Repair systems: Better than their reputation!

Surprisingly good results in the IKT „Repair Systems" test

Test conduits in the IKT test facility

Partial repair or rehabilitation of drains and sewers enjoys an at best dubious reputation. The corresponding systems are considered unreliable in operation, and not particularly durable. IKT's most recent product test, on „Repair systems for main drains", on the other hand, arrives at a more encouraging conclusion: five of the twelve systems analyzed received a „Good" grade, four „Satisfactory", and only three a „Sufficient".

Repair techniques are used extremely frequently in Germany when there is a need to eliminate isolated conduit damage. They are then preferred, frequently for cost reasons, over the alternative rehabilitation options, those of complete renewal and section-by-section renovation. Throughout Germany, around 25% of drain and sewer damage are tackled by means of repair methods (renovation: 26%, renewal: 49%; source: DWA survey, 2004).

Repair systems under test

Twelve repair systems in current use, subdivided into three groups, were submitted to comparative testing:

1. Injection and grouting/pressure filling
- Janßen Riss- und Scherbensanierung (Janßen crack and fragmentation repair system), Umwelttechnik Franz Janßen GmbH
- KASRO 2 Komponenten-Verpresssystem (KASRO two-component pressure-filling system), ProKASRO Mechatronik GmbH
- KA-TE PMO-Verfahren (KA-TE PMO system), KA-TE PMO AG

2. Short liners
- 3P-Plus-Kurzliner (3P-Plus short liner), sikotec GmbH / JT-elektronik GmbH
- ALOCIT Kurzliner (ALOCIT short liner), ALOCIT Chemie GmbH
- K-LINER, Kuchem GmbH
- KM-Kurzliner (KM short liner), KMG Pipe Technologies GmbH
- Konudur Sewer Repair Kit (VP), MC-Bauchemie Müller GmbH & Co. KG
- Point-Liner®, Bodenbender GmbH

3. Internal sleeves
- Quick-Lock, UHRIG Kanaltechnik GmbH
- Quick-Lock mit einseitiger Aufbördelung (Quick-Lock flared at one end), UHRIG Kanaltechnik GmbH
- Stuttgarter Hülse (Stuttgart Sleeve), Haas GmbH & Co. KG

System operators examine the repair results

Clients and steering committee

This product test was financed by the environment ministries of the German states of Baden-Württemberg and North Rhine-Westphalia, and twenty-six municipal drain/sewer-system operators. The latter, in particular, are in need of neutral and independent evaluation of the available procedures, in order to provide a better basis for their investment decisions in future.

The participating municipalities formed a steering committee which met a total of eleven times and took all the central decisions. It decided, for example, which systems were to be tested, how the test program should be compiled, and which test criteria were to be taken as the basis. Finally, it also decided on the concluding award of grades.

Test program

The central elements of the test program are provided by the system suppliers' Quality Assurance and the system tests.

Example of „branching crack" damage type in vitrified clay pipes

Manuals, training provisions, third-party supervision, environmental impact certificates and technical approval by the Deutsches Institut für Bautechnik (German Institute for Building Technology, a government body, German abbreviation: DIBt) were registered and evaluated, inter alia, for the Quality Assurance item.

Four test lines consisting of concrete and vitrified clay, with nominal diameters ranging from ND 200 to ND 600, and also an additional ND 400/600 oval-section concrete line where the corresponding system could be used, were set up in the IKT test facility for each system for the purpose of the system tests. Typical forms of damage, such as transverse and longitudinal cracking, spalling, fragmentation and leaking joints were artificially incorporated into these conduits. Precisely the same amounts and types

of damage were assigned to all test participants, who were then instructed to repair it.

The rehabilitation target was that of restoring the tightness and correct functioning of the conduit. Each participant was responsible for deciding how to achieve this, i.e., planning, conception, surface pretreatment, repair and any necessary reworking. The only additional condition imposed was that the repairs had to be performed without trench working, i.e., via the end manholes of the test conduits. There was no time limit.

High-pressure cleaning operations of fifteen flushing cycles per repair point (flushing load from fifteen years of operation, assuming annual flushing) were performed after completion of the work, in order to simulate operating loadings. Slight to clear traces of the cleaning operation remained apparent at many repaired points during the subsequent inspection.

Function

The function test evaluates whether the conduit section's assuredness of disposal has been restored. Every repaired point was awarded a grade by the system operators on the criteria of visual appearance, stabilization/protection of the damaged point, and possible flow obstructions.

In the case of the short liners, the surface, in the base zone, at least, was generally slightly roughened. In individual cases, glass fibers were also exposed, or detachment of material and cracking had occurred. Annular gaps or edges in the boundary zones were also measured on individual short liners.

In the injection and grouting/pressure-filling group, detachment of material had occurred in some cases in the Janßen Riss- und Scherbensanierung, and in the KASRO 2 Komponenten-Verpresssystem. In most cases, such detachment of material was, it is true, of no importance for the sealing action of the repair and could be removed, but could also form obstructions to flow. In the case of the KA-TE PMO-Verfahren, small upturns on the edges of the resin bodies had occurred at a few points only.
Flushing damage, significant in some cases, in the form of indentations, was observed in the case of the Stuttgarter Hülse, for which an incorrect tooth setting based on the manufacturer's data had resulted in incorrect tensioning of the sleeve. Edges, in some cases significant, had also formed on some sleeves, due to remnants of resin.

The two Quick-Lock sleeve variants tested produced differing results: in the first model tested, with no flaring, defective teeth on the locking wheel were observed after high-pressure flushing. This caused declining tensioning of the sleeve, with a corresponding reduction in its internal diameter, and therefore leaks. The sleeve subsequently tested, flared at one end, did not exhibit damage of this type. In both variants, upturns of a few millimeters can occur in the overlap zone of the sheet, depending on gap formation.

Tightness

Before and after high-pressure cleaning, all the repair points were subjected to hydraulic pressure testing for tightness, at increasing pressure levels of between 0.05 and 0.5 bar. The test times at each pressure level were between 15 and 30 minutes. The verdict of „Tight" or „Not tight" was awarded in the case of the tightness tests following the high-pressure flushing operation (which was significant for evaluation by means of visual assessment of egress of water on the exterior side of the pipe at the point of repaired damage). Differentiation of the „Tightness" test criterion was made on the basis of the six test-pressure levels.

In the injection and grouting/pressure-filling group, all the repaired points relevant for assessment remained tight up to at least 0.1 bar in the case of the Janßen Riss- und Scherbensanierung and the KA-TE PMO-Verfahren. At the highest pressure level, only six of the twelve repaired points (Janßen Riss- und Scherbensanierung) and twelve of fifteen repaired points (KA-TE PMO-Verfahren) remained tight at the highest pressure level. In the case of the KASRO 2 Komponenten-Verpresssystem, on the other hand, eight of twelve repaired conduits were not tight at any pressure level. Difficulties had occurred with the pressure-filling operation during the repair operation, with the consequence that a number of damaged points had not been completely filled with the repair resin.
The results of tightness testing also varied greatly in the short liners group. The 3P-Plus Kurzliner and KM Kurzliner were significantly above the average, with a tightness rate of 11/12 and 9/11

Example of short liners without (top) and with (down) visible traces of high-pressure flushing

tight repaired points, respectively. The Konudur Sewer Repair Kit (VP) short liners, in which weak points within the GRP laminate resulted in leaks, passed the tightness test up to the highest pressure level only in two of twelve cases. The other three short liners systems tested were all in the mid-range.

The results obtained with the three internal sleeves tested were similarly dispersed: in the case of the Stuttgarter Hülse, for which, according to the manufacturer's information, an incorrect tooth dimension had inadvertently been used, thirteen of fifteen repaired points leaked at all pressure levels. Tightness at nine of twelve repaired points up to and including 0.5 bar and of one up to 0.1 bar was demonstrated for the Quick-Lock sleeve flared at one end, on the other hand. In the case of the Quick-Lock sleeve without flaring, five of twelve repaired points remained tight at pressure levels of between 0.05 bar and 0.5 bar after high-pressure cleaning.

Test results

It is apparent, all in all, that successful conduit rehabilitation using repair systems is possible in principle. Significant quality differences are apparent, however. The grades awarded in each system group range, for example, from „Good" to „Sufficient". The system tests performed in the IKT test lines (weighting: 85%) and the

Example of sleeve without (top) and with (down) visible traces of high-pressure flushing

system suppliers' Quality Assurance (weighting: 15%) were evaluated.

The best result in the injection and grouting/ pressure-filling group, and simultaneously the best result in the entire test, was achieved by the KA-TE PMO-Verfahren, which received the grade „Good" (1.6), followed by the Janßen Riss- und Scherbensanierung, also with a grade of „Good" (2.3). The recently developed KASRO 2 Komponenten-Verpresssystem still exhibited significant need for optimization, and was awarded only a grade of „Sufficient" (4.0).

In the lead in the short liners group are the KM-Kurzlinerand 3P-Plus-Kurzliner, each with the grade of „Good" (2.2). The K-Liner (Grade: 2.8), the ALOCIT short liners (Grade: 2.9) and the Point-Liner® (Grade: 3.1) were all in the mid-range, with a grade of „Satisfactory". The Konudur Sewer Repair Kit (VP), a recent development with a significant requirement for optimization, failed to achieve a grade better than „Sufficient" (4.2).

A similar spread in the grades awarded was also apparent in the case of the internal sleeves: the modified Quick-Lock sleeve flared at one end achieved a „Good" (2.2), whereas the previously tested Quick-Lock sleeve without flaring received a „Satisfactory" (3.1). The Stuttgarter Hülse (Grade: 4.3) manifested significant weaknesses and is now no longer available in its present form for waste-water conduits but is, according to the manufacturer, instead now used in combination with a short liner.

All in all, all the systems exhibited various weaknesses and strengths. The three systems which were awarded only the grade of „Sufficient" can, in the development status as tested here, scarcely be recommended for practical use. The manufacturers of the three systems have, however, already reacted to the results of the test, with the consequence that further development work has been initiated, and that these systems are no longer available in the form as tested at IKT.

On-site execution decisive

Not only the material components and selection of the system, but also on-site execution, are decisive for the quality of a repair. This applies to all systems, irrespective of their evaluation within the test scope. All working operations, ranging from the conception of the repair, e.g., the length and number of layers of a short liner, via the type and scope of preparatory work, up to and including the actual repair operation and finishing work, can have a significant influence on subsequent quality.

There is, in principle, the risk with all the repair systems that important work may be hurried - or even omitted - on site, whether for reasons of time and/or cost, and differing quality standards at the various contractors, or as a result of this work not being expressly specified - and therefore not remunerated - by the client. This applies, in particular, to preparatory and support provisions, such as high-pressure flushing, cutting and milling work, and the withdrawal from service of conduit sections, the (lack of) satisfactory execution of which is not immediately apparent at the acceptance inspection of the completed repair.

The client can combat these factors by ensuring that, at the initial stage, the necessary preparatory work is included in the invitation to tender. In a second step, the materials used, the nature and scope of the preparatory work performed, and of the repair systems, can be monitored - on a random-sample basis, if necessary - in the context of site supervision. Otherwise, repair documentation, including images of the damaged point before starting work, after completion of

Example of injection/grouting without (top) and with (down) visible traces of high-pressure flushing

the preparatory work and after completion of the repair, should at least be required.

Product-improvement cycle stimulated

The aim of the IKT product test is that of comparatively evaluating the quality of repair systems, outlining potential for improvement and, simultaneously, stimulating corresponding market pressure, in order that the suppliers utilize these potentials. The drain/sewer system operator, as the client, is the person who stipulates the quality requirements for the products, and how the products perform on these criteria.

Four of the twelve systems tested have already been taken off the market as a result of the results obtained in these tests, or have been replaced by a modified system or a previously envisaged market launch postponed. Alternatives for two of the systems are already available on the market, and the two other systems are currently undergoing improvement.

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(Result tables on the following pages)

Table 1: IKT „Repair systems for main drains" product test

Injection and grouting/pressure-filling system

System tests in test lines:

- Repair of three points of damage in each case in four sand-covered ND 200/ND 300 vitrified clay test lines and ND 300/ND 600 concrete pipes with grease depositions
- Damage in vitrified clay: 1) spalling 20x20 cm, 2) extensive crack ramification across approx. 1 m length, 3) leaking socket with crown crack and spalling (d = 5 cm)
- Damage in concrete: 1) transverse crack, 2) longitudinal cracks in side zone and crown, starting from tapered end (l = approx. 1 m), 3) leaking socket with crown crack and spalling (d = 5 cm)

System type	**Grouting/Pressure-Filling Method**	**Injection Method**	
System supplier	**KA-TE PMO AG**	**Umwelttechnik Franz Janßen GmbH**	**ProKASRO Mechatronik GmbH**
System	**KA-TE PMO-Verfahren**	**Janßen Riss- und Scherbensanierung**	**KASRO 2 Komponenten-Verpresssystem**
			
Resin system used	BASF CONCRESIVE® 1850 and EPOXSONIC® EX 1355	JaGoPur	Konodur Robopress 07 with Konodur Additive RP
IKT test verdict*	**GOOD (1.6)**	**GOOD (2.3)**	**SUFFICIENT (4.0)**
System tests in test lines (weighting 85%)	**Good (1.7)**	**Satisfactory (2.6)**	**Sufficient (4.2)**
Function[1] (50%)	2.0	3.5	4.2
Tightness[2] (50%)	1.3	1.6	4.2
System-suppliers' Quality Assurance3 (weighting 15%)	**Excellent (1.0)**	**Excellent (1.0)**	**Satisfactory (3.0)**
System manual (20%)	Yes	Yes	Yes
Training provisions (20%)	Yes	Yes	Yes
Third-party supervision (20%)	Yes	Yes	No
Environmental impact (10%)	Yes	Yes	Yes
DIBt approval (10%)	Yes	Yes	No
Test certificates (10%)	Yes	Yes	No
Back-tracing of supply route (10%)	Yes	Yes	Yes
Additional information: Impression gained from site investigations and test-line use	Practically-orientated handling and use	Practically-orientated handling and use	Difficulties with pressure-filling during test, system not mature for practical use
Suitability for oval concrete section, ND 400/6004	proven	not available	not available
Suitability for use with ingress of groundwater and external water pressure5	proven	not proven	not tested
Available for the diameters (information from supplier)	Round section: ND 150 - ND 800 Oval section: ND 300/450 - ND 600/900	Round section: ND 100 - ND 700 Oval section: not for use with oval section lines	Round section: ND 200 - ND 600 Oval section: not suitable for use with oval section
Potential for improvement	/	Removal of remnants of resin; modification of packer system to permit easier positioning	Prolonged resin-reaction time; optimization of resin feed-line changing; individual pressure-filling of damaged points; removal of remnants of resin
Remarks	/	/	System not longer available in this form

1 Evaluation of function by visual assessment by system operators on basis of point scores (30% weighting after completion; 70% weighting after HP cleaning): 100 points = 1.0 to 0 points = 6.0; arithmetical averaging and statement of points in grades using a linear function

2 Evaluation on basis of internal water-pressure tests after HP cleaning (visual checking for escape of water); grading depending on pressure level with no egress of water: 0.5 bar = 1.0 / 0.4 bar = 1.7 / 0.3 bar = 2.3 / 0.2 bar = 3.0 / 0.1 bar = 3.7 / 0.05 bar = 4.0 / not tight at any pressure = 6.0; Damage-type 2 (longitudinal cracks) in the concrete test lines were eliminated from the evaluation due to non-uniform cracking patterns

3 Evaluation: existent = yes and non-existent = no; approval/certificates/proof analyses must apply to the materials used in the test

4 Evaluation: „proven" = system tested in ND 400/600 concrete test line with three types of damage, both criteria „Tightness" and „Function" assessed as at least „Sufficient" (≤ 4.5) for each type of damage; „not proven1" = system tested and at least one repaired point assessed as poorer than „Sufficient" for at least one of the criteria of „Tightness" and „Function"; „not proven2" = the system is available for ND 400/600 concrete pipes, but the supplier did not use it in the test; „not available" = the system is not available for use in ND 400/600 concrete pipes

5 Evaluation: „proven" = system loaded in ND 300 vitrified clay test line with three leaking sockets with ingress of water and with external water pressure, and all repaired points exhibited no ingress of water upon internal inspection; „not proven" = system tested, at least one repaired point exhibited ingress of water upon internal inspection; „not tested" = system not tested

* Grade calculated using non-rounded off data

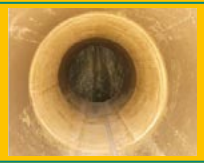
Key to test-result grades: Excellent = 1.0 - 1.5; Good = 1.6 - 2.5; Satisfactory = 2.6 - 3.5; Sufficient = 3.6 - 4.5; Deficient = 4.6 - 5.5; Insufficient = 5.6 - 6.0

Table 2: IKT „Repair systems for main drains“ product test

Short liners

System tests in test lines:

- Repair of three points of damage in each case in ND 200/ND 300 (jacketed) vitrified clay test lines and ND 300/ND 600 concrete pipes (exposed), all pipes with grease depositions
- Damage in vitrified clay: 1) spalling 20x20 cm, 2) extensive crack ramification across approx. 1 m length, 3) leaking socket with crown crack and spalling (d = 5 cm)
- Damage in concrete: 1) transverse crack, 2) longitudinal cracks in side zone and crown, starting from tapered end (l = approx. 1 m), 3) leaking socket with crown crack and spalling (d = 5 cm)

System supplier	sikotec GmbH / JT-elektronik GmbH	KMG Pipe Technologies GmbH	Kuchem GmbH	ALOCIT Chemie GmbH	Bodenbender GmbH	MC-Bauchemie Müller GmbH & Co. KG
System	3P-Plus-Kurzliner	KM-Kurzliner	K-LINER	ALOCIT Kurzliner	Point-Liner®	Konudur Sewer Repair Kit (VP)
						
Resin system used	3P resin	ARALDITE GY 240 BD, with ARADUR 16 BD, air expeller, curing agent	ARALDITE GY 250 BD, with ARADUR 16 BD	ALOCIT Resin® Alocan, with Peroxan BP 50+ (curing agent)	Multi - PL® resin	Konudur 266 SR (VP)
IKT test verdict*	**GOOD (2.2)**	**GOOD (2.2)**	**SATISFACTORY (2.8)**	**SATISFACTORY (2.9)**	**SATISFACTORY (3.1)**	**SUFFICIENT (4.2)**
System tests in test lines (weighting 85%)	**Good (2.4)**	**Good (2.2)**	**Satisfactory (3.1)**	**Satisfactory (3.3)**	**Satisfactory (3.4)**	**Sufficient (4.3)**
Function[1] (50%)	3.3	2.4	2.3	2.6[9]	3.0	3.6
Tightness[2] (50%)	1.4	2.0[6]	2.9[7]	4.0[8]	3.9	5.0
System-suppliers' Quality Assurance[3] (weighting 15%)	**Excellent (1.0)**	**Good (2.0)**	**Excellent (1.5)**	**Excellent (1.0)**	**Excellent (1.0)**	**Sufficient (4.0)**
System manual (20%)	Yes	Yes	Yes	Yes	Yes	Yes
Training provisions (20%)	Yes	Yes	Yes	Yes	Yes	No
Third-party supervision (20%)	Yes	Yes	Yes	Yes	Yes	No
Environmental impact (10%)	Yes	Yes	Yes	Yes	Yes	Yes
DIBt approval (10%)	Yes	No	No	Yes	Yes	No
Test certificates (10%)	Yes	No	Yes	Yes	Yes	No
Back-tracing of supply route (10%)	Yes	Yes	Yes	Yes	Yes	Yes
Additional information: Impression gained from site investigations and test-line use	Practically-orientated handling and use, extremely extensive cutting work in test	Practically-orientated handling and use	Practically-orientated handling and use	Practically-orientated handling and use	Practically-orientated handling and use	Practically-orientated handling and use
Suitability for oval concrete section, ND 400/600[4]	not proven[2]	not available	not available	not proven[1]	not proven[2]	not available
Suitability for use with ingress of groundwater and external water pressure[5]	proven	proven	not tested	not tested	not tested	not tested
Available for the diameters (information from supplier)	Round section: ND 100 - ND 700 Oval section: ND 250/375 - ND 500/750	Round section: ND 150 - ND 600 Oval section: not used	Round section: ND 100 - ND 1000 Oval section: not used	Round section: ND 100 - ND 800 Oval section: ND 200/300 - ND 500/750	Round section: ND 100 - ND 1200 Oval section: ND 250/375 - ND 400/600	Round section: ND 100 - ND 800 Oval section: not used
Potential for improvement	Improve flushing resistance	Three-layer installation in case of missing wall elements, even in small NDs	Improve flushing resistance (possibly with three-layer short liner)	Increase resin viscosity; possibly: increase scope of preparatory work	Improve sealing action	Improve laminate's sealing action and flushing resistance
Remarks	/	/	/	/	Use of an additional PES nonwoven in all NDs	System no longer available

1 Evaluation by visual assessment by system operators on basis of point scores (30 % weighting after completion; 70 % weighting after HP cleaning): 100 points = 1.0 to 0 points = 6.0; arithmetical averaging and statement of points in grades using a linear function; averaging of the grade averages for the vitrified clay and concrete test lines
2 Evaluation on basis of internal water-pressure tests after HP cleaning (visual checking for escape of water); grading depending on pressure level with no egress of water: 0.5 bar = 1.0 / 0.4 bar = 1.7 / 0.3 bar = 2.3 / 0.2 bar = 3.0 / 0.1 bar = 3.7 / 0.05 bar = 4.0 / not tight at any pressure = 6.0; Damage-type 2 (longitudinal cracks) in the concrete test lines were eliminated from the evaluation due to non-uniform cracking patterns
3 Evaluation: existent = yes and non-existent = no; approval/certificates/proof analyses must apply to the materials used in the test
4 Evaluation: „proven“ = system tested in ND 400/600 concrete test line with three types of damage, both criteria „Tightness“ and „Function“ assessed as at least „Sufficient“ (≤ 4.5) for each type of damage; „not proven1“ = system tested and at least one repaired point assessed as poorer than „Sufficient“ for at least one of the criteria of „Tightness“ and „Function“; „not proven2“ = the system is available for ND 400/600 concrete pipes, but the supplier did not use it in the test; „not available“ = the system is not available for use in ND 400/600 concrete pipes
5 Evaluation: „proven“ = system loaded in ND 300 vitrified clay test line with three leaking sockets with ingress of water and with external water pressure, and all repaired points exhibited no ingress of water upon internal inspection; „not proven“ = system tested, at least one repaired point exhibited ingress of water upon internal inspection; „not tested“ = system not tested
6 Damage-type 3, vitrified clay, ND 200 not evaluated, due to not sufficiently clear test result
7 Damage-type 1, vitrified clay, ND 200 and Damage-type 3, vitrified clay, ND 300, not evaluated due to cracking additional to the basis damage-type, with unclear causes
8 Damage-type 3, vitrified clay, ND 200 not evaluated due to cracking additional to the basic damage-type, with unclear causes
9 Damage-type 1, vitrified clay, ND 300 not evaluated, due to covering of end of short liner as a result of unplanned positioning error (overlapping) by the repair contractor (applies to the first-laid end in FR and the end subjected to greater loads during HP cleaning)
* Grade calculated using non-rounded off data

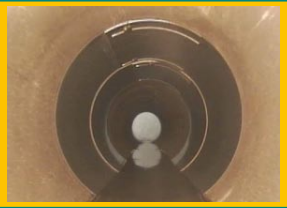
Key to test-result grades: Excellent = 1.0 - 1.5; Good = 1.6 - 2.5; Satisfactory = 2.6 - 3.5; Sufficient = 3.6 - 4.5; Deficient = 4.6 - 5.5; Insufficient = 5.6 - 6.0

Table 3: IKT „Repair systems for main drains" product test

Internal sleeves

System tests in test lines:

- Repair of three points of damage in each case in ND 200/ND 300 (jacketed) vitrified clay test lines and ND 300/ND 600 concrete pipes (exposed), all pipes with grease depositions
- Damage in vitrified clay: 1) spalling 20x20 cm, 2) extensive crack ramification across approx. 1 m length, 3) leaking socket with crown crack and spalling (d = 5 cm)
- Damage in concrete: 1) transverse crack, 2) longitudinal cracks in side zone and crown, starting from tapered end (l = approx. 1 m), 3) leaking socket with crown crack and spalling (d = 5 cm)

System supplier	**UHRIG Kanaltechnik GmbH**	**UHRIG Kanaltechnik GmbH**	**Haas GmbH & Co. KG**
	Quick-Lock flared at one end	**Quick-Lock**	**Stuttgarter Hülse**
System			
Sealing system used	**EPDM rubber seal**	**EPDM rubber seal**	**Grouting Compound 03567L51**
IKT test verdict*	**GOOD (2.2)**	**SATISFACTORY (3.1)**	**SUFFICIENT (4.3)**
System tests in test lines (weighting 85%)	Good (2.4)	Satisfactory (3.4)	Sufficient (4.3)
Function[1] (50%)	2.9	3.1	3.6
Tightness[2] (50%)	1.9	3.7	5.1
System-suppliers' Quality Assurance3 (weighting 15%)	**Excellent (1.5)**	**Excellent (1.5)**	**Sufficient (4.0)**
System manual (20%)	Yes	Yes	Yes
Training provisions (20%)	Yes	Yes	No
Third-party supervision (20%)	Yes	Yes	Yes
Environmental impact (10%)	Yes	Yes	No
DIBt approval (10%)	Yes	Yes	No
Test certificates (10%)	Yes	Yes	No
Back-tracing of supply route (10%)	No	No	No
Additional information: Impression gained from site investigations and test-line use	Practically-orientated handling and use	Practically-orientated handling and use	Practically-orientated handling and use Pressure prefilling of all damage in test
Suitability for oval concrete section, ND 400/600[4]	not available	not available	not proven[1]
Suitability for use with ingress of groundwater and external water pressure[5]	proven	not tested	not tested
Available for diameters (information from supplier)	Round section: ND 150 - ND 800 Oval section: not used	Round section: ND 150 - ND 800 Oval section: not used	Round section: ND 70 - ND 2000 Oval section: up to ND 900/1350
Potential for improvement	Reduce edges in overlap zone	Improve flushing resistance, improve hydraulic properties of sleeve	Improve tensioning of sleeve and sealing action
Remarks	/	/	System no longer available for this application

1 Evaluation of function by visual assessment by system operators on basis of point scores (30 % weighting after completion; 70 % weighting after HP cleaning): 100 points = 1.0 to 0 points = 6.0; arithmetical averaging and statement of points in grades using a linear function

2 Evaluation on basis of internal water-pressure tests after HP cleaning (visual checking for escape of water); grading depending on pressure level with no egress of water: 0.5 bar = 1.0 / 0.4 bar = 1.7 / 0.3 bar = 2.3 / 0.2 bar = 3.0 / 0.1 bar = 3.7 / 0.05 bar = 4.0 / not tight at any pressure = 6.0; Damage-type 2 (longitudinal cracks) in the concrete test lines were eliminated from the evaluation due to non-uniform cracking patterns

3 Evaluation: existent = yes and non-existent = no; approval/certificates/proof analyses must apply to the materials used in the test

4 Evaluation: „proven" = system tested in ND 400/600 concrete test line with three types of damage, both criteria „Tightness" and „Function" assessed as at least „Sufficient" (≤ 4.5) for each type of damage; „not proven1" = system tested and at least one repaired point assessed as poorer than „Sufficient" for at least one of the criteria of „Tightness" and „Function"; „not proven2" = the system is available for ND 400/600 concrete pipes, but the supplier did not use it in the test; „not available" = the system is not available for use in ND 400/600 concrete pipes

5 Evaluation: „proven" = system loaded in ND 300 vitrified clay test line with three leaking sockets with ingress of water and with external water pressure, and all repaired points exhibited no ingress of water upon internal inspection; „not proven" = system tested, at least one repaired point exhibited ingress of water upon internal inspection; „not tested" = system not tested

* Grade calculated using non-rounded off data

Key to test-result grades: Excellent = 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

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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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