contractors	2011		2010	Trend
	No. of samples	Target* achieved in % of tests	Target* achieved in % of tests	
AKS Umwelttechnik GmbH	51		100.0	↔
Erles Umweltservice GmbH	61		100.0	↔
Fleer-Tech GmbH	48		–	–
Geiger Kanaltechnik GmbH & Co. KG	26		–	–
Hamers Leidingtechniek B.V. (NL)	27		–	–
Hertha Ehnes GmbH	34		–	–
Insituform Rohrsanierungstechniken GmbH using the Impreg Liner	115		100.0	↔
Jeschke Umwelttechnik GmbH using the Alphaliner	89		100.0	↔
Jeschke Umwelttechnik GmbH using the Brandenburger Liner	72		–	–
Kanaltechnik Agricola GmbH	42		–	–
KATEC Kanaltechnik Müller & Wahl GmbH	41	100.0	–	–
KMG Pipe Technologies GmbH using the Saertex Liner	86		97.5	↑
KMG Pipe Technologies GmbH using the Brandenburger Liner	44		–	–
KTF GmbH	25		96.2	↑
Max Bögl Bauservice GmbH & Co. KG	72		–	–
Rainer Kiel Kanalsanierung GmbH	118		100.0	↔
Rohr Fuchs Rohrreinigung GmbH	62		98.4	↑
Rohrsanierung Jensen GmbH & Co. KG	36		–	–
Swietelsky-Faber GmbH Kanalsanierung	99		98.1	↑**
Van der Velden Rioleringsbeheer (NL)	34		–	–
Win-Line GmbH	25		–	–
Umwelttechnik und Wasserbau GmbH	149	99.3	100.0	↓**
TKT Jens und Lutz Meißner GbR	233	99.1	97.4	↑
Average		**98.5**	**96.0**	↑
Karl Weiss GmbH & Co. KG	51	98.0	96.3	↑
Arkil Inpipe GmbH using the Berolina Liner	117	95.7	100.0	↓
Diringer & Scheidel Rohrsanierung GmbH	84	95.2	100.0	↓**
Insituform Rohrsanierungstechniken GmbH using the Insituform-Schlauchliner	181	93.4	98.5	↓
Arkil Inpipe GmbH using the Inpipe Liner	45	84.4	–	–

* Target values as per client's data (statics / traveller card) | ** Different liner system used in 2010 than in 2011 | – Not evaluated, too few liner samples

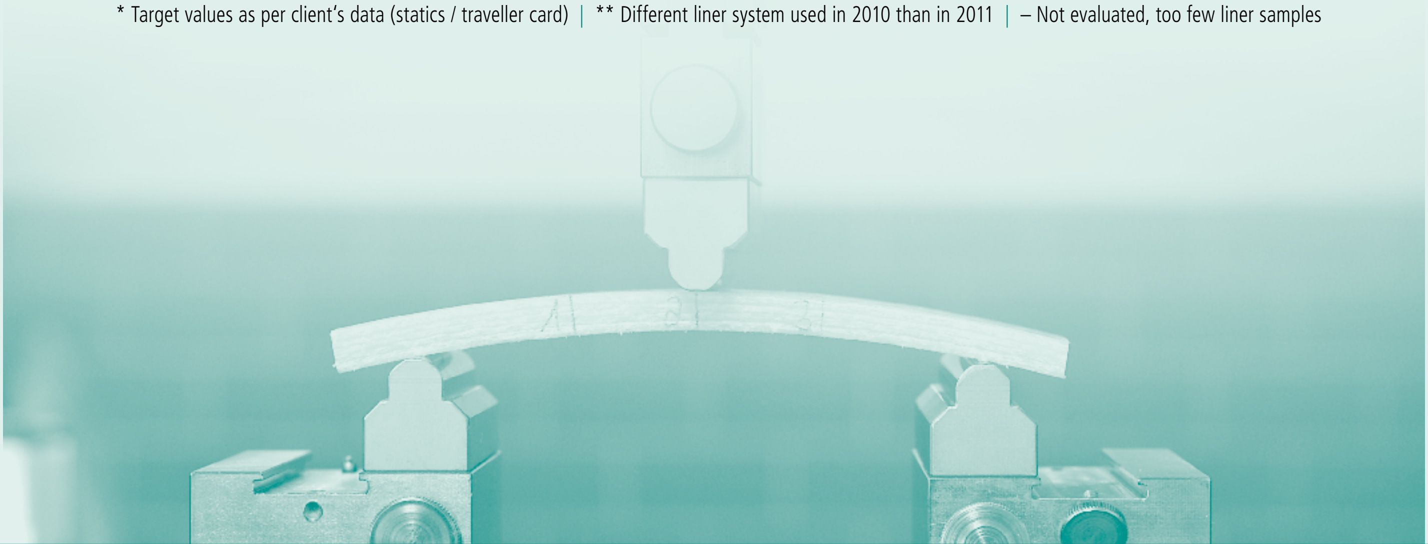
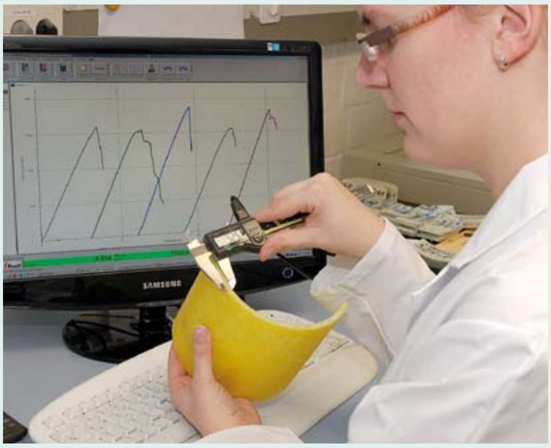


Table 4: Test results for wall thickness (mean combined thickness in accordance with DIN EN 13566, Part 4)

Contractors	2011		2010	Trend
	No. of samples	Target* achieved in % of tests	Target* achieved in % of tests	
Arkil Inpipe GmbH using the Berolina Liner	107	100.0	77.8	↑
Arkil Inpipe GmbH using the Inpipe Liner	42		–	–
Hamers Leidingtechniek B.V. (NL)	27		–	–
Insituform Rohrsanierungstechniken GmbH using the Insituform-Schlauchliner	140		80.0	↑
Jeschke Umwelttechnik GmbH using the Brandenburger Liner	65		–	–
Kanaltechnik Agricola GmbH	42		–	–
KTF GmbH	26		100.0	↔
Max Bögl Bauservice GmbH & Co. KG	69		–	–
Rohr Fuchs Rohrreinigung GmbH	53		98.4	↑
Rohrsanierung Jensen GmbH & Co. KG	36		–	–
Van der Velden Rioleringsbeheer (NL)	32		–	–
Swietelsky-Faber GmbH Kanalsanierung	100	99.0	52.7	↑**
Jeschke Umwelttechnik GmbH using the Alphaliner	83	98.8	100.0	↓
Fleer-Tech GmbH	44	97.7	–	–
Erles Umweltservice GmbH	42	97.6	98.3	↓
KMG Pipe Technologies GmbH using the Saertex Liner	78	97.4	87.9	↑
Umwelttechnik und Wasserbau GmbH	130	96.9	88.0	↑**
Insituform Rohrsanierungstechniken GmbH using the Impreg Liner	31	96.8	88.2	↑
Average		**96.2**	**89.1**	↑
Karl Weiss GmbH & Co. KG	46	95.7	70.6	↑
Diringer & Scheidel Rohrsanierung GmbH	60	95.0	100.0	↓**
TKT Jens und Lutz Meißner GbR	150	93.3	98.2	↓
KMG Pipe Technologies GmbH using the Brandenburger Liner	28	92.9	–	–
KATEC Kanaltechnik Müller & Wahl GmbH	35	91.4	–	–
Hertha Ehnes GmbH	34	91.2	–	–
Geiger Kanaltechnik GmbH & Co. KG	22	86.4	–	–
AKS Umwelttechnik GmbH	50	84.0	86.0	↓
Rainer Kiel Kanalsanierung GmbH	68	80.9	96.6	↓
Win-Line GmbH	25	80.0	–	–

* Target values as per client's data (statics / traveller card) | ** Different liner system used in 2010 than in 2011 | – Not evaluated, too few liner samples



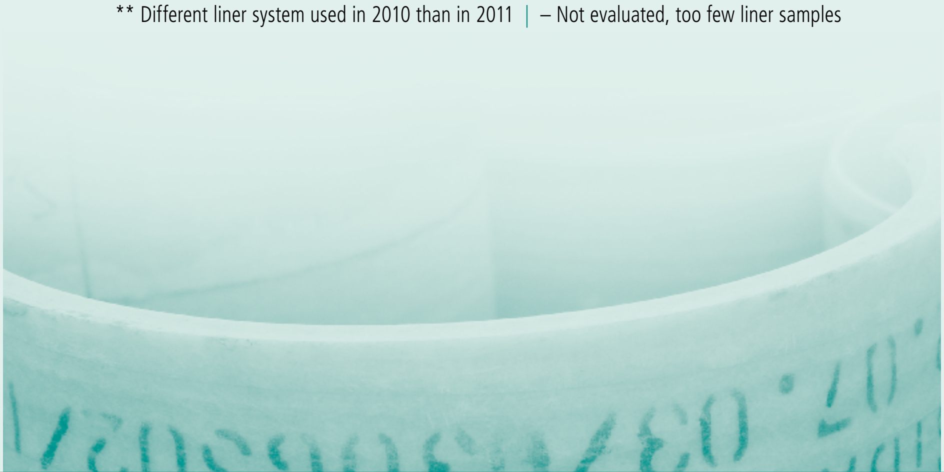
Liner-wall thickness is measured using a precision slide gauge

Tightness testing of tube liners

Table 5: Test results for water-tightness

<table>
<tr><th rowspan="2">Contractors</th><th colspan="2">2011</th><th>2010</th><th rowspan="2">Trend</th></tr>
<tr><th>No. of samples</th><th>Target* achieved in % of tests</th><th>Target* achieved in % of tests</th></tr>
<tr><td>AKS Umwelttechnik GmbH</td><td>51</td><td rowspan="18">100.0</td><td>100.0</td><td>↔</td></tr>
<tr><td>Arkil Inpipe GmbH using the Berolina Liner</td><td>117</td><td>97.8</td><td>↑</td></tr>
<tr><td>Arkil Inpipe GmbH using the Inpipe Liner</td><td>44</td><td>–</td><td>–</td></tr>
<tr><td>Diringer & Scheidel Rohrsanierung GmbH</td><td>84</td><td>100.0</td><td>↔**</td></tr>
<tr><td>Geiger Kanaltechnik GmbH & Co. KG</td><td>26</td><td>–</td><td>–</td></tr>
<tr><td>Hamers Leidingtechniek B.V. (NL)</td><td>27</td><td>–</td><td>–</td></tr>
<tr><td>Hertha Ehnes GmbH</td><td>34</td><td>–</td><td>–</td></tr>
<tr><td>Jeschke Umwelttechnik GmbH using the Alphaliner</td><td>63</td><td>100.0</td><td>↔</td></tr>
<tr><td>Jeschke Umwelttechnik GmbH using the Brandenburger Liner</td><td>72</td><td>–</td><td>–</td></tr>
<tr><td>Kanaltechnik Agricola GmbH</td><td>42</td><td>–</td><td>–</td></tr>
<tr><td>Karl Weiss GmbH & Co. KG</td><td>51</td><td>98.1</td><td>↑</td></tr>
<tr><td>KATEC Kanaltechnik Müller & Wahl GmbH</td><td>23</td><td>–</td><td>–</td></tr>
<tr><td>KTF GmbH</td><td>26</td><td>100.0</td><td>↔</td></tr>
<tr><td>Max Bögl Bauservice GmbH & Co. KG</td><td>91</td><td>–</td><td>–</td></tr>
<tr><td>Rohrsanierung Jensen GmbH & Co. KG</td><td>36</td><td>–</td><td>–</td></tr>
<tr><td>Swietelsky-Faber GmbH Kanalsanierung</td><td>100</td><td>98.1</td><td>↑**</td></tr>
<tr><td>Umwelttechnik und Wasserbau GmbH</td><td>106</td><td>100.0</td><td>↔**</td></tr>
<tr><td>Win-Line GmbH</td><td>24</td><td>–</td><td>–</td></tr>
<tr><td>TKT Jens und Lutz Meißner GbR</td><td>233</td><td>99.6</td><td>100.0</td><td>↓</td></tr>
<tr><td>Insituform Rohrsanierungstechniken GmbH using the Insituform-Schlauchliner, with no cut*</td><td>181</td><td>99.4</td><td>100.0</td><td>↓</td></tr>
<tr><td>Using thetelwert</td><td></td><td>98.9</td><td>98.4</td><td>↑</td></tr>
<tr><td>Rainer Kiel Kanalsanierung GmbH</td><td>146</td><td>98.6</td><td>100.0</td><td>↓</td></tr>
<tr><td>Rohr Fuchs Rohrreinigung GmbH</td><td>62</td><td>98.4</td><td>100.0</td><td>↓</td></tr>
<tr><td>Erles Umweltservice GmbH</td><td>61</td><td>96.7</td><td>100.0</td><td>↓</td></tr>
<tr><td>Insituform Rohrsanierungstechniken GmbH using the Impreg Liner</td><td>115</td><td>96.5</td><td>95.6</td><td>↑</td></tr>
<tr><td>KMG Pipe Technologies GmbH using the Saertex Liner</td><td>86</td><td>96.5</td><td>100.0</td><td>↓</td></tr>
<tr><td>KMG Pipe Technologies GmbH using the Brandenburger Liner</td><td>44</td><td>95.5</td><td>–</td><td>–</td></tr>
<tr><td>Van der Velden Rioleringsbeheer (NL)</td><td>34</td><td>94.1</td><td>–</td><td>–</td></tr>
<tr><td>Fleer-Tech GmbH</td><td>48</td><td>89.6</td><td>–</td><td>–</td></tr>
</table>

* With no cutting of integrated inner film/with cutting of the integrated inner film (at the request of the client)
** Different liner system used in 2010 than in 2011 | – Not evaluated, too few liner samples



Modulus of elasticity and flexural strength at high levels

The repair contractors all achieved extremely good results for the "modulus of elasticity" test criterion in 2011. The vast majority of the samples passed this test without any criticism whatsoever. Even the contractors with below-average test results are nonetheless extremely creditable, and achieve good results in more than 90% of all cases. The average of all tests passed has improved in comparison to the previous year by +1.4 percentage points (%P), to 98.2%. GRP liners improved by +0.8 %P, to 99.2% passed, and needle-felt (NF) liners by +3.5 %P, to 90.4% passed.

The test results for flexural strength are actually even slightly better: the average for all samples is 98.5% (+2.5 %P), the lowest score achieved being 84.4% passed, however. In comparison with the previous year, GRP liners score virtually just as well, at 98.9% passed (-0.3 %P), whereas NF liners have bettered their score by a noteworthy +17.8 %P, to 94.8%.

Wall thickness significantly improved

In the past, wall thickness has been the test criterion in which GRP liners regularly performed more poorly than NF liners. This remains the case in 2011, but on the basis of a significantly higher average score of 96.2% (+7.1 %P) achieved by all samples. Both GRP and NF liners have improved significantly compared to the previous year, by +7,1 %P, to 95.8%, and by 8.2 %P, to 99.5%, respectively.

Water-tightness nearly 100%

The score for water-tightness reaches a previously unattained 98.9% passed (+0.5 %P) on average. GRP liners remain unchanged at 99.1% tight of all cases, whereas NF liners have made a mighty leap forward, by a remarkable +7.0 %P, to 97.4%. The number of contractors achieving tightness in 100% of cases is again pleasingly high: no less than eighteen contractors supplied samples which achieved perfect tightness. Leaks are now also the exception for the other contractors, however, who diverged only very seldom from the top score.

Table 6: Test results by liner type

Linear system	Water-tightness: No. of samples	Water-tightness: Target* achieved in % of tests	Modulus of elasticity: No. of samples	Modulus of elasticity: Target* achieved in % of tests	Flexural strength: No. of samples	Flexural strength: Target* achieved in % of tests	Wall thickness: No. of samples	Wall thickness: Target* achieved in % of tests
Brandenburger Liner	416	99.5	397	99.5	397	99.7	367	96.5
Impreg Liner	340	97.4	339	100.0	339	100.0	226	99.1
Berolina Liner	143	100.0	143	99.3	143	96.5	129	97.7
Alphaliner	572	99.8	659	99.4	659	98.9	521	96.0
Inpipe Liner	44	100.0	45	93.3	45	84.4	42	100.0
Insituform Schlauchliner	181	99.4	181	90.1	181	93.4	140	100.0
RS CityLiner	48	89.6	48	91.7	48	100.0	44	97.7
Saertex Liner	283	98.2	255	98.0	255	100.0	196	88.3
Average		**98.9**		**98.2**		**98.5**		**96.2**

above the average

below the average

* Target values according to client's data (statics / traveller card)

Table 7: Test results compared to results for previous year

Liner type	Watertight in % of tests			Modulus of elasticity Target* achieved in % of tests			Flexural strength Target* achieved in % of tests			Wall thickness Target* achieved in % of tests		
	2011	2010	+/–	2011	2010	+/–	2011	2010	+/–	2011	2010	+/–
Averages												
of all samples	98.9	98.4	+0.5 ↑	98.2	96.8	+1.4 ↑	98.5	96.0	+2.5 ↑	96.2	89.1	+7.1 ↑
GRP	99.1	99.1	±0.0 ↔	99.2	98.4	+0.8 ↑	98.9	99.2	-0.3 ↓	95.8	88.7	+7.1 ↑
NF	97.4	90.4	+7.0 ↑	90.4	86.9	+3.5 ↑	94.8	77.0	+17.8 ↑	99.5	91.3	+8.2 ↑

GRP:Glass-fibre backing material

NF:Needle-felt backing material

* Target values as per client's data (statics / traveller card)

Conclusion

The test results obtained for 2011 by the IKT tube liner test centre demonstrate that water-tightness is, pleasingly, no longer a serious problem for tube liners. This was not the case in the past, and shows that the repair contractors take the subject of tightness very seriously, and have significantly improved their products and procedures. The same also applies to the mechanical test results, which have also followed an upward trend, with major leaps in some cases.

The needle-felt liners, which have in some cases fallen significantly behind the GRP liners in recent years, have achieved a considerable feat of catching up. Comparison against the previous year's results indicates that both GRP and NF liner manufacturers have worked on eliminating their respective weaknesses.

Despite tough price competition on the repair market, obviously no downward quality spiral has occurred, but rather the opposite, with achievement of improved on-site results. This positive trend may be attributed primarily to the heightened quality awareness of clients, who now have every tube liner project inspected and sampled, and insist on corresponding improvements in case of non-conformities. Ultimately, the publication of the test results will also have led to greater market transparency and comparability, and thus have increased the pressure for improvements in materials and in procedures.

It can, all in all, be ascertained that tube liners have achieved in 2011 a high quality level appropriate to their 40th anniversary celebrations. Our warmest congratulations!

The Authors

Dipl.-Ök. Roland W. Waniek
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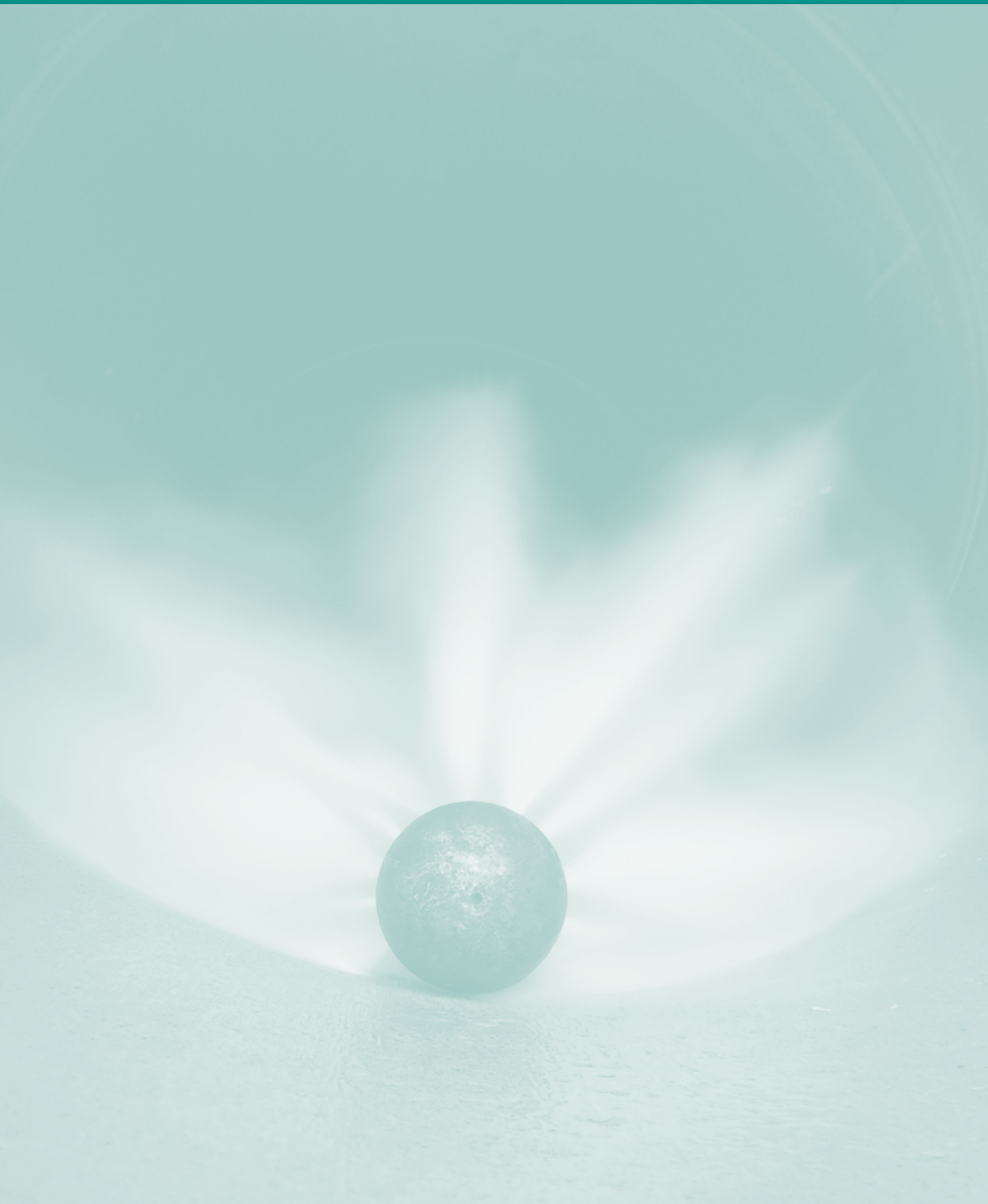
Dipl.-Ing. (FH) Nicole Leying
IKT - Institute for Underground Infrastructure



Inspection of pressure lines and culverts

Searching
for a pressure pipeline

The IKT has now completed the first project phase on "Inspection and state-registration of pressure waste-water lines and culverts". The aim of this initial phase was that of obtaining information on the general inspectability of such conduits using the available technology, on the preconditions for use and usability of the various inspection methods, and on the necessary cost and labour inputs.

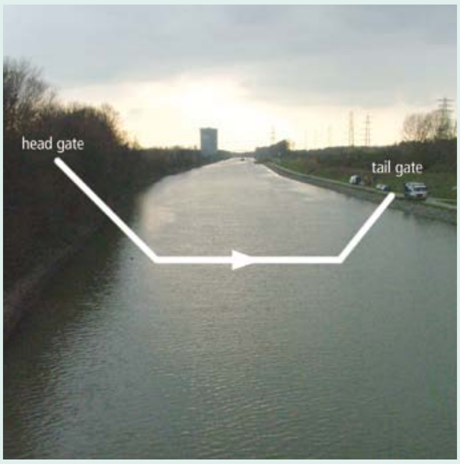
Results published

The German version of the detailed concluding report for the first project phase [1], and also an abridged version, are available for download on the Internet at: www.ikt.de

Pumping stations and waste-water pressure lines are frequent features of drain and sewer systems. They are used in sectors of these systems in which it is possible to implement drainage by means of gravity lines only with technical difficulty and/or at high cost. This is the case, in particular, where natural topographical gradients are lacking, where waste-water occurs only in small amounts and/or only periodically (due, for example, to low population densities), in case of the necessity of overcoming obstructions and in case of unfavourable underground circumstances as a result, for instance, of the presence of rock or of high groundwater tables.

In the German Federal State of North Rhine-Westphalia (NRW), some 90% of all drain/sewer operators (357 of a total of 396) operate pressure waste-water pipelines [2]. The total length of pressure waste-water pipes in the state is no less than 3,491 km, thus equating to just on 4% of the total public waste-water conduit system [2].

Waste-water culverts are among the "crossing elements" necessary when the course of pipelines encounters obstacles, such as rivers, for example. A total of 1,278 waste-water culverts are operated and maintained [2] by the 396 municipal waste-water system operators and eleven water boards in North Rhine-Westphalia. A survey of 208 system operators in NRW performed by IKT indicated that 131 (63%) of the operators polled have one or more culverts [3].



Course of a culvert underneath the Rhine-Herne Canal in Oberhausen; head and tail gate

Assurance of permanent good functioning is particularly important in the case of pressure lines and culverts. Blockages and resultant flooding (and thus hazards for the groundwater and for main drains), and also damage to connected property, may be the consequence if a pressure line or a pumping station fails, or if flow through a culvert becomes obstructed. Leaking conduits can result in waste-water escaping into the groundwater and/or soil, and may cause cavitation in the surrounding soil, with the result that harm to the surface cannot be excluded.

The (visual) assessment of condition is one of the customary operational tasks in the field of gravity drains and sewers. The situation is different in the case of pressure conduits. Maintenance and inspection activities are generally restricted to pumping stations and the venting valves of the conduits. Inspections are generally not scheduled during the operating period of these lines, and they are classified as "maintenance-free" under DWA (German Association for Water, Wastewater and Waste) Code 116-2 [4]. Numerous system operators are nonetheless confronted with the question of the condition of their pipelines, particularly if operational problems have already occurred. A decision as to whether a conduit should continue in operation, in order to utilise possibly still existing reserves of service-life, and thus save costs, or whether the conduit should be renewed or refurbished, will need to be taken, at the latest, toward the end of the scheduled period of service. This, however, is a decision which can scarcely be made without knowledge of the condition of the conduit.

Provisions for the assessment of condition are necessary to permit appraisal of the state of pressure pipelines. Access ports are either present only at great intervals, if at all, however, since inspections of pressure lines during operation are generally not envisaged at the original planning stage. In addition, the conditions for inspection are made more difficult by bends, partial or complete filling of the conduits, and rising and falling gradients. Many system operators are therefore uncertain of the extent to which inspections and/or appraisals of condition are possible, and concerning the methods available for these activities.

The recently completed project was commissioned by the NRW environment ministry against the background of the fact that experience in the assessment of the condition of pressure waste-water conduits is virtually totally lacking.

The initial project phase was supported in terms of content by a steering committee featuring the representatives of twenty-seven system operators. Research was firstly conducted into the methods available on the market for condition assessment; the civil-engineering boundary conditions of pressure waste-water conduits, the operating experience of the participating system operators and the various types and forms of damage were compiled in parallel. Test deployments of selected methods on existing pressure conduits owned by the operators were then conducted by way of example. The objective of this first project phase was that of obtaining information on the general "inspectability" of the conduits using the available technology, on the preconditions for use and general suitability for use of the inspection methods, and on the necessary financial and labour input, in order to permit derivation of initial recommendations for action concerning the inspection and appraisal of the condition of pressure waste-water conduits.

The operators' operating experience

As a survey of the participating system operators concerning measures for appraisal of the condition of pressure waste-water conduits illustrated, inspection and maintenance activities currently relate predominantly to pumping stations, valves, etc., and to venting stations. Pressure conduits in these systems had been tested for tightness by means of hydraulic pressure testing only in individual cases, or part-sections of conduits camera-inspected, generally in conjunction with operational problems and repairs.

On the basis of the experience of the steering committee, a large number of existing pressure conduits can continue to be operated without problems occurring and without any cleaning and/or inspection activities. The precondition for this is that the conduits were constructed in accordance with the requirements and have not, for example, proven to be overdimensioned, and that flow velocity does not fall below the specified minimum. Odour problems associated with pressure waste-water conduits do appear to be problematical for the overwhelming majority of operators, however. Such odour problems generally occur at the outlet from pressure conduits as a result of emissions of hydrogen sulphide, which is evolved in waste-water in the absence of oxygen after prolonged periods of immobilisation.

Declining pump delivery heads and rates, depositions, grease fouling of venting valves, valve corrosion and also, in isolated cases, damage to the conduit and/or blockages causing operational failures, were stated as problems occurring in the operation of pressure waste-water conduits.

When operational problems occur, the conduits approach their design service-life limit and/or greater operational reliability is desired in the case of large transmission pipelines, failure of which would cause serious consequences, system operators are frequently confronted with the question of how to determine and evaluate the condition of their conduits.

These conduits must, in principle, be replaced upon the expiry of their design service-life, in order to keep the likelihood of operational problems caused by damage to a pressure conduit as low as possible. A number of operators do in fact adopt this procedure. Others continue to operate conduits which have up to now not exhibited any problems beyond the design service-life, in order thus to save costs but at the risk of incurring unforeseeable operational problems. The KVR (Ruhr Regional Alliance) guidelines [5] for pressure pipe and culvert lines state an average operational service-life of 30 to 50 years, irrespective of their material. DWA Code 116-2 [4] states a figure of 50 to 80 years. The assumptions made by the operators are diverse, with periods of 40 to 80 years mentioned as scheduled service-lives.

By way of preparation for possible test deployments, operators who had proposed test sections from their own systems compiled the information available on their conduits. An evaluation demonstrated that only little data on the pressure conduits usually existed, and that in many cases neither the precise course of a conduit, nor the location and nature of bends were known. It did, it is true, prove possible to provide plans in most cases, but these contained information and data which largely failed to reflect the actual circumstances, while it was possible to estimate the location and gradient profile of the conduits only using known reference points, such as manholes and venting valves.

Types and forms of damage

A catalogue of types and forms of damage to pressure waste-water conduits was compiled in the context of a survey of the participating system operators. Evaluation demonstrated that only few damage patterns of informational value are available at present. Inspections, which could provide information on damage patterns, are not customary practice. Damage is therefore frequently only noticed when significant defects which restrict operation of the line occur, such as a ruptured conduit, for example. Such damage then necessitates immediate repair of the conduit, however. Further information obtained from the literature concerning types of damage occurring in drinking-water conduits consisting of similar materials was therefore used in order to expand the data-base, with the result that an initial overview of possible damage types is available for pressure waste-water conduits. A summary of the various types of damage can be found in the concluding report [1].

Methods for determination of condition

Numerous methods for determination of the condition of pressure conduits are available on the market. These, however, have mainly been developed specifically for inspection of oil and/or gas pipelines, or of community-heating and water supply pipes and industrial piping systems. They are therefore generally orientated around steel as the pipe material, and around the common DNs, access facilities and bends encountered in such systems.

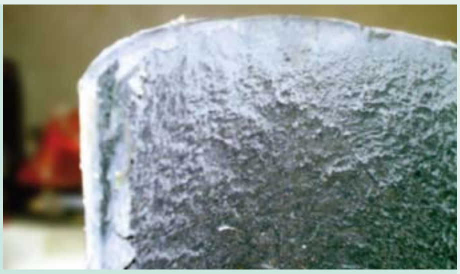
An overview of methods which can be considered in principle for determination of the condition of pressure waste-water conduits, and of their functioning principles, preconditions for use and costs, was drafted as part of this project. Commercially available technologies which have already proven their basic suitability for use in the context of waste-water drains/sewers and/or supply and industrial pressure conduits were primarily included in this overview:

- **Internal inspection methods**
  - In-conduit cameras and add-on modules
  - Inspection robots
  - Inspection pigs
  - Float-in and drawn inspection methods
- **External inspection methods**
  - Inspections of exposed pipe wall
  - Inspections of soil-covered pipes
- **Hydraulic pressure testing**
- **Tests performed on material samples**

Pitting corrosion in a grey cast iron pressure waste-water conduit (photo: Nuremberg Municipal Drainage and Environmental Analysis Services)

graphitised cast iron drinking-water pipe (photo: H.-C. Sorge)

Swollen asbestos-cement pipe in a pressure waste-water conduit (photo: Eastern Holstein municipal alliance)



Section from a corroded asbestos-cement pipe in a pressure waste-water conduit (photo Emmerich/Rhine municipal services)

Cracking at a flanged joint in a PVC pressure waste-water pipe at the pumping station (photo: Emmerich/Rhine municipal services)

Ovality caused by point load in an HDPE pressure waste-water conduit (photo: Emmerich/Rhine municipal services)

Deformation caused by point load in an HDPE pressure waste-water conduit (photo: Emmerich/Rhine municipal services)

Blistering

Blistering

Detachment of material on the pipe wall of an asbestos-cement drinking-water conduit (photo: M.J. Oomen BV)

Research on inspection methods, talks with manufacturers and practical deployments performed by way of example all illustrated that there is, at present, no "ideal" technology available on the market, using which inspections could be performed simply and cost-efficiently, as in the case of gravity conduits, and which would, in addition, supply adequate information on the condition of the conduit. Pressure waste-water conduits present more difficult boundary conditions than gravity conduits, due to the rarity or complete absence of access facilities, complete filling of the conduits, or at least of sections thereof, due to bends and, in addition, due to the in many cases not precisely known courses of the conduits and to the in some cases small nominal diameters (DNs).

It can be assumed that it will be possible to investigate the condition of many conduits only by means of a combination of various inspection methods, and with preparatory civil-engineering modifications involving a high technical and financial input. Conduits of diameters of 150/200 mm and above appear to be relatively easily inspectable, whereas the potentials are significantly poorer in the case of smaller diameters. The extent to which the necessary input is rational in each individual case will essentially depend on the operational importance of the individual conduit, and the hazard potentials its failure would present.

It remains, overall, to be ascertained that there are, up to now, no technologies available on the market which can, in general, be used for pressure waste-water conduits and/or culverts and which, simultaneously, will supply comprehensive information for evaluation of conduit condition. Where determination of the condition of a pressure conduit is required, it is necessary to select appropriate procedures on the basis of civil-engineering boundary conditions such as material, DN, type and distances between access facilities, potentials for evacuation, the type and number of bends, and of the pressure conditions and inspection target, such as obtainment of information on tightness and/or corrosion, etc., and to combine these technologies correspondingly.

An appropriate procedure on cost:benefit criteria would be to firstly test conduits for tightness by means of a hydraulic pressure test and then perform TV inspections on accessible conduits sectors, and also to record operational data, such as delivery flows, power take-up at the pump and pressure at the pumping station.

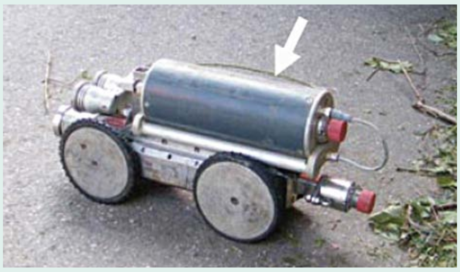
The work, etc., input necessary for hydraulic pressure tests varies depending on the facilities for sector isolation, the elevation profile and the potentials for venting of the particular conduit. Pressure conduits which rise continuously from the pumping station, and which are (almost) completed filled, can be tested comparatively easily. Such testing will be more difficult in the case of conduits with high and low points, and also gradients which empty toward the end of the conduit. Here, filling is more complicated, and high points with no venting facility mean that pockets of air may occur in the conduit and falsify the test. Where great elevation differences exist, it may be necessary to isolate individual sectors for testing.

Despite the fact that DIN EN 1610 [6] draws attention to DIN EN 805 [7] for acceptance inspection of pressure waste-water conduits, it should, nonetheless, be noted that this standard was, in principle, drafted for drinking-water conduits. The degree to which the respective detailed provisions can actually be applied to the situation in the waste-water sector must therefore be continuously assessed. The reasons for this are that, on the one hand, it is in many cases not possible to adhere to the civil-engineering boundary conditions assumed in DIN EN 805 in terms, for example, of accessibility, venting and isolation during the test. In addition, there are, on the other hand, no test criteria/limiting values for evaluation of the test result for tightness testing, since the hazard potentials relevant to the waste-water sector were not taken into account in EN 805. The question also arises of the extent to which the test pressures specified for acceptance inspection of new conduits are also in fact appropriate for tightness testing during ongoing conduit operation. Lower test pressures are specified in ATV-M 143, Part 6 [8] for tests performed on gravity lines than are required for acceptance testing of new conduits in accordance with DWA A 139 [9].

Where a pressure test supplies indications of leaks, the question arises of the conduit components on which the leaks are located. Leak detection using helium appears highly promising for this purpose. According to the supplier, dissolved helium is pumped with water through the conduit and then enters the soil via any leaks, and is detected using detectors at the surface. It has not yet been possible to observe any practical deployments of this method in the context of the project, however. The extent to which leak detection would also be possible using hydrophones, which register the typical sounds of escaping water, and can, for example, be floated in a ball through the conduit, or conveyed on a pig, is also questionable. Leaks in a long-distance drinking-water pipeline were detected in a monitored practical deployment of the SmartBall®, but the experience of the Water Research Centre (WRc, Swindon, UK) indicated that leaks in pressure waste-water conduits remain undetected if they have become covered with fouling.

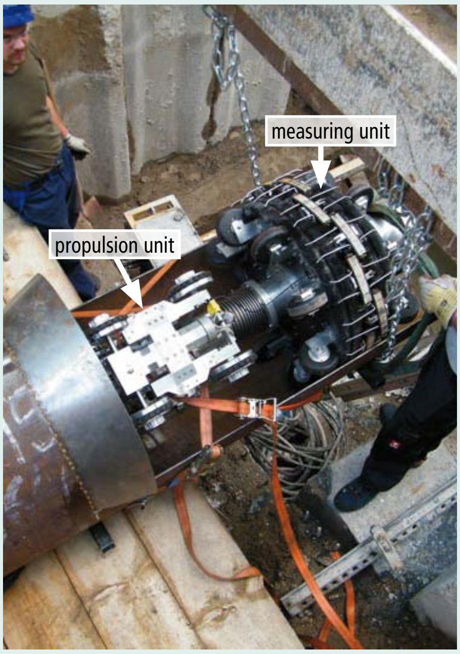
TV inspections are possible, at least on a distributed pattern at accessible points, in order to obtain approximate reference data concerning conduit condition. High points possibly featuring air pockets, in which corrosion can occur in the case of asbestos cement and cast-iron pressure conduits, in particular, are sites predestined for such inspections. It must be noted that purely visual inspection is of only limited informational value in the case of precisely these conduit materials, however, since not all types of corrosion and/or material abnormalities are visually perceptible. Inspection of the course of the conduit as a whole is possible only rarely without structural changes in pressure conduits, due to lack of accessibility, frequently restricted facilities for evacuation, and bends in the course of the conduit. Optical inspection using a tractor camera is, in any case, significantly more complex than in a gravity conduit, since it is necessary to stop operation of the conduits and drain them.

Towed video camera – an axial camera with suction-mount screen



Radar antenna on a camera tractor

The "towed video camera", an axial camera with a suction-mount screen for nominal diameters of between DN 50 and DN 250, is drawn into a pressure conduit by means of a partial vacuum, and proved to be a technology well suited to pressure waste-water conduits. Experience gained in practical deployments appears to indicate that it is realistic to assume inspection of up to 750 m of conduit in a single operation using this method, depending on nominal diameter and bends. The camera proved to be extremely capable of negotiating bends. Friction between the pipe wall and the cable naturally becomes higher, the more bends a conduit features, reducing actual range as a result. An estimate should be made in advance to determine whether evacuated pressure conduits will withstand a partial vacuum of up to 0.8 bar, i.e., a uniform external overpressure of the same magnitude. As in the case of the customarily used tractor cameras, it is necessary to ascertain the extent to which the types of damage relevant to the particular pipe material are visually perceptible.



Inspection robot featuring eddy-current inspection unit for internal inspections

It may be possible to use sewer radar for determination of the thickness of the remaining intact pipe wall in the case of asbestos-cement conduits. Potential uses are correspondingly limited by the fact that the sewer radar is conveyed through the conduit in combination with a tractor camera. It is also possible to determine the pH of the pipe wall by means of a phenolphthalein test on pipe specimens, in order to obtain information on any material abnormalities. The precondition for this is that the conduit can be exposed and a pipe specimen taken, however.

Electromagnetic methods can be used, where possible, for examination of cast-iron conduits for corrosion. The primary operation currently practicable is the external examination of a conduit, after its exposure. Pigs and robots incorporating such technology are also available; these are currently suitable for use in pressure waste-water conduits only in individual cases, however, due to the high costs involved and the lack of explosion-protection provisions. According to information from manufacturers, the prototype of a robot incorporating electromagnetic inspection technology, and to be tailored to the needs of pressure waste-water conduits, is currently undergoing testing. In addition, pipe specimens can also be taken and analysed in the laboratory for corrosion and other materials properties.

Instruments for measurement of deformation and/or cross-section are of interest for inspection of flexible pipes, for example, and in the context of preparations for refurbishing projects. Here, inspection using a calibration pig is, for instance, conceivable; it must be ensured in advance, however, that the conduits do not include any bend radii of less than 1.5xD or other obstructions such as major fouling deposits, for example. The laser light ring methods used in the gravity-line sector have, up to now, not featured explosion-safety provisions, and can therefore not be used with assured safety. Mechanical measuring systems which are conveyed through the conduit by means, for example, of a rope winch or a flushing hose, are also suitable for use only to a limited degree, due to these systems' restricted bend capability and/or the lack of suitable access to the conduit.

Inspection employing smart pigs derived from pipeline technology is conceivable for steel, and possibly also for cast-iron conduits (electromagnetic technology), and can, in the manufacturers' opinion, possibly also be adapted for inspection of PE and PVC systems (ultrasonics). These machines are suitable for the waste-water sector only in exceptional cases, however, as a result of their high mobilisation costs.

It must be remembered, in the case of random-sampling examination of a conduit, that conclusions concerning overall condition are permissible only to a limited extent. The damaged pipe elements obtained during repairs should in all cases be kept and further analysed if appropriate.

As became apparent during this project, the precise course of pressure lines is in many cases not known. Location methods are therefore the first necessity in conjunction with leak detection and/or with the refurbishing or replacement of the conduit along the same route. Here, bend-capable foamed-plastic ("polly") pigs carrying locating transmitters, and possibly also ground-penetrating radar (GPR) methods, can be used, depending on factors such as installation depth, conduit material and conduit overcover (and also other factors, such as soil type, and salt and water contents). The use of pigs bearing measuring systems for determination of location is also conceivable, always assuming adequate bend-capability.

The most important preconditions for the use of the inspection technologies examined here, and approximate cost horizons for inspection services, are compiled in the following tables in the form of an evaluation matrix; an initial estimation of applicability to pressure waste-water conduits and culverts is also provided. These tables can be used as an aid to preliminary selection of an inspection method suitable for determination of the condition of a pressure waste-water conduit. Detailed discussions of functional principles, applications and preconditions for use of these technologies can be found in the full version of the report, available at: www.ikt.de (German version)

Table 1: Internal-inspection methods: Sewer cameras and add-on modules – Preconditions for use and applicability in pressure waste-water conduits and culverts

Method	Inspection aim[1]	Conduit material and nominal diameters[1]	Most important preconditions for use[2]	Cost rates, examples[3]	Suitability for use in pressure waste-water conduits and culverts[4]
Sewer cameras and add-on modules					
Tractor camera	**Optical inspection**	• Not material-dependent • As from DN 100, frequently bend-capable only from DN 125/150 onward	• Inspection ports in course of conduit • Port spacings dependent on bends, nominal diameter, surface condition, etc. (from a few metres to several hundred metres) • Shut-down and drainage of the conduit	• approx. 800 €/d • Daily average practical deployments: 35-175 m/h	**Pressure waste-water conduits:** • Suitable for random inspection of accessible zones, in particular • Inspection frequently possible only in sub-sectors (inadequate access, bends) **Culverts:** • Suitable for partial or complete inspection, depending on culvert bends, gradients, length, etc. **General:** • Inspection lengths restricted by conduit bends, gradients, etc.; experience indicates significantly less than the tractor's maximum range (maximum inspection length system-dependent: 200 to 1,000 m) • Informational value of optical inspection restricted
Axial camera with suction-mount screen	**Optical inspection**	• Not material-dependent • DN 50 – DN 250	• Access at start and end of conduit • Inspection ports in course of conduit in conduits > 1,000 to 1,500 m in length • Shut-down and drainage of the conduit • Possibility of connecting a suction vehicle to the conduit • Maximum height difference in conduit: 8 to 9 m	• approx. 1,400 €/d • Daily average practical deployments: 60 m/h	**Pressure waste-water conduits:** • System tailored to pressure waste-water conduits, with good bend capability • Range restricted to max. 500 m (DN 50) to 750 m (DN 250); actual range dependent on number of bends • Capability of conduit to withstand partial vacuum of approx. 0.8 bar must be determined **Culverts:** • Deployment conceivable only in individual cases **General:** • Informational value of optical inspection restricted
Sewer radar	• **Residual wall thickness and bedding anomalies** in asbestos cement, concrete, PVC, GRP, stoneware • **Thickness of cement-mortar lining** in cast-iron and steel • As from DN 200		• Inspection ports (see "Tractor camera") • Shut-down and complete drainage of the conduit • Knowledge of original wall thickness/coating thickness (sampling/measurement if necessary)	• approx. 2,500-3,000 €/d not including tractor • approx. 3,500-4,000 €/d not including tractor	**General:** • Method of interest for non-destructive inspection of the pipe wall in asbestos-cement conduits, in particular **Pressure waste-water conduits:** • Suitable primarily for random inspection, due to limited range (see "Tractor camera") **Culverts:** • Suitable for partial or complete inspection, depending on culvert bends, gradients, length, etc.
Laser cross-section measurement	**Cross-section measurement**	• Not material-dependent • DN 150 to DN 1500	• Use in combination with tractor (see "Tractor camera") • Shut-down and drainage of the conduit	approx. 1.80 – 2.25 €/m	**Pressure waste-water conduits/culverts:** • Method not explosion-safe up to now, suitability for use in pressure waste-water conduits and culverts therefore dubious (complete exchange of air necessary) • Otherwise suitable for measurements of deformations in PE and PVC pressure conduits/culverts and may possibly supply information concerning material erosion caused, for example, by abrasive damage to internal coatings and/or by corrosion in cast-iron conduits • see also "Tractor camera"

1 According to manufacturer's information
2 According to manufacturer's information, supported by experience from practical deployments in some cases
3 Typical net costs, delivery costs to be added; according to supplier's information, costs vary greatly depending on local boundary conditions and order volume in individual cases
4 Estimation on the basis of preconditions for use of the methods and civil-engineering boundary conditions of pressure conduits, supported by experience from practical deployments in some cases

Table 2: Internal-inspection methods: Inspection robots – Preconditions for use and applicability in pressure waste-water conduits and culverts

Method	Inspection aim[1]	Conduit material and nominal diameters[1]	Most important preconditions for use[1]	Cost rates, examples[2]	Suitability for use in pressure waste-water conduits and culverts[3]
Inspection robots					
Camera	**Optical inspection**	• Not material-dependent • DN 75 – DN 750	• Inspection ports in course of conduit, spacing 500 m as from DN 130, every 100 m below this • Shut-down and drainage of the conduit	approx. 3,000-5,000 €/d	**Pressure waste-water conduits/culverts:** • Method not explosion-safe up to now, suitability for use in pressure waste-water conduits and culverts therefore dubious (complete exchange of air necessary) • Inspection robots appear to be suitable for conduits featuring bends and gradient lengths • Informational value of optical inspection restricted
Ultrasonics	**Measurement of wall thickness**	• Steel • DN 130 – DN 750	• Inspection ports in course of conduit, spacing 200 to 1,000 m, depending on conduit diameter • Shut-down and drainage of the conduit • Clean pipe surface • Complete filling of the conduit with particle-free water	approx. 7,000-10,000 €/d	**Pressure waste-water conduits/culverts:** • Method not explosion-safe up to now, suitability for use in pressure waste-water conduits and culverts therefore dubious (complete exchange of air necessary) • For use only in steel conduits, therefore only infrequent potentials for use • Complete filling with clean, particle-free water in clean pipe difficult to implement
Eddy current, combined with permanent magnet	**Detection of changes in wall thickness and/or corrosion**	• Steel DN 400 – DN 750 • Prototype for cast-iron conduits DN 400 – DN 600	• Inspection ports in course of conduit every 300 m	approx. 7,000-10,000 €/d	**Pressure waste-water conduits/culverts:** • Method not explosion-safe up to now, suitability for use in pressure waste-water conduits and culverts therefore dubious (complete exchange of air necessary) • Possibly of interest for the inspection of cast-iron conduits once the inspection technology has been completed

[1] According to manufacturer's information
[2] Typical net costs, delivery costs to be added; according to supplier's information, costs vary greatly depending on local boundary conditions and order volume in individual cases
[3] Estimation on the basis of preconditions for use of the methods and civil-engineering boundary conditions of pressure conduits, supported by experience from practical deployments in some cases

Table 3: Internal-inspection methods: Inspection pigs – Preconditions for use and applicability in pressure waste-water conduits and culverts

Method	Inspection aim[1]	Conduit material[1]	Most important preconditions for use[1]	Cost rates, examples[2]	Suitability for use in pressure waste-water and culverts[3]
Inspection pigs					
Ultrasonics	• **Measurement of wall thickness/corrosion** (quantitative) • **Inspection for cracking**	• Steel • Possibly cast steel • Possibly suitable for use with PE and PVC	• Methods generally available from DN 80 to 200, depending on procedure and manufacturer • Access port with fixed or temporary pigging valve • Differential pressure of 0.5 to 2 bar above operating pressure for pig propulsion, plus 0.5 to 2 bar for starting of the pig (depending on pig and pipe material) • Conduit negotiability: minimum conduit bend radii generally 1.5 to 3-fold pipe diameter necessary; no obstructions caused by fouling or impinging valve discs, etc. • Ultrasonics: complete filling of the conduit with clean, particle-free water • Acoustic leak location: a minimum pressure necessary (approx. 3 bar)	from approx. 60,000-80,000 €/deployment	**Pressure waste-water conduits:** • Use tested only in steel conduits up to now; rational in individual cases only, due to high costs **Culverts:** • Not suitable in principle for civil-engineering boundary conditions
Stray magnetic flux	• Detection of **changes in wall thickness and corrosion** (qualitative) • **Inspection for cracking**	• Steel • possibly cast-iron			**Pressure waste-water conduits:** • Use tested only in steel conduits up to now, rational in individual cases only, due to high costs **Culverts:** • Not suitable in principle for civil-engineering boundary conditions
Eddy current	• **Measurement of geometry** • Detection of **changes in wall thickness and/or corrosion** (qualitative)* • **Inspection for cracking***	• Steel • possibly cast-iron			**Pressure waste-water conduits:** • Use tested only in steel conduits up to now, rational in individual cases only, due to high costs **Culverts:** • Not suitable in principle for civil-engineering boundary conditions
Mechanical measurement of geometry	• **Measurement of geometry**	• Not material-dependent		from approx. 15,000 €/deployment	**Pressure waste-water conduits:** • Use conceivable, necessary to determine conduit negotiability (in terms of bends and obstructions) **Culverts:** • Not suitable in principle for civil-engineering boundary conditions
Acoustic leak location	• **Leak location**	• In principle not material-dependent**		approx. 6,000-11,000 €/deployment	**Pressure waste-water conduits:** • Use conceivable for leak location following tightness testing, but restricted suitability due to necessity of complete filling and a minimum pressure • Detectability of leaks possibly restricted by the sealing effects of fouling **Culverts:** • Not suitable in principle for civil-engineering boundary conditions
Geodetic locating	• **Locating**	• Not material-dependent		No data	**Pressure waste-water conduits:** • Use conceivable (depending on costs), necessary to determine conduit negotiability (in terms of bends and obstructions) **Culverts:** • Not suitable in principle for civil-engineering boundary conditions
Camera	• **Optical inspection**	• Not material-dependent		No data	**Pressure waste-water conduits:** • Visibility restricted due to propulsion using water, in addition to restricted informational value of optical inspection: use therefore not recommendable **Culverts:** • Not suitable in principle for civil-engineering boundary conditions
Locator transmitter (foamed-plastic pig from waste-water sector)	• **Conduit location**	• Not material-dependent		Cost example: Conduit DN 80, 420 m length: 2,300-3,900 €/deployment	**Pressure waste-water conduits:** • Good bend-capability thanks to combination of foamed-plastic pig and locator transmitter, use therefore possible in principle • Costly, due to necessity of walking the route on the surface **Culverts:** • Not suitable in principle for civil-engineering boundary conditions

* Purely eddy-current inspection applicable only in case of low wall thicknesses, therefore combination with other inspection technologies in some cases ** where typical background noise generated by the conduit material can be filtered out
[1] According to manufacturer's information
[2] Typical net costs, delivery costs to be added; according to supplier's information, costs vary greatly depending on local boundary conditions and order volume in individual cases
[3] Estimation on the basis of preconditions for use of the methods and civil-engineering boundary conditions of pressure conduits, supported by experience from practical deployments in some cases

Table 4: Internal-inspection methods: Floated-in and drawn technologies – Preconditions for use and applicability in pressure waste-water conduits and culverts

Method	Inspection aim[1]	Conduit material and nominal diameters[1]	Most important preconditions for use[2]	Cost rates, examples[3]	Suitability for use in pressure waste-water conduits and culverts[4]
Float-in and drawn methods					
Drawn-in mechanical diameter and deformation measuring system	• **Determination of diameter** Not material-dependent • **Measurement of deformation** (ovality) Flexible pipes • DN 150 - DN 1200		• Floating/drawing-in of a flushing hose/rope winch and/or insertion of a camera for conveyance of the measuring instrument; corresponding access ports necessary • No shapes (bends) in the conduit	approx. 1.80-3.00 €/m	**Pressure waste-water conduits/culverts:** • Measurement conceivable, but rarely useable, due to lack of bend-capability • Range restricted due to cable length (max. 400 m) and insertability/float-in capability of the conveying element (flushing hose, winch, camera)
Float-in hydrophone (e.g. SmartBall®)	• **Leak location** • **Location of air pockets**	• In principle not material-dependent* • DN 200 – DN 1600**	• Complete filling of the conduit for leak location; otherwise, detection of air pockets • Minimum pressure 3-4 bar • Minimum flow velocity 0.15-0.5 m/s • Conduit accessibility every 1,100-1,300 m for positioning of sensors • Necessary to assure conduit negotiability	approx. 4 €/m	**Pressure waste-water conduits:** • Use conceivable for detection of leaks following tightness test/detection of air pockets; detectability of leaks possibly restricted due to sealing action of fouling • Restricted usability, since minimum pressure, minimum flow velocity and complete filling necessary **Culverts:** • Not suitable in principle for civil-engineering boundary conditions
Drawn-in hydrophone (e.g. Sahara®)	• **Leak location** • **Location of air pockets**	• In principle not material-dependent* • DN 100 – DN 2700	• Complete filling of the conduit for leak location; otherwise, detection of air pockets • Minimum pressure > 1 bar • Access ports every approx. 100 – 1,000 m, depending on flow velocity and bends	No data	**Pressure waste-water conduits:** • Usability severely restricted: in the supplier's experience, fouling in the pressure waste-water conduit tends to seal leaks • Further restricted usability, due to necessary minimum pressure and complete filling • Only partial inspections possible if access ports lacking along the course of the conduit **Culverts:** • Not suitable in principle for civil-engineering boundary conditions
Drawn-in carrier-unit with ring laser gyroscopes and position encoders (e.g. DuctRunner™)	• **Locating**	• In principle not material-dependent • DN 40 – DN 1200	• Floating-in of a steel cable for subsequent drawing-in of the measuring instrument • Conduit negotiability: minimum bend radii in conduit must be 1.5 to 3-fold pipe diameter; also, no obstructions caused by fouling deposits and/or impinging valve disks, etc.	approx. 4,000 €/d	**Pressure waste-water conduits/culverts:** • Measurement conceivable, given corresponding bend-capability for the instrument • Inspectability primarily dependent on ability to flush in steel cable • Conduit's capability to withstand loads exerted by steel cable in bends must be investigated, particularly in the case of asbestos-cement conduits

* provided typical background noise generated by the conduit material can be filtered out ** suitable for use between DN 200 and DN 600, with restrictions
[1] According to manufacturer's information
[2] According to manufacturer's information, supported by experience from practical deployments in some cases
[3] Typical net costs, delivery costs to be added; according to supplier's information, costs vary greatly depending on local boundary conditions and order volume in individual cases
[4] Estimation on the basis of preconditions for use of the methods and civil-engineering boundary conditions of pressure conduits, supported by experience from practical deployments in some cases

Table 5: External-inspection methods: Methods for inspection of exposed pipes - Preconditions for use and applicability in pressure waste-water conduits and culverts

Method	Inspection aim[1]	Conduit material and nominal diameters[1]	Most important preconditions for use[2]	Cost rates, examples[3]	Suitability for use in pressure waste-water conduits and culverts[4]
Inspection of exposed pipes					
Electromagnetic inspection systems (e.g. SLOFEC™)	• Detection of **changes in wall thickness and/or corrosion** (qualitative)	• Steel, cast iron • from approx. DN 50	• Uncovering of the pipe sector to be inspected • Possibly necessary to remove anti-corrosion coatings, depending on material and thickness • Knowledge of the conduit material and original wall thickness necessary for calibration of the measuring instrument	approx. 2,000 €/d	**Pressure waste-water conduits:** • Method suitable in principle for use with cast-iron and steel pressure waste-water conduits • Limited informational value of random-sampling inspection **Culverts:** • Uncovering of culvert normally not possible, due to the obstacles traversed
Ultrasonic measuring systems (e.g. DSM GO)	• **Measurement of wall thickness** (distributed measurement of pipe wall)	• for steel, cast iron, PE, inter alia • Not dependent on DN	• Uncovering of the pipe to be inspected • Possibly necessary to remove anti-corrosion coatings, depending on material and thickness • Knowledge of the conduit material and original wall thickness necessary for calibration of the measuring instrument	approx. 50-90 €/h (Measuring instrument: approx. 8,000 €)	**Pressure waste-water conduits:** • Method suitable in principle for use with cast-iron and steel pressure waste-water conduits • Extremely restricted informational value due to only distributed inspection using ultrasonic probe **Culverts:** • Uncovering of culvert normally not possible, due to the obstacles traversed
Ultrasonic measuring systems (e.g. Wavemaker™)	• Detection of extensive **corrosion** and **cracking** (inspection of conduit sections)	• Steel, cast iron • DN 25 – DN 1000	• Uncovering of the conduit at intervals of 1 to 50 m, depending on conduit material, included sockets, flanges, welds, bends, etc. • Knowledge of the conduit material and original wall thickness necessary for calibration of the measuring instrument	approx. 2,000 €/d	**Pressure waste-water conduits:** • Method not practicable, due to necessity of uncovering pipe sections at short intervals, range of ultrasonic signal in the case of bitumen-coated conduits is estimated at 1 to 5 m, for example **Culverts:** • Uncovering of culvert normally not possible, due to the obstacles traversed

[1] According to manufacturer's information
[2] According to manufacturer's information, supported by experience from practical deployments in some cases
[3] Typical net costs, delivery costs to be added; according to supplier's information, costs vary greatly depending on local boundary conditions and order volume in individual cases
[4] Estimation on the basis of preconditions for use of the methods and civil-engineering boundary conditions of pressure conduits, supported by experience from practical deployments in some cases

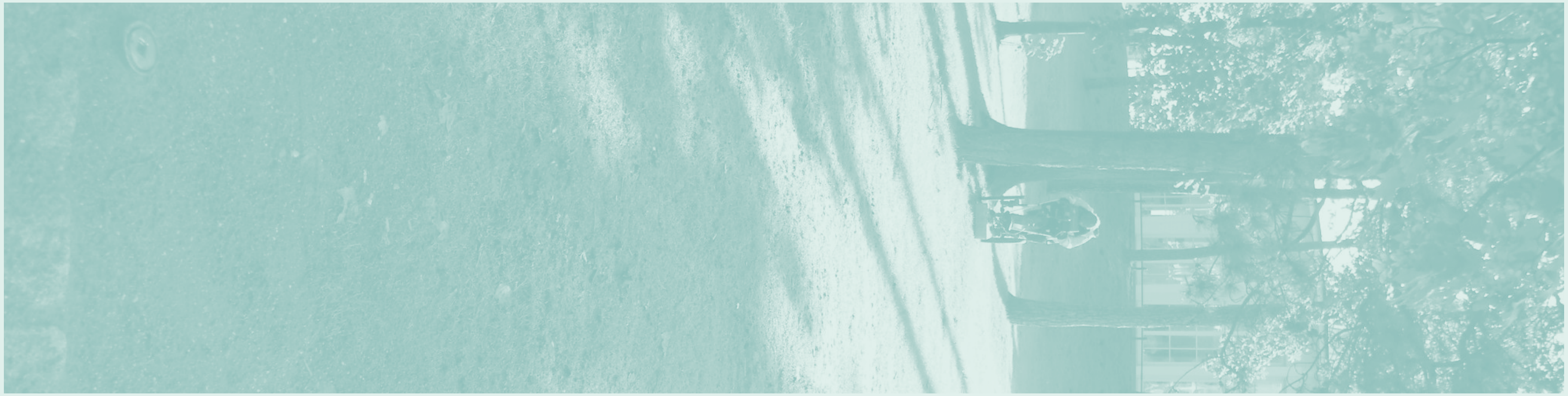


Table 6: External-inspection methods: Methods for inspection of soil-covered pipes – Preconditions for use and applicability in pressure waste-water conduits and culverts

Method	Inspection aim[1]	Conduit material and nominal diameters[1]	Most important preconditions for use[2]	Cost rates, examples[3]	Suitability for use in pressure waste-water conduits and culverts[4]
Inspection of buried pipes					
Acoustic leak location (ground microphone)	• **Leak location**	• In principle not material-dependent • In principle not dependent on DN	• Minimum pressure of 1 to 10 bar, depending on pipe material • Complete filling of the conduit	approx. 270 €/2h, for every further hour approx. 75 €/h	**Pressure waste-water conduits:** • Suitability dubious, due to a number of factors, such as interference from pump noise, and also the necessary minimum pressure and complete filling • In the supplier's estimation, fouling in pressure waste-water conduits tends to seal leaks **Culverts:** • Not possible, due to passage under obstructions in the conduit route
Leak location using dissolved **helium**	• **Leak location**	• In principle not material-dependent • In principle not dependent on DN	• Facility for connection of a metering system (e.g. flange in the pumping station) • Minimum pressure of 1 bar, with corresponding complete filling of the pipe section to be inspected	approx. 5,300 – 6,300 € for leak location on a 1 km conduit	**Pressure waste-water conduits:** • Leak location using dissolved helium appears to be possible and practicable; the precondition is filling of the conduit sections with helium-enriched water (ponding at the end of the pressure conduit may be necessary) **Culverts:** • Restricted suitability, depending on the obstacle traversed (e.g. river), must be anticipated
Thermography	• **Leak location** • **Conduit location**	• In principle not material-dependent • In principle not dependent on DN	• Temperature differences generated by pressure conduit/leaks necessary • Only suitable for conduits not located in built-up areas • Necessity for most precise possible knowledge of the conduit route, and also of factors such as soil type and vegetation	Walking of the route with a hand-held camera: 1,500 €/d Overflight (aerial survey): > 9,000 €/d	**Pressure waste-water conduits:** • Leak location may be possible, but presupposes variations in soil moisture content caused by leak; conditions made more difficult in many cases by lack of knowledge of the precise conduit route • Conduit locating appears not to be possible, due to only slight temperature differences between the waste-water and the soil, and also in many cases to lack of knowledge of the precise conduit routes **Culverts:** • Normally not possible, due to passage under obstructions in the conduit route
Ground-penetrating radar	• **Conduit location** • Detection of **bedding anomalies**	• In principle not material-dependent • In principle not dependent on DN	• Pedestrian/vehicle accessibility of the area to be investigated • Suitability dependent on numerous boundary conditions (such as soil type, water content, groundwater table, salt content, terrain surface), and must be estimated by suppliers in each individual case	Individual radar antenna: 2,500 – 3,000 €/d; Complex measuring technology*: 12 €/m²	**Pressure waste-water conduits:** • Use conceivable, but as many boundary conditions of the sub-surface zone (and all conduit routes, in particular) should be known, in order to exclude possibility of incorrect interpretations • Conduit locating complex (movement at right-angles to the pipe axis) **Culverts:** • Suitability dependent on pedestrian/vehicle access to the obstacle traversed (see "Pressure waste-water conduits" for further notes)

* Example: "Detectino" ground-penetrating radar, featuring five radar antennas, referencing function and electromagnetic sensors

[1] According to manufacturer's information
[2] According to manufacturer's information, supported by experience from practical deployments in some cases
[3] Typical net costs, delivery costs to be added; according to supplier's information, costs vary greatly depending on local boundary conditions and order volume in individual cases
[4] Estimation on the basis of preconditions for use of the methods and civil-engineering boundary conditions of pressure conduits, supported by experience from practical deployments in some cases

Determination of conduit condition: recommendations for action

The appropriate and rational scope of investigation, and the investigation targets for pressure conduits, taking account of cost:benefit aspects, have been discussed on a co-operative basis with the steering committee of participating system operators on the basis of the information concerning the preconditions for use and costs of currently available methods, and the experience gained in test deployments. Generalised and regular inspection of all pressure conduits, as is customary in the case of gravity lines, is consequently deemed to be unreasonably complex and expensive. The market can thus be said not to provide the technologies necessary to permit inspection of all conduits at rational expense. There are, for conduits of less than 100 mm diameter, scarcely any potentials for determination of condition, while inspection of larger-diameter conduits is possible only to a limited degree, and/or at extremely high complexity and cost. In addition, the experience of the system operators participating indicates that pressure lines can be operated without problems occurring and without further examination throughout the design service-life, and beyond this in some cases, if odour problems caused by hydrogen sulphide are set aside. The efficiency of pressure waste-water conduits vis-à-vis gravity lines is also revealed in their daily operation. Functional problems are discovered significantly earlier than in the case of gravity lines, particularly if delivery rates are MID-monitored and assessed against delivery pressures at the pumping station, machine speeds and energy consumption.

Operationally and cost-optimised provisions for determination of condition, rather than generalised periodic inspections, therefore appear rational in the case of pressure waste-water conduits. The IKT has, jointly with the participating system operators, drafted a three-stage procedure:

Stage 1: Data acquisition concerning the pressure-conduit system

As a first stage, all available data on the pressure conduits operated should be compiled and continuously updated. An obvious procedure here is to collate and record information on, for example, year of manufacture/installation and planned service-life, material and nominal diameter, information concerning any operational problems, damage and/or repairs which have occurred, and also data concerning catchment area and waste-water yield.

Stage 2: Risk assessment

The best option for the second step is a risk assessment for every conduit, to permit a decision concerning whether, and to what extent, inspections are necessary. Risk classifications of "Low", "Medium" and "High" can be derived via estimation of the probability of occurrence of damage/operational failure and of the consequences/severity of damage. The risk levels which are tolerable,

and those at which provisions for minimisation must be initiated, must then be ascertained on the basis of the operator's safety requirements.

Stage 3: Provisions for determination of condition

Priorities, and the scope of any further provisions to be applied to the pressure conduit system, can be defined during the next stage, on the basis of the operator's risk assessment. There is always, in principle, a greater need for action in the case of high-risk conduits than in the case of medium-risk conduits.

The detailed recommendations for action can be found in the report – available for download at: www.ikt.de (German version)

Outlook

Discussion of the project results with the participating system operators confirmed the great need for more extensive investigations into the topic of "Determination of the condition of pressure waste-water conduits". Five main focuses were established:

1. The recommendations for action elaborated during this project provide for the initiation of inspection provisions of a type and scope based on a risk assessment orientated around the probability and effects of damage to/failure of/operational problems in pressure waste-water conduits. Up to now, however, there has been a lack of reliable evaluation criteria to permit substantiated determination of failure risks for estimation of the probability of damage/operational failure of such conduits.

2. The technologies currently available, including those intended for other types of conduit (gas systems, pipelines, etc.), do not permit economically rational use in pressure waste-water conduits. There is therefore an immense need for development of systems for the determination of the condition of pressure waste-water conduits. It may be possible to combine methods already in widespread use in the waste-water sector, such as tractor cameras and foamed-plastic pigs, with more extensive inspection techniques used in the industrial sector. The use of new technologies is of interest in this context not only for determination of condition during conduit operation, but also for the planning and tendering procedures for renewal and repair projects. Here, suitable requirement profiles for the (further) development of inspection methods have been drafted in close co-operation between system operators and technology suppliers.

3. Tightness tests can be performed on pressure waste-water conduits only with significantly greater difficulty than on gravity lines as a result, for example, of the lack of facilities for access and/or venting. There are no dedicated technical codes and rules for the inspection of existing soil-covered pressure waste-water conduits. DIN EN 1610 [6] merely draws attention, for the purpose of project acceptance, to the inspection procedures set down for drinking-water conduits in DIN EN 805 [7]. The extent to which this inspection method can be applied to existing pressure waste-water conduits at all, and the appropriate inspection criteria and limits, requires clarification.

4. The action chart developed does not, up to now, include any recommendations for the stipulation of intervals for determination of condition. Operational planning (estimation of expenditure) is significantly dependent on this, however. The extent to which general principles for the specification of intervals for determination of condition, or even guide figures for these intervals, can be developed, remains unclear at present.

5. Knowledge of the refurbishing/repair methods available on the market, and of their preconditions for use and their costs, is needed. The costs and the use of provisions for the determination of the condition of pressure waste-water conduits should, on the one hand, be lower and simpler than those for repair and for renewal. Preparations for a repair/refurbishing project may, on the other hand, necessitate separate determination of condition, such as, for example, measurements of deformations in the existing conduit.

Results available in the Internet

This article discusses only extracts from the research project. Both an abridged and a detailed complete version of the concluding report can be downloaded from the Internet at: www.ikt.de (German Version)

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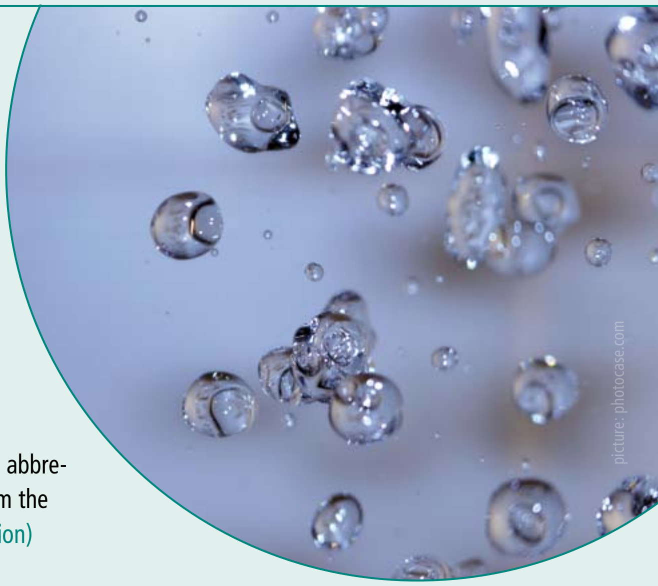
Pipes tight against infiltration, too!



The IKT research report covering the field of "Elimination of infiltration" makes the point: even if a waste-water conduit passes the internal-pressure test, this is by no means a guarantee that it will be tight against external groundwater pressure.

What new perceptions has the first project phase generated?

Infiltration frequent at points of material change and size transitions

Modern acceptance tests for the tightness of waste-water conduits are orientated solely around the internal-pressure test. In the case of waste-water conduits located in the groundwater, however, the internal-pressure test can, in individual cases, result in incorrect assessments of the assumed infiltration tightness of the system, particularly in cases in which the sealing systems involved react differently to internal and external pressure.

The detailed, full-length report and an abbreviated version can be downloaded from the Internet at: www.ikt.de (German Version)

Typical sites of weakness can be found at points of material change and of diameter transitions and also at adhesively bonded joints between existing piping stock and repair materials. Acceptance criteria and test procedures were elaborated for these weak points during Phase I of this multistage IKT project. The results at a glance:

- Overview of all functional principles of jointing technology and of the standards and codes applicable to pipe shapes and sealing systems
- Market surveys of the products used at points of material and/or diameter transition
- Specimen tests of the infiltration tightness of sleeves / couplings for new conduits, connection of manholes in conduits and tube liners, and on expanding sealing materials
- Initial conclusions concerning acceptance criteria for points of material change and model computations on the infiltration capacity of leaking conduits

Where should clients focus at acceptance?

Positive pressure tests using air or water presuppose identical behaviour of the sealing systems under exposure to both internal and external hydraulic pressure. Further provisions at acceptance are advisable, if this is not the case, or is, at least, in doubt:

1. Inclusion of qualification analyses (as early as the award of contract stage), including, for example, verification of infiltration tightness by means of supplementary product tests

2. Examination of on-site documentation, including that applying, for example, to preparation of conduit surfaces, in view of the interaction between old and new material

3. Modification of acceptance-inspection procedures, including the performance, for example, of modified positive pressure tests using test pressures related to the groundwater table, in combination, where appropriate, with negative pressure tests and visual infiltration assessments

Typical weaknesses: points of material change and/or size transition

Conclusion

The action of jointing systems under exposure to external hydraulic pressure can in many cases be determined only with precise observation of the design details, including bonding effects and thrust mechanisms, for example. These aspects must be taken into account in planning, implementation and project acceptance; the IKT report contains detailed civil-engineering notes concerning installation of jointing systems, taking due account of infiltration tightness criteria.

Prospects

The NRW environmental ministry‘s support project should be continued. The aim here is that of obtaining more extensive perceptions concerning the performance, and of the limitations on use, of the product groups intended for elimination of infiltration.

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picture: kunstfisch, photocase.com

Connex sewer laterals with ball joint score "GOOD"

Funke Kunststoffe GmbH's "Connex connection with ball joint" achieved the "GOOD" (1.9) test verdict in the IKT's "Private Sewer Laterals" product test. The installation of a ball joint resulted in visibly improved resistance to structural and operational loads compared to the original sewer lateral model.

On test

After many years of practical use, Funke Kunststoffe GmbH wanted to determine precisely how its Connex connection with ball joint would perform in the "Private Sewer Laterals" test programme. For this purpose, Funke commissioned the IKT to conduct a precise analysis of the suitability of the Connex connection with ball joint for practical use. The test was performed in accordance with the conditions specified for the IKT "Private Sewer Laterals" product test.

The Connex connection passed the test programme with the grade of "GOOD" (1.9) and has thus been awarded the IKT product test seal of quality.

The main evaluation criterion in the IKT product test is the tightness of the sewer laterals both after installation and after exposure to structural and operational loads.

Connects differing materials

The Connex connection with ball joint can be used to connect laterals with main drains consisting of differing pipe materials. The sewer lateral can be installed in main drains consisting of rigid PVC, GRP, PP, asbestos cement or fibre-reinforced cement (FC). The outgoing connecting lines can consist of rigid PVC and PP, or of other materials, such as GRP, PP (corrugated/ribbed), cast iron and/or stoneware, provided suitable adapters are used.

System test on the Connex connection

A total of three models have been developed for the various wall thicknesses and nominal diameters of DN 150/DN 200 of the connecting pipes. The Connex DN/OD 160/162 connection, which was conceived for DN 150 connecting lines and main-conduit wall thicknesses of between 3 and 15 mm, was examined in the context of the IKT product test.

Connex connection following installation
(from site study)

The Connex connection was subjected to detailed testing under structural and operating conditions in drain/sewer test lengths at the IKT. More extensive on-site studies examined the handling characteristics of the Connex connection with ball joint under in-situ conditions, with influencing factors such as available space, prevailing weather and/or time pressure.

The tests were conducted in accordance with the test programme developed jointly with fourteen system operators for the IKT "Private Sewer Laterals" product test. The test, completed in June 2002, combines the system operators' practical and operational experience with the IKT's scientific expertise. The test focuses on system testing of installed sewer laterals, on the evaluation of information provided by the manufacturer (such as the installation manual, for example) and on on-site tests. This test, which continues to be completely up-to-date, can be performed by sewer lateral suppliers at any time, whether on sewer lateral models already tested and subsequently improved, or on totally new developments.

Results available in the Internet

This article contains only extracts from the complete results. The detailed report can be downloaded from the Internet at: www.ikt.de (German Version)

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(Result table on the following page)

IKT "Private Sewer Laterals" product test

Manufacturer **Model**	Funke Kunststoffe GmbH CONNEX - sewer lateral, DN/OD 160/162 with ball joint 
Price for one sewer lateral / 100 sewer laterals in Euro, approx.	95.00 / 8,300.00
IKT test verdict	**GOOD** **(1.9)**
System test (weighting: 85%)	Good (2.0)
Sewer lateral installed in main pipes consisting of:	Rigid PVC pipe DN/OD 315
Sewer lateral connected to pipes consisting of:	Rigid PVC pipe DN/OD 160
Tightness after installation*	++
Tightness after loading**:	
after HP cleaning	+
after flailing	-
after angling off	+
after shear loading	+
Manufacturer's information (weighting: 15%)	Very good (1.0)
Installation manual***	++
Test certificates****	++
Additional information: On-site boundary conditions	
High space requirement	No
High time input	No
Special tools necessary	Manufacturer's installation tool necessary for installation
Technical features	
Available for connection to main pipes:	Rigid PVC pipes DN/OD 200 - DN/OD 1500 GRP pipes DN 250 - DN 1500 PP pipes DN 200 – DN 630 AC and FC pipes DN 200 - DN 600 (these applications covered by three models)
Available for connecting pipes:	Rigid PVC/PP pipes (smooth-walled) DN/OD 160/200; DN 150/200 GRP/PP (corrugated/ribbed) pipes, cast-iron and stoneware with appropriate adapter (DN/OD 160 and/or DN 150 covered by two models, DN/OD 200 by one model)
Recommended improvements	
Improve sealing action after installation	No
Improve sealing action after loading	Yes (flail)
Reduce space requirement for installation	No
Reduce time input for installation	No
Improve installation manual	No

* Evaluation: 100% of tightness tests passed after installation = ++; > 85 % = +; > 70 % = o; ≥ 50 % = - ; < 50 % = --
** Evaluation: > 50% of tightness tests passed after loading = +; ≤ 50 % = -
*** Evaluation: Comprehensibility and layout Very good = ++; Good = +; Satisfactory = o; Sufficient = -; No installation manual/inadequate installation manual = --
**** Evaluation: Extremely extensive tests = ++; Extensive tests = +; Standard tests = o; Low scope of testing = - ; No test certificates submitted = --

Key to test results: Very good = 1.0 - 1.5. Good = 1.6 - 2.5. Satisfactory = 2.6 - 3.5. Sufficient = 3.6 - 4.5. Deficient = 4.6 - 5.5. Insufficient = 5.6 - 6.0.

REHAU Awadock Polymer Connect scores "VERY GOOD"

The "Awadock Polymer Connect" sewer lateral from REHAU AG & Co. achieved a "VERY GOOD (1.0)" test verdict in IKT Product Test's "Private Sewer Laterals" category.

Under test

REHAU commissioned IKT to perform the "Private Sewer Laterals" product test, in order to determine precisely their sewer lateral's suitability for practical use.

The Awadock Polymer Connect with modified hole saw passed the test program with the "VERY GOOD" (1.0) grade, and has therefore been awarded the IKT Product Test seal of quality.

The primary evaluation criterion applied in the IKT Product Test "Private Sewer Laterals" category is the tightness of the sewer lateral both after installation and after application of structural and operational loads. The table of results and a detailed report can be downloaded from: www.ikt.de (select: Download/IKT-Warentest)

A total of nine Awadock Polymer Connect sewer laterals were tested to the limit under civil-engineering and operational conditions on test drain/sewer lengths at IKT. Further on-site tests covered handling characteristics under in-situ conditions. It was possible to install the sewer lateral on the site without difficulty, despite limited available time and constricted space.

A total of nine sewer laterals were installed in test lengths at IKT. All nine sewer laterals proved to be "tight" in the tightness test performed immediately after installation. The connecting lines were angled off on three of the nine sewer laterals; these sewer laterals still passed the tightness tests after angling off.

For the subsequent shear load test, a shear load was applied to the connected PP pipes for a period of 15 minutes (short-term shear load) and three months (long-term shear load). This test simulates loads imposed by soil and traffic ("live") loads. The shear load test indicated that there was no deterioration in the sewer laterals' sealing function.

Results of "tight" were also achieved following high-pressure cleaning. The use of a flail caused erosion of material on the inner sleeves projecting into the main pipe, however. One of the three loaded sewer laterals then indicated "not tight" in the tightness test as a result; for this reason, it is recommended that flails not be used in practice.

Installation of the Awadock Polymer Connect


Awadock Polymer Connect in the IKT test

Connection of plastic pipes

The Awadock Polymer Connect takes the form of a polypropylene sewer lateral, and is used to connect laterals and main drains/sewers with one another. Both conduits must be smooth-walled and must consist of PP, rigid PVC, PE or GRP. The Awadock Polymer Connect features an integrated ball joint which permits adaptation to angling off of the connecting pipe of up to 7.5° in both the horizontal and the vertical.

A different hole saw was used in a previous test for installation of the Awadock Polymer Connect. Six of the nine drill holes were significantly outside the pitch tolerances of 162 ± 1 mm, resulting in leaks from one of the sewer laterals. The first test result was consequently only "GOOD (1.9)". Rehau modified the Awadock hole saw, and had the test performed again at IKT. It proved possible to drill the necessary holes during the second test quickly and with no difficulties using this modified hole saw.

The IKT Product Test “Private Sewer Laterals” category

The tests were performed in conformity to the test program developed jointly with fourteen system operators for the IKT “Private Sewer Laterals” product test. This test, performed for the first time in June 2002, combines the practical and operating experience of the system operators with IKT’s scientific knowledge and discoveries.

Central focuses of the test are system tests on installed sewer laterals and the evaluation of information supplied by the manufacturers (e.g. instructions for installation), and also on-site tests. This test, which continues to meet the latest standards, can be performed by sewer lateral suppliers at any time, either with sewer lateral types already tested and subsequently improved, or on newly developed products.

Results available in the Internet

This article contains only extracts from the complete results. The detailed report can be downloaded from the Internet at:
www.ikt.de (select: Download/IKT -Warentest) (German Version)

IKT tests new private-site manhole – Verdict: Infiltration-proof!

BERDING BETON GmbH has developed a new manhole for separation systems on private sites: the Aqua-Duo®. Rainwater and sewage run separately from one another via a lower manhole section. Only a single manhole is therefore required on the site, even if a separation system is installed. The IKT tested the new manhole for infiltration tightness in May 2011.

Separate collection of sewage and rainwater is set to be become ever more important in the future, and is already standard practice in a large percentage of municipalities. Two separate pipelines are required on the site for this purpose and, in most cases, two manholes, as well.

A branch has been routed upward over the berm to facilitate inspection of the rainwater line (photo: BERDING BETON GmbH).

Strictly separated: sewage is routed off via the open channel, while rainwater runs off via a PVC pipe in the berm (photo: BERDING BETON GmbH).

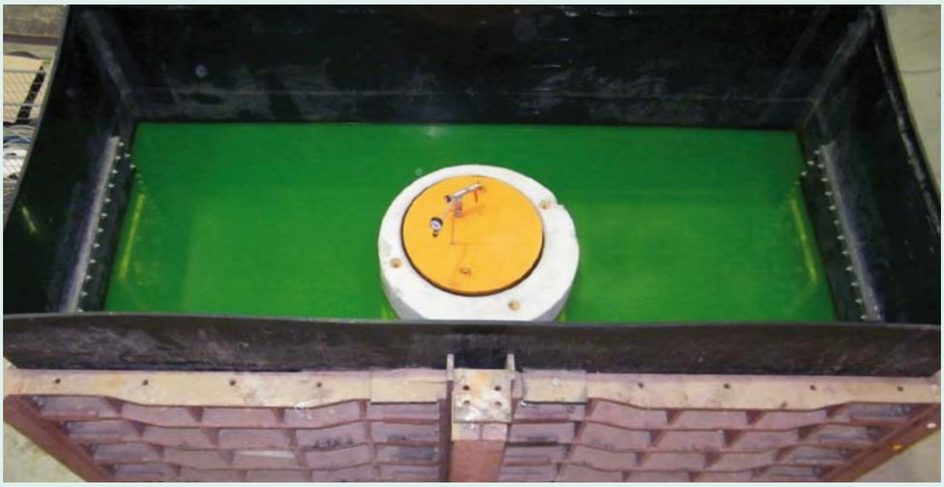
BERDING BETON GmbH recently introduced a private-site manhole which permits separate routing of rainwater and sewage via a single collection chamber. IKT - Institute for Underground Infrastructure comprehensively tested the Aqua-Duo® model for tightness against infiltration and exfiltration.

In the Aqua-Duo® private-site manhole, sewage is conveyed through an open DN 150 stoneware channel. The rainwater is routed via a PVC pipe installed in the berm. A branch (DN/OD 150/200), which is routed up over the berm and features a closure cover, is incorporated as the inspection port for the rainwater channel.

1,000 hours of infiltration pressure

Ingress of surrounding groundwater (so-called "infiltration") is a problem which occurs frequently in manhole structures. For this reason, BERDING BETON had its Aqua Duo® manhole inspected extremely precisely by the test engineers at IKT - Institute for Underground Infrastructure. The infiltration tightness of the manhole structure was tested in the context of a long-term tightness test in which an external infiltration pressure of 8 m was simulated for a period of 1,000 hours.

Tightness against exfiltration must also be assured, however - particularly when rainwater and sewage are to be routed through the same component. Both the rainwater and the sewage lines were therefore successively submitted to a tightness test at a water pressure of 0.5 bar for a period of twenty-four hours.



Test apparatus: the method used to test infiltration tightness. No indicator liquid (water containing a green dye) entered the manhole, even after 1,000 hours.

The result: the system passed all the infiltration and exfiltration tests. The Aqua Duo® manhole thus now bears the IKT "Infiltration tight" test seal.

2 in 1 – Cost benefits in both construction and maintenance

Manufacturer BERDING BETON perceives the advantages of the Aqua-Duo® on the one hand in lower construction costs, since only one manhole is necessary for both rainwater and sewage, even using an open separation system. Another obvious benefit: only one manhole also means only one manhole cover in the front garden. In addition, the system makes parallel pipe routing possible, according to BERDING BETON. This will subsequently permit easier location of pipes for maintenance and repair purposes. This, in general, thus simplifies servicing and maintenance, and reduces costs significantly.

The manufacturer promises high long-term stability and static loadability thanks to greater wall thicknesses, and also high operational reliability, thanks to the dependable and permanent tightness of the econorm® sealing and load-transmission system. The Aqua-Duo® private-site manhole is easy to install and can be installed quickly and without complications. According to BERDING BETON, the generously dimensioned manhole entry, and a manhole joint which can be disconnected again without damage, make the Aqua-Duo® particularly servicing-friendly.

Results available in the Internet

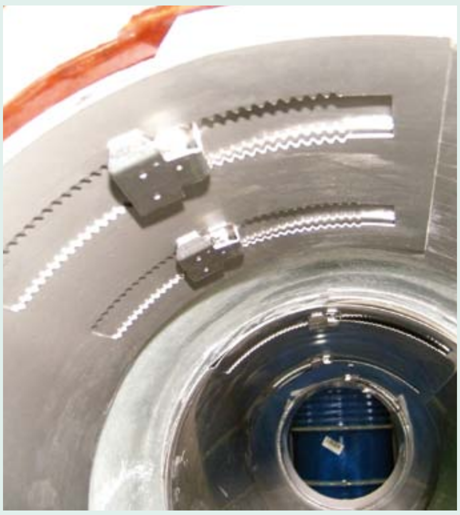
This article contains only extracts from the complete results. The detailed report can be downloaded from the Internet at:
www.ikt.de (select: Download/Berichte der Prüfstelle) (German Version)

Flushing-resistant and infiltration-proof – Test successfully passed!

Uhrig Kanaltechnik GmbH's Quick-Lock liner-end sleeve passes strict IKT tests.

The IKT - Institute for Underground Infrastructure has subjected Uhrig Kanaltechnik GmbH's recently developed Quick-Lock liner-end sleeve to exhaustive testing. The sleeve's durability was tested in high-pressure flushing cycles, its sealing action against external water pressure, and its resistance against high-pressure jets. The Quick-Lock liner-end sleeve passed all these tests in exemplary fashion, and now bears the IKT seal of approval.

Uhrig's new product consists, like its familiar Quick-Lock system, of a stainless steel sleeve with an elastomeric seal of large surface area, which balances out misalignment between the liner and the pipe. The sleeve can be used both for sealing of the annular gap between the liner and the existing pipe and for connection of tube liners to manhole shafts; here, it also covers the manhole shaft connecting socket. In addition to its now proven sealing action, the sleeve can also, apparently, protect the liner end against damage from high-pressure flushing, as Uhrig Kanaltechnik points out.



Liner-end sleeve: an elegant solution for joining of a liner to the existing pipe (photo: Uhrig Kanaltechnik)

Complex test apparatus: the 12 m long test line in IKT's test shop

The new Quick-Lock liner-end sleeve is available for pipes of nominal diameters of DN 150 to DN 600, in lengths of 250 mm (DN 150 to DN 400) and 300 mm (DN 450 to DN 600). The research and test institute in Gelsenkirchen tested the sleeves for pipes of nominal diameter DN 300.

Complex programme of tests

IKT set up a test length of around 12 metres for these tests: five concrete lower manhole sections (dia. 1000 mm) with four intervening DN 300 conduit sections. Two of these sections consisted in each case of two concrete articulated elements, and two sections in each case of two stoneware articulated elements.

Following setting-up of this test system, the client firstly installed a continuous tube liner (wall thickness: 6 mm) with an outer film into the conduit sections and removed it again from the manhole conduit area after curing. The liner ends were sealed using the new sleeves.

Lasting tightness

The sleeves installed in the test line were firstly submitted to a short external hydraulic pressure test at 1 bar test pressure for 30 minutes. The overpressure in the annular gaps of the drain sections was then reduced to 0.5 bar; this pressure was then maintained for 1,000 hours, in order to test tightness against contacting groundwater. All liner-end sleeves withstood the pressure in both tests, and no water penetrated into the pipe.

Testing the tightness against external water pressure

Proof against high-pressure flushing

Materials installed in the drain are subjected to particularly severe loads during high-pressure cleaning. Even after sixty cleaning cycles (DIN 19 523, Procedure 2: Practical testing) using a commercially available omnidirectional nozzle, the Quick-Lock liner-end sleeves continued to exhibit an extremely good condition. The liner-end sleeves manifested virtually no traces after the test - only in the pipe sole did the IKT testers find slight, isolated scratch marks on the stainless steel sleeve, these probably having been caused by the flushing nozzle. The subsequent short external hydraulic pressure test at 0.5 bar for 30 minutes and at 1 bar for a further half hour confirmed everyone's initial impression: No leaks, and the DIN 19 523 practical test successfully passed!

All the sleeves tested also passed the DIN 19 523 [1], Procedure 1 (Materials testing) high-pressure flushing resistance test. After removal of the liner-end sleeves, the elastomer seals and their sealing lips exhibited no damage capable of impairing the system's sealing action.

The detailed report can be downloaded from the Internet at: www.ikt.de (German Version)

Bert Bosseler appointed "Privatdozent" by University of Hanover

Scientific head of IKT awarded full lecturer's licence for "Underground drain, sewer and conduit engineering"

PD Dr.-Ing. Bert Bosseler

Dr.-Ing. Bert Bosseler has been appointed to a superior lectureship (German "Privatdozentur") at the Leibniz University of Hanover, and has been awarded the full academic lecturer's licence, the so-called venia legendi (including the right to supervise PhD students), for "Underground Drain, Sewer and Conduit Engineering". The qualified civil engineer's principal occupation since 2000 has been as the scientific head of the IKT – Institute for Underground Infrastructure (www.ikt.de); the IKT Supervisory Board has voted Bert Bosseler its special recognition, and granted him power of procuration with sole signature rights.

Following his inaugural lecture in late October 2010, Bosseler received his academic certificate from Prof. Dr.-Ing. Udo Nackenhorst, Dean of Studies of the university's Faculty of Civil Engineering and Geodesics. Bosseler (43) now becomes a member of this faculty, in the capacity of "Privatdozent", and will exercise his lecturer's licence as a subsidiary activity alongside his primary responsibilities as scientific head of the IKT in Gelsenkirchen.

Comparative product assessment

Bert Bosseler's professorial thesis, "Testing and evaluation of products and procedures for the construction and maintenance of underground drains, sewers and conduits", is based on his comprehensive activities and experience he has gained from his research work at the IKT and also, since the winter term of 2006/2007, as a supernumerary lecturer at the Institute for Geotechnical Engineering (IGtH) at the Leibniz University of Hanover. The professorial thesis was assessed by Prof. Dr.-Ing. Martin Achmus (Hanover), Prof. Dr.-Ing. Jörg Londong (Weimar) and Prof. Dr.-Ing. Markus Thewes (Bochum).

In his professorial thesis, Bosseler elaborates the processes and capabilities necessary for the substantiated, transparent and comparative assessment of various products and procedures. He then develops a system for the validation of test and evaluation concepts and, simultaneously, for the identification of development perspectives. The scientific benefits of this newly developed and systematic descriptive concept are convincingly documented via the analysis of existing test and inspection concepts.

Priv.-Doz. Dr.-Ing. Bert Bosseler during his inaugural lecture, "Underground drain, sewer and conduit engineering", in Hanover

Practical significance for investment decisions

The work is also of importance for practical purposes, since the construction and maintenance of underground drains, sewers and conduits involve high investment risks. System operators encounter uncertainties with respect, inter alia, to the quality of the products and procedures used. In most cases, only information provided by manufacturers is available to the relevant decision-makers for evaluation of product and procedure characteristics. Only the minimum requirements concerning occupational health and safety, environmental safety and basic civil-engineering suitability are presently covered by legal provisions and approvals.

IKT research and product tests as the basis

Against this background, Bosseler analysed the testing and evaluation of products and procedures on the basis of the IKT's own research, testing and product test projects. This work was financed primarily from third-party funds, provided by the environment ministry of the German state of NRW, by Germany's "Bundesstiftung Umwelt" federal environmental foundation (DBU) and by municipal system operators.

Neutrality and impartiality

An overall survey illustrates that there are numerous diverse correlations between the institutions and decision-makers involved in testing and evaluation, that the individual tasks necessitate greatly differing capabilities, and that the aspects of neutrality and impartiality, and also understanding of the backgrounds of decision-making processes, all play an important role.

Reading of Bosseler's academic certificate by Prof. Dr.-Ing. Udo Nackenhorst (Dean of Studies of the Faculty of Civil Engineering and Geodesics at the Leibniz University of Hanover)

Bosseler's professorial thesis for the first time describes these correlations in a systematic manner, and thus provides the scientists and inspecting engineers involved in test, inspection and evaluation work in underground drain, sewer and conduit engineering with illustrative orientation for handling of these complex topics.

Prüfung und Bewertung von Produkten und Verfahren zum Bau und zur Instandhaltung unterirdischer Kanäle und Leitungen,
Habilitationsschrift by Dr.-Ing. Bert Bosseler, published (in German only) as Volume 70 of the Proceedings of the Institute for Geotechnical Engineering (IGtH), Leibniz University of Hanover.
Nominal fee: 15 Euro
e-mail: info@igth.uni-hannover.de

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IKT now also in Arnhem

The IKT now also has its own presence and branch in the Netherlands.

IKT Nederland

Since April 2012, the IKT - Institute for Underground Infrastructure has had its own independent branch in the Netherlands, based in Arnhem and operating under the "IKT Nederland" name. This branch provides all the necessary knowledge, on the spot - and even for established experts - in the fields of new construction, maintenance and renovation of piping systems. The current focuses of its activities are:

- Materials tests on tube liners in the IKT test laboratory
- Stress-analysis calculation for tube liners in accordance with ATV M 127, Part 2
- Site supervision and inspections, and
- Training courses in tube-liner renovation (tendering, taking of samples, stress-analysis calculation, materials tests, etc.)

IKT Nederland has at its disposal all the experience possessed by the IKT - Institute for Underground Infrastructure, a non-profit-making, independent and impartial research, consulting and testing institute founded in Gelsenkirchen, Germany, in 1994.

In association with various universities and a polytechnic in Germany, the IKT studies the many and diverse questions involved in the conduit-based gas, water and waste-water infrastructure.

The IKT, an impartial and dependable partner for municipalities, local government alliances and industry, furnishes highly qualified and innovative research and testing services, implementing the results systematically in practice.

It is now our desire to develop these services further, in co-operation with Dutch system operators.

We look forward to working with you.
Just contact us!

IKT NL

- neutraal
- onafhankelijk
- non-profit

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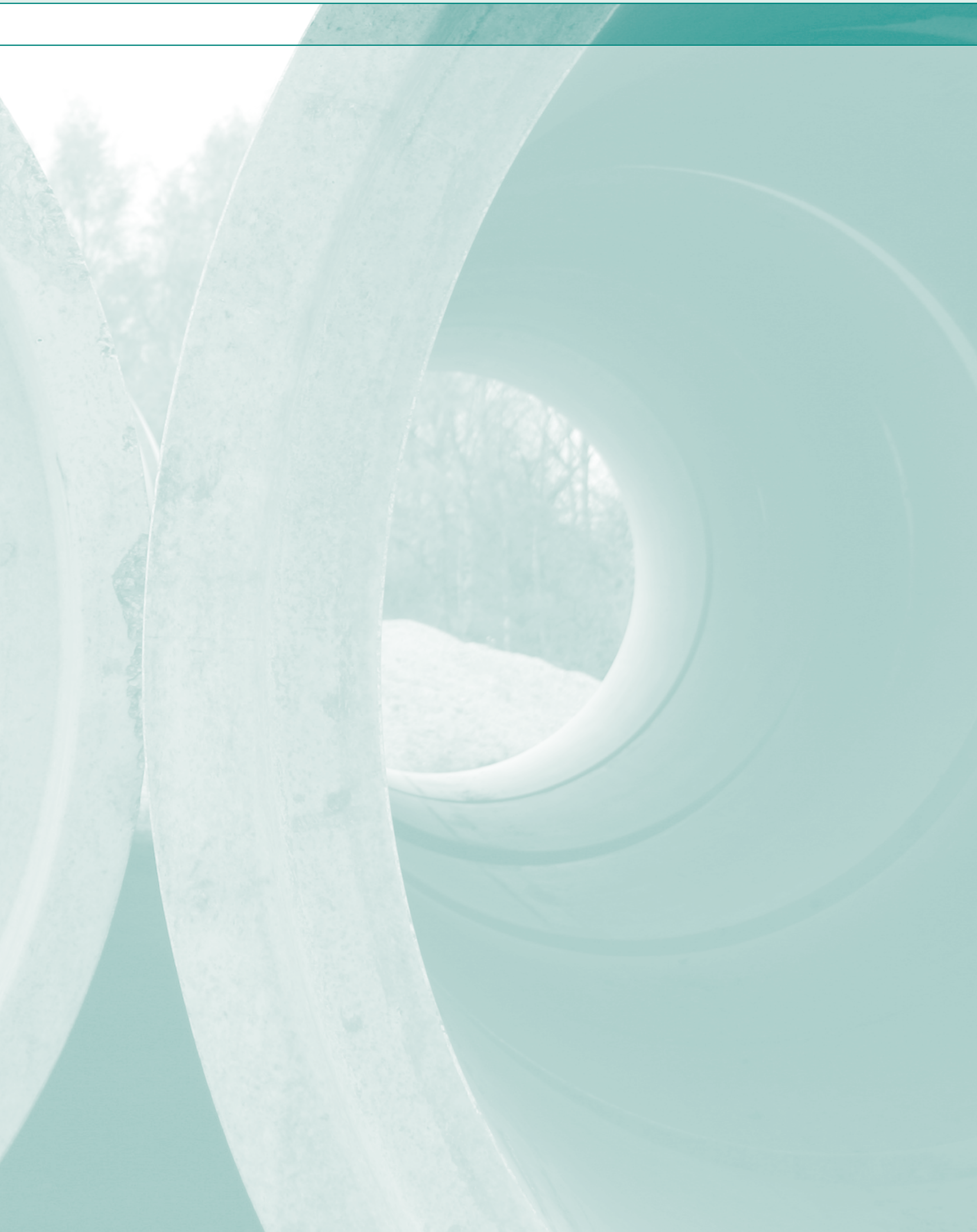
IKT Nederland



What does IKT do?

The IKT is a neutral, independent non-profit institution, and works on a practically and application-oriented basis on questions concerning underground sewer, pipe and other conduit engineering, its primary focus being on sewer systems. The institute conducts research projects, inspections, product tests, consultations and seminars on the construction, operation and renovation of underground infrastructures.

The IKT's main target group consists of the operators of both public and private conduit systems; its fields of activity are primarily oriented around questions and problems encountered by system operators, activities which derive from the institute's founding charter, signed in 1994, and stating its aims as the acquisition of scientifically founded expertise for the achievement of the cost-effective, technically innovative, and both environmentally and citizen-friendly installation, renovation and maintenance of conduit systems.

The IKT also performs other supporting activities in the field of testing and trial of new products and methods for industrial companies.

The fields of activity of the IKT are in details:

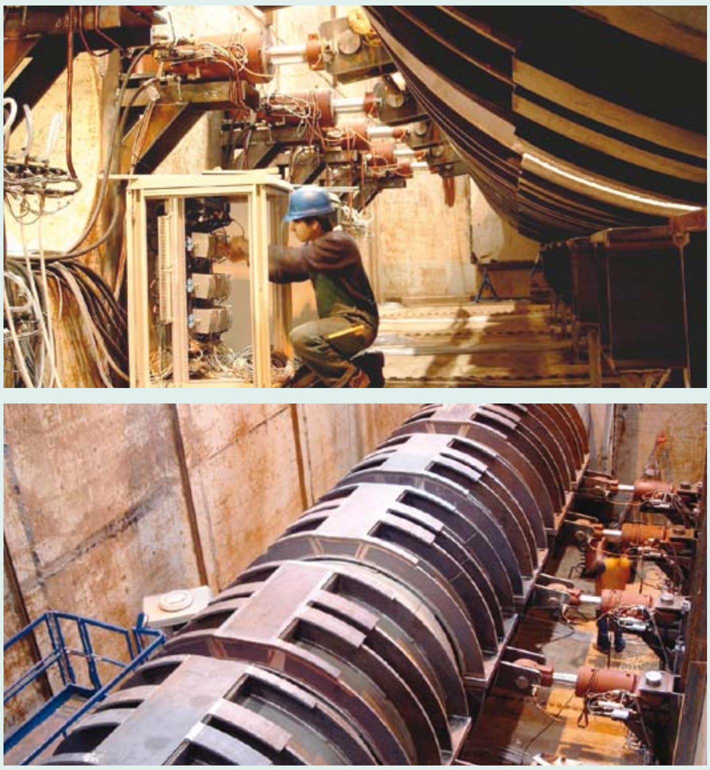
- Practice-oriented research
- Construction supervision, materials testing, flow measurement
- Comparative product tests
- Organisation of networks
- Further training
- Consultation and expert appraisals

Practice-oriented research

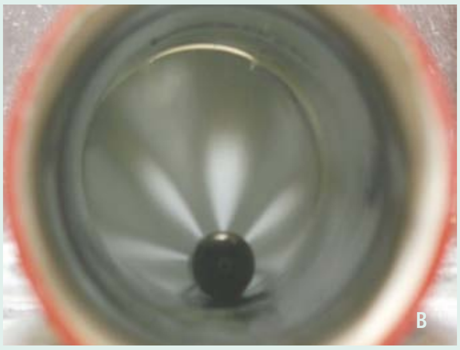
The IKT's application-related research focuses predominantly on the solution of system operators' problems and questions. The institute maintains continuous close contacts with the operators, in order to detect topics needing attention. The system operators' steering committees support and monitor all IKT research projects; members of these steering groups select the products to be tested and evaluated, determine boundary conditions for such tests, and are directly informed concerning the latest findings and developments at regular intervals.

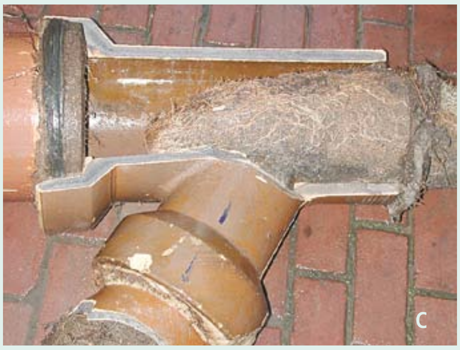
The first step in any IKT research project is a thorough analysis and definition of the problem.

Hydraulic cylinder in the IKT large scale test facility



IKT jacking simulator, DN 1600





A View into a sewer manhole
B HP nozzle in sewer
C Root ingrowth into a sewer

Practical solutions are then drafted, and subsequently implemented at pilot sites or incorporated into instructions for action and recommendations for the system operators.

Research topics:

- Sewer operation
- Sewer cleaning
- Urban drainage
- Sewer renovation
- Sewer manholes
- Sewer construction
- Pipe-jacking
- Root ingrowth

Construction supervision, material testing, and flow measurement

The results of the IKT's research activities are incorporated via short routes into the institute's subsequent activities.

- Vertical compression test
- Flow measurement
- Adhesive pull test on a coated manhole

The IKT provides system operators with practical product and system tests for Quality Assurance purposes, construction supervision, comparative flow measurements at sewage treatment plants, storm-water tanks and reservoir channels, calibration of flow and control equipment, and also tests in accordance with the self-diagnosis ordinances of the federal German states.

Initial and suitability tests, standard materials tests, DIBt certification procedures, special individually co-ordinated tests, and also supporting tests for method development, can be performed for manufacturers.

These tests are performed by the IKT's three test units:

The three IKT test units

Test unit for construction products	Test unit for flow measurements	Test unit for water-permeable surface coatings
Accredited in accordance with DAP-PL-443.00 **DIBt-accredited** • Test, supervision and certification unit	**Nationally accredited** • in accordance with EKVO Hessen • in accordance with SüwV Kom NRW	**DIBt-designated**
Main focus • Materials tests (plastics, concrete, vitrified clay, tube liners) • Construction supervision • Quality Assurance (e.g. of sewer and manhole renovation projects) • Test institute for DIBt construction-supervision certification	**Main focus** • Comparative measurements at sewage treatment plants, storm-water tanks, reservoir channels • Calibration of flow-measurement and control instruments • Tests in accordance with SüwV-Kan and SüwV-Kom • Detection/quantification of extraneous water • Expert appraisals	**Main focus** • Suitability tests for surface coatings • Verification of water permeability • Pollutant-retention studies • DIBt certification test

A Adhesive pull test on a coated manhole
B Crown pressure test
C Flow measurement

In addition, first and suitability tests, standard material tests, technical approval by the Deutsches Institut für Bautechnik (German Institute for Construction Technology, a government body, German abbreviation: DIBt), individually coordinated special tests, as well as supporting tests in procedure development can be carried out for product manufacturers.

Comparative product tests

Comparative product tests, in which products and methods are intensively tested under both laboratory and practical conditions, are a particular IKT speciality. All product tests are conducted by a group of system operators. Decisions concerning test contents, procedures and criteria, and also the concluding assessment, are taken jointly by a group control committee, thus ensuring that these tests are performed on a practical basis, impartially, and without influence by commercial interests.

The test results supply sound and reliable information on the strengths and weaknesses of the products available on the market to system operators, enabling them to make purchasing decisions on the basis of facts, rather than manufacturers' advertising. The IKT's product tests also provide suppliers with criteria for the improvement of the products and procedures tested, and thus for enhancing their market position.

Organisation of networks

The IKT increasingly sees its role as that of providing a platform for networks. The "Municipal Network for Site Drainage" (KomNetGEW) has existed since as long ago as the summer of 2008. The principal concern of the around sixty-five member municipalities is "citizen-friendly" implementation of tightness testing in accordance with Article 61a LWG NRW. Materials for PR activities and advisory services for citizens are centrally drafted under the overall leadership of the IKT and provided for use by all participants. The KomNetGEW has, in addition, now also certified several hundred site drainage consultants and expert tightness inspectors.

The southern German municipalities meet at the IKT-Süd ("IKT South") "Site Drainage Forum" to discuss constitutional municipal matters, and Quality Assurance in the maintenance of private waste-water facilities.

Network members adopt common paths

The "Sewer Operators Forum" within the IKT was founded in 2011 and provides all waste-water organisations with the opportunity for intensive interchange of experience. The results obtained in workshops, workgroups and research activities are structured and summarised by the IKT.

Construction of a pipeline system at the IKT large-scale test facility

System operators assess dismantled test objects

IKT-Services

Further training

Over the years, the IKT has acquired a pleasing reputation as a training and further-training institution. Consultants certified in Gelsenkirchen and Munich are trained in site drainage at regular intervals. Expert tightness inspectors also obtain the necessary know-how here. The "Site Drainage Day", held by the IKT for the third time in 2011, has also become a permanent feature in the industry's events calendar. The IKT-SummerSchool and WinterSchool focus on quality in pipe and sewer engineering. The institute's further-training programme is rounded off by training events and courses on various topics of waste-water management, including manhole renovation, occupational health and safety, and photo reference catalogue.

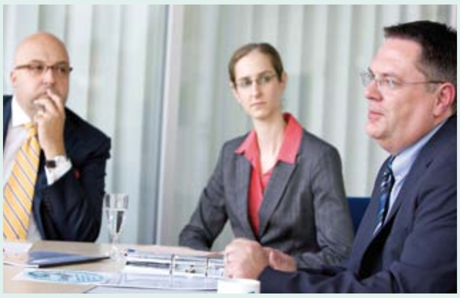
Consultation and expert assessments

The IKT provides, on the basis of findings from research, inspection and testing activities, support services orientated around specific questions encountered by system operators (e.g. on-site analyses, feasibility studies, presentation and mediation, technical and economic assessments, economic and social cost analyses, etc.). The IKT's services also include thoroughly scientifically founded expert assessments for courts, municipal and private system operators, building contractors, product manufacturers and engineering consultancies (e.g. expert damage assessments, expert opinions as evidence in court and in out-of-court settlements). An overview of the IKT's specific consulting services in its various fields of activity is shown below:

Sewer cleaning/operation

Day of practical sewer operation, checking of tendering, assessment of damage caused by sewer cleaning (e.g. flow back-ups, cellar flooding, etc.), cause analysis of cleaning damage to sewage conduits, malfunction analysis (drain blockages, clogging, etc.), assessment of cleaning strategies, recommendations for non-destructive sewer cleaning, drafting of market surveys, recommendations concerning the high-pressure flushing resistance of pipe products, organisation and presentation of system operators' regional interest groups, optimisation of reporting.

Training and further-training at the IKT



IKT consulting services

New sewer construction

Trenchless ("no-dig") installation (pipe-jacking), open-trench installation (timbering supported, pipe-trenches), statics calculations (stability), core drilling and testing (materials testing), damage documentation and assessment, registration and evaluation of current construction methods.

Manhole renovation

Selection of renovation procedures, Quality Assurance for renovation projects, registration and assessment of renovation quality, analysis and evaluation of renovation damage, practical suitability testing of renovation systems.

Sewer renovation

Quality Assurance for renovation projects, recommendations concerning use of modern materials in sewer renovation (and plastics, in particular), tube liners, part-liners and coating methods; analysis and inspection of renovation damage.

Urban drainage

Trenchless installation methods (renovation of connection points and pipes), open-trench installation (pipe installation, connection to main sewer systems), malfunctions (drain blockages, clogging, etc.), damage documentation and evaluation, registration and evaluation of actual condition.

Water-permeable surface coating

Seepage capacity, pollutant retention, drain performance, DIBt certification.

Root ingrowth into sewer systems

Tree identification using samples of ingrown roots, documentation and evaluation of cases of damage, recommendations for the removal of ingrown roots and for repair of damage.

Reporting and self-diagnosis ordinance

Consulting services on implementation of legal requirements (EKVO, SüwVKan), documentation and optimisation of structure and flow organisation, updating of servicing and operating instructions orientated around the relevant requirements, finalisation and systematisation of reporting, co-ordination with responsible supervisory authorities.

Flow analysis and comparative measurement

Review of measuring instruments for use at storm-water tanks and sewage treatment plants, on-site comparative measurements using ultra-modern measuring instruments calibrated at regular intervals, measurement of extraneous water flows, determination of extraneous water sources and causes.

Economic analyses

Cost:benefit analyses comparing trenchless and open-trench installation methods, evaluation of investment and rehabilitation strategies, economic evaluation of sewer systems and structure, cost-cutting and economic optimisation provisions, macro- and microeconomic analyses.

More information?

We are always pleased to answer your questions about our services - just contact us!

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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:
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.

You can find information on projects and services at:
www.ikt.de

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