Can wastewater manholes be rehabilitated so that they remain permanently watertight? What are the benefits and the drawbacks of mortar coating, plastic coating and lining. What quality can be expected? This first comparative product test in this field gives you the answers!

“Now for the manholes” – this is a thought in the repair/rehabilitation departments of many wastewater network operators. There is, indeed, little point in rehabilitating wastewater pipes without paying attention to the numerous defective manholes. This is particularly true in water infiltration zones, since a really watertight sewer network can only be achieved provided the manholes are also rehabilitated.

Under test: thirteen manhole-rehabilitation methods
But which of the many manhole rehabilitation methods should we choose? Which one will seal reliably and durably? Which is suitable in which situation, and which are not suitable? Thirteen commercially available methods have now been analysed in IKT’s „Manhole Rehabilitation” Comparative Test. The results range from GOOD to ADEQUATE, with one method failing the test.

Rehabilitation task and test programme
The task set for the participants was to rehabilitate an approximately 5 m high DN 1000 concrete manhole in which defined defects had been

Joint state/municipal funding
The North Rhine-Westfalia environmental ministry and the municipalities on the steering committee jointly funded this IKT Comparative Test. Testing and documentation of the results was performed by IKT, an independent and impartial institute. IKT was responsible for the engineering science development of the test concept and for the implementation of the test programme. Relevant decisions were coordinated and agreed with the steering committee.

Installation of the manholes: conditions can be replicated on a 1:1 scale in the IKT large-scale test facility, which is unique in the world.
This project’s wastewater network operator steering committee selected the following methods:  

<table>
<thead>
<tr>
<th>Supplier</th>
<th>System</th>
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<tbody>
<tr>
<td>Hermes Technologie GmbH &amp; Co. KG</td>
<td>Ergelit KS 1</td>
</tr>
<tr>
<td>MC-Bauchemie Müller GmbH &amp; Co. KG</td>
<td>Ombran MHP</td>
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<td>Silicate R</td>
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<td>Sika Deutschland GmbH</td>
<td>Sewer reprofiling mortar</td>
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<td>FSB Bautechnik GmbH</td>
<td>Spectrashield</td>
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<tr>
<td>PSL Handels GmbH</td>
<td>Oldodur WS 56</td>
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<tr>
<td>Source One Environmental UK (S1E)</td>
<td>Ultracoat</td>
</tr>
<tr>
<td>Aarsleff Rohrsanierung GmbH</td>
<td>GRP, back-anchored</td>
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<td>Hobas Rohre GmbH</td>
<td>GRP inner shaft</td>
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<td>SEKISUI SPR Germany GmbH</td>
<td>HDPE segmental lining</td>
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<tr>
<td>Schacht + Trumme Sielregulierungen W. Schwarz GmbH</td>
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</table>

The central elements of the test programme were testing of system performance and examination of the participant’s quality assurance provisions. A total of thirteen manholes consisting of prefabricated concrete elements with a nominal diameter of DN 1000 were installed in IKT’s large-scale test facility for the system tests.

The participating wastewater network operators selected the following damage scenarios in order to simulate as authentically as possible the condition of a damaged manhole and the actual challenges involved in rehabilitation:

- 8x „isolated damage“: point damage in the form of a 10 mm dia. drill hole
- 4x „area damage“: nine drilled holes of 5 mm dia. in a 20 cm x 20 cm area, with simulation of point defects in substrate preparation (mould release agent)
- 5x „leaking ring joint“: ring joint with four 6 mm dia. drill holes

The rehabilitation target was to restore the water-tightness and load-bearing capability of the manhole. How this was to be achieved was left up to each individual comparative test participant, i.e., each had sole responsibility for planning, conception, rehabilitation and finishing work. There was no time limit.

**Test programme and assessment system**

After completion of the manhole rehabilitation operations, performance against rising water level was first measured in accordance with DIN EN 1610. The focus during the system tests was on loads exerted by external water pressure:

- Short-term exposure to groundwater, in increments up to 5 m, holding time: 17.5 days (3.5 days per load level)
- Long-term exposure to groundwater, constant at 5 m, holding time: 67 days

The manholes were inspected after each increase in water level. They continued to be visually and acoustically inspected once per week when the maximum water level of 5 m had been rea-
The criterion of “load bearing capability” was evaluated on the basis of observations made during the short-term and long-term groundwater exposure tests. Differentiation was made here between the following conditions:

- No abnormalities
- Damp patch ≤ 25 cm²
- Damp patch > 25 cm²
- Damp patch with spreading plume ≥ 40 cm
- Infiltration

After completion of the groundwater loading test, tensile adhesion strengths were measured and any leaking points on the access system documented. The non-destructive MAC method, which functions using a horizontal pressure and fine sensors, was also used to measure ring stiffness. For more information about MAC see page 33. These criteria were incorporated into the Comparative Test as additional information with no grading. Proofs of load-bearing capability and protective action, and aspects of quality assurance, were also investigated.

**Infiltration water-tightness**

The criterion of „infiltration water-tightness“ was evaluated during the short-term and long-term groundwater exposure tests. Differentiation was made here between the following conditions:

- No abnormalities
- Damp patch ≤ 25 cm²
- Damp patch > 25 cm²
- Damp patch with spreading plume ≥ 40 cm

**Load bearing capability**

The criterion of „load bearing capability“ was evaluated for 5 m external water pressure. The systems used were grouped in terms of their functional mechanism. Whether they form an adhesive bond with the substrate (the „adhesive bond“ case), whether they are back-anchored by means of special support elements or are completely self-supporting (the „back-anchored/self-supporting“ case).

In the „adhesive bond“ cases, „tensile adhesion strength“, „hollow points“, „cracks“ and „blisters“ were observed, and any abnormalities were evaluated and graded. Where hollow points occurred, these were included, referred to in the total area treated, as „zero values“ in the averaging of the tensile adhesion tests.

In the „back-anchored/self-supporting“ cases, there is no large-area adhesive bond with the substrate. A self-supporting action was then considered to be system behaviour if it could be substantiated by means of corresponding proof of structural-analysis. This criterion was graded as „deficient“ if such proof could not be furnished.

**Robustness**

The „robustness“ criterion relates solely to the „area damage“ scenario. A mould release agent was applied to the target surfaces immediately prior to rehabilitation, in order to provide indications of the resistance of the rehabilitation system to unexpected bonding defects. These can occur in practice where there is a lack of substrate pre-treatment.

Differentiation was made between the rehabilitation systems according to their load-bearing behaviour for evaluation of the „robustness“ criterion:

- Case 1: Adhesive bond with the substrate
- Case 2: Back-anchoring using special support elements
- Case 3: Pipe-in-pipe system

„Bonding with the surrounding material“ (not relevant for Case 3), „deformations“, „tensile strength deficiencies“ and „infiltration“ were recorded and abnormalities evaluated and graded for the „robustness“ criterion.

**Acceptability of completed work**

An assessment of the acceptability of the completed work was undertaken by the assessment committee (a group of network operators from the steering committee) throught inspection directly in the manhole and by the entire steering committee, with award of grades, using camera-based video documentation material.

**Steering committee**

Every IKT Comparative Test is supported by a steering committee consisting of sewer network operators. The role of the committee is to:

- select the products to be tested;
- specify the test concept;
- define performance targets and quality requirements, and
- evaluate and grade the test results.

The steering committee for the „Manhole Rehabilitation“ Comparative Test consisted of seventeen sewer network operators:

- The municipality of Arnhem (NL)
- Backnang municipal drainage department
- Burscheid municipal utilities
- City of Emsdetten wastewater treatment plant
- Essen municipal utilities
- City of Euskirchen
- Hagen municipal services
- City of Iserlohn
- Kempen municipal services
- Kiel municipal drainage department
- Cologne municipal drainage utilities
- Lünen municipal wastewater management services
- Minden municipal services
- Bad Oeynhausen municipal utilities
- Troisdorf wastewater management department
- Vogtland water/wastewater special-purpose municipal alliance
- City of Willich wastewater management department

**Protective action**

Demonstrations of suitability of the systems for use in wastewater facilities within the permissible pH range were required from the suppliers. Such proof of “protective action” was considered to have been provided if a DIBt (German...
Institute for Building Technology) approval or evidence analogous to the DIBt approval tests was submitted. Exposure tests on mortar and plastic in aggressive and particularly aggressive fluids were then performed, in order to verify the protective action of the materials used on a random-sampling basis. Scores were uprated by one grade if no abnormalities were found.

Quality Assurance

The suppliers’ quality assurance assessment covered criteria such as method description, training provisions, test certificates and third-party supervision. “Particular abnormalities” were recorded for any additional features of the performance of the work that were observed.

On-site tests

The on-site tests were undertaken to determine the practicability of the rehabilitation methods under real on-site conditions. These on-site tests provided a check of how representative the testing in the IKT test facilities was of real conditions. For this purpose, essential working operations were observed. In particular, the nature and scope of preparatory work were noted and deviations from the requirements in the method manuals and/or from the work performed at the IKT test facilities were recorded. In addition, the on-site tests were also used to record any “particular abnormalities” as part of the suppliers’ quality assurance assessment.

Table 2 summarises the overall evaluation system, including additional information, and shows the weighting of these criteria that was specified by the network operators.

IKT Comparative Test „Manhole rehabilitation“: Test results

The overall scores in the IKT Comparative Test, „Manhole rehabilitation“ ranged from GOOD to ADEQUATE:

- GOOD (1.6): Hobas Rohre GmbH, using GRP inner manhole shaft
- GOOD (1.7): PCI Augsburg GmbH, using Nanocret R4
- GOOD (2.1): Schacht + Trumme GmbH, using HDPE segmental lining
- GOOD (2.1): Sika Deutschland GmbH, using sewer reprofiling mortar
- GOOD (2.2): Aarsleff Rohrsanierung GmbH, using GRP – back-anchored
- SATISFACTORY (2.6): PSL Handels GmbH, using Oldodur WS 56
- SATISFACTORY (2.7): Hermes Technologie GmbH, using Ergelit KS 1
- SATISFACTORY (2.8): Source One Environmental UK, using Ultracoat
- SATISFACTORY (2.9): Remmers Baustofftechnik GmbH, using Betofix R4 SR
- SATISFACTORY (3.5): SEKISUI SPR Germany GmbH, using GRP – adhesive
- SATISFACTORY (3.5): Remmers Baustofftechnik GmbH, using Silicate R
- ADEQUATE (3.6): MC-Bauchemie Müller GmbH, using Ombran MHP
- NOT EVALUABLE: FSB Bautechnik GmbH, using Spectrashield

Due to a system failure caused by the „pre-damage“ areas (mould release agent applied to assess „robustness“), it was not possible to evaluate the „Spectrashield“ system. It was no longer possible to enter the manhole.

Results for infiltration water-tightness

None of the methods exhibited any abnormalities after the short-term and long-term groundwater exposure resulting from the „isolated damage“ scenarios. All of the 96 points of damage across the rehabilitated manholes were watertight (100%). This damage scenario clearly presented no problem to the rehabilitation systems tested.

Abnormalities caused by the “leaking ring joint” became apparent during the short-term groundwater simulation at 5 m affecting 14 of the 60 repairs (approx. 23%). During the subsequent long-term groundwater simulation at 5 m, three of these exhibited a change in their condition and new abnormalities (damp patches) were...
recorded at three more points, bringing the total to 17 of the 60 repairs. So at the end of the experiment there were no abnormalities recorded for 43 points of damage (around 72 %).

Where a point of damage had been suitably repaired and exhibited no abnormalities at the start of the groundwater exposure testing, it generally remained in this condition throughout (139 of 156 points of damage, approx. 89 %). No additional infiltration (long-term groundwater simulation at 5.0 m) was exhibited at 154 points of damage (approx. 99 %) up to the end of the test.

A grade of 1.0 was awarded to 7 of 10 suppliers for „load-bearing capability“. Three systems („Ombran MHP“, „Ergelit KS 1“ and „Spectrashield“) each scored 5.0.

No abnormalities were exhibited by 7 of 10 systems (70 %) in the „remaining manhole wall“ sector. The „Ombran MHP“ and „Ergelit KS 1“ mortar systems exhibited extensive hollow points. In addition, tensile strength deficiencies (cracks), which resulted in minus points, were apparent in the case of the „Ergelit KS 1“ system.

Deficiencies in substrate preparation: blisters and cracks may be the result if the mould release agent prevents secure bonding.

Load-bearing capability: adhesive bond with substrate
In the case of the „isolated damage“ scenario, repairs to 216 of the 240 points of damage (approx. 90 %) exhibited no abnormalities. With one exception, this damage scenario thus presented no significant problem for the rehabilitation systems tested.

In the case of the „leaking ring joint“ damage scenario, 133 of 150 load-bearing evaluations (approx. 89 %) exhibited no abnormality. The „Ombran MHP“ system exhibited two slight tensile strength deficiencies, which did not result in loss of score. Therefore, this damage scenario also presented no significant problem to the rehabilitation systems tested.

No abnormalities were exhibited by 7 of 10 systems (70 %) in the „remaining manhole wall“ sector. The „Ombran MHP“ and „Ergelit KS 1“ mortar systems exhibited extensive hollow points. In addition, tensile strength deficiencies (cracks), which resulted in minus points, were apparent in the case of the „Ergelit KS 1“ system.

Immunity („robustness“) to punctual deficiencies in substrate preparation
No abnormalities were apparent at 44 of the 52 (approx. 85 %) points for the „inadequate bonding with the surrounding material“ points of damage. Two mortar coatings exhibited abnormalities in the form of hollow point enlargements („Ombran MHP“ 1 of 4 and „Silicate R“ 2 of 4 damage locations). Two plastic coatings („Spectrashield“ and „Oldodur WS 56“) exhibited abnormalities at five of eight points of damage. No abnormalities were found on the four remaining lining systems and four mortar systems, or on the epoxy-resin plastic coating.

No abnormalities for „excessive deformation“ were observed for 46 of 52 points of damage (approx. 89 %). For two plastic coatings („Spectrashield“ and „Oldodur WS 56“), abnormalities in the form of blisters were observed at six of the eight points of damage. The six mortar
IKT Comparative Test

Cracking in a zone pre-treated with mould release agent.

coatings, the four lining systems and the epoxy-
resin plastic coating („Ultracoat“) exhibited no
abnormalities.

For „tensile strength deficiency“, 41 of the 48
points of damage (approx. 85 %) had no abnor-
malities. Three mortar coatings exhibited cracks.
The four lining systems, three mortar systems
and two plastic coatings had no abnormalities.

For „infiltration“, there were no abnormalities
at 33 of 48 points of damage (approx. 69 %).
Damp patches and/or spreading plumes were
found on all six mortar coatings. One plastic
coating („Oldodur WS 56“) exhibited infiltrat-
ing water at one of four points of damage. No
abnormalities were noted on the four lining
systems and on the epoxy-resin plastic coating.

Where inadequate bonding had been ascer-
tained in the vicinity of „area damage“, leaks
generally also occurred at these locations. Leaks
were also exhibited in all cases where cracks
occurred in a mortar coating. No abnormalities
were found in the four lining systems and in the
epoxy-resin plastic coating.

Acceptability of repair
The overall grades awarded for the acceptability
of repair ranged from Very Good (1.1) to Ade-
quate (3.7). Three systems were Very Good, five
were Good, three were Satisfactory and one was
graded Adequate (average overall grade: 2.2).
Significant differences in grades were found bet-
ween the individual systems.

Protective action
Evidence for verification of protective action
was provided for four of thirteen systems. A
DIBt approval exists for three systems („Ombran
MHP“, „Ergelit KS 1“ and „Spectrashield“). An
analysis certificate, as necessary for DIBt appro-
val, was submitted for the „Silicate R“ system.
None of the systems exhibited any abnormalities
in random-sampling tests. All systems therefore
had their scores increased by one grade.

Quality assurance by the system suppliers and/
or refurbishing contractors was extremely patchy.
Results are compiled in the test tables.

Conclusions
Reliable manhole rehabilitation possible
using commercially available systems
The systems tested in the IKT Comparative
Test demonstrated that reliable manhole reha-
bilitation is possible even when exposed to
groundwater pressure. However, the range of
scores awarded to the individual systems is wide,
extending from GOOD to ADEQUATE.

System failure due to substrate-preparation
deficiencies in individual cases
One of the coating systems could not be evalu-
ated, since it proved to be extremely sensitive
to isolated deficiencies in substrate preparation
(test criterion „robustness“). Giant bubbles,
which prevented renewed entry to the manhole,
developed under exposure to external water
pressure, starting from the local weak points
where mould release agent had been applied
for the test. Other systems exhibited cracking,
blistering, hollow point enlargements and leaks
at such points.

Water-tightness performance recognisable
at early stage if groundwater present
Where the refurbished manholes were water-
tight immediately after initial exposure to
groundwater, no further deterioration in quality
was generally observed, even under greater
and more prolonged exposure to groundwater.
Therefore acceptance inspection is recommen-
ded when groundwater is present on-site.

Load-bearing capability critical or unknown
in some systems
Analyses of the load-bearing capability of the
various systems produced greatly differing
results. Some systems based on adhesive
bonding exhibited extensive cavity areas and
cracking, and received the „Deficient“ grade,
wheras others convincingly achieved „Very
Good“. A structural-analysis certificate was
available only in one case for the two self-
supporting linings and one system incorporating
back-anchoring using support elements, while
the load-bearing capability of the two other
systems still remains unknown.

Protective action not clarified in a large
number of systems
Only four of thirteen suppliers were able to
submit certificates for the use of their materials/
systems in wastewater facilities. No abnor-
malities were found in random-sampling tests
(exposure tests), however.
Quality assurance very patchy
The majority of system suppliers and rehabilitation contractors were able to cite training certificates, test certificates, DIBt approvals, etc., only in individual cases. Overall large gaps were apparent.

MAC measurement confirms auxiliary supporting action
The MAC measurements showed that all coatings, and linings with full-area contact/bonding with the original manhole walls, are capable of making a significant contribution to the restoration of horizontal ring stiffness. In many cases, the data for an intact system were again achieved - or even exceeded - even in the case of cracked manhole-shaft rings.

Acceptance impression of system operators confirms test results
The evaluation of the work performed, undertaken by the representatives of the wastewater network operators – the „acceptance impression“ - largely coincided with the results of the extensive tests performed for the IKT Comparative Test. However, this presupposes extensive experience on the part of the individual employees.

The Authors
Dipl.-Ing. (FH) Serdar Ulutas, MBA, Prof. Dr.-Ing. habil. Bert Bosseler
Dipl.-Ök. Roland W. Waniek
Henning Winter
IKT – Institute for Underground Infrastructure

Photos of the presentation of results at IKT

Dipl.-Ök. Roland W. Waniek, director, welcomes the guests to the presentation of results of the IKT „Manhole rehabilitation“ Comparative Test.

Dipl.-Ing. (FH) Serdar Ulutas, MBA, head of IKT Comparative Test, presents the results of this Comparative Test.

Guests await the results of the latest IKT Comparative Test.

Prof. Dr.-Ing. habil. Bert Bosseler, Scientific Head of the IKT, answers guests’ questions.

Critical questions from the audience are always welcome.

Dipl.-Ing. Frank W. Grauvogel, of the Burscheid municipal technical services, presents the steering committee’s viewpoint.

The summary report contains all the essential information (download German versions: www.ikt.de/downloads/warentest-berichte/).

Lively discussion continues after presentation of the results.
**IKT Comparative Test “Manhole Rehabilitation”**

**Task:** Rehabilitation of an approximately 5 m high DN 1000 concrete manhole in which defined defects had been installed, against a rising groundwater table.

- **5x “isolated damage”:** Point damage in the form of a 10 mm dia. drill hole.
- **4x “area damage”:** Nine drilled holes of 5 mm dia. in a 20 cm x 20 cm area, with simulation of point defects in substrate preparation (mould release agent).
- **5x “leaking ring joint”:** Ring joint with four 6 mm dia. drill holes.

**Systems**

<table>
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<tr>
<th>Contractor</th>
<th>Hobas Rohre GmbH</th>
<th>PCI Augsburg GmbH</th>
<th>Schacht + TrummeSielenregulierungen W. Schwarz GmbH</th>
<th>Sika Deutschland GmbH</th>
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<th>PSL Handels GmbH</th>
<th>Hermes Technologie GmbH &amp; Co. KG</th>
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**IKT test results¹**

<table>
<thead>
<tr>
<th>System tests (85 %)</th>
<th>Very Good (1.2)</th>
<th>Very Good (1.3)</th>
<th>Good (2.0)</th>
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<td>Robustness² (20 %) to point defects in substrate preparation</td>
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<td>Quality Assurance⁴ (15 %)</td>
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<td>Adequate (4.5)</td>
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</table>

**Method description**

- **Short-term exposure to groundwater, in increments up to 5 m, holding time: 17.5 days (35 days per load level) (20 %)**
- **Load-bearing capability (20 %)**
- **Robustness² (20 %)** to point defects in substrate preparation
- **Acceptability of completed work ³ (15 %)**

**Training provisions (20 %)**: Training of rehabilitation (15 %), Manufacturer’s training courses (10 %)

**Test certificates (20 %)**

**Third-party supervision (20 %)**

**“Particular abnormalities” (20 %)**

- **Improvement of grading value (10 %), Technical note sheets (10 %)**

**Method description**

- **Training of rehabilitation (15 %), Technical note sheets (10 %)**

**Training provisions (20 %)**: Training of rehabilitation (15 %), Manufacturer’s training courses (10 %)

**Test certificates (20 %)**

**Third-party supervision (20 %)**

**“Particular abnormalities” (20 %)**

- **Improvement of grading value (10 %), Technical note sheets (10 %)**

**Information annex (with no grading)**

- **Static Axial load (intact system) = 100 %**
- **Surface preparation: Implementation and time required (approx.)**
- **Total working hours (approx.) on site**
- **Filling level test after rehabilitation**
- **Costs, not including VAT**

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

¹ Note: All values indicate mean of non-repeated values.
² System failure after 8 days of short-term exposure to groundwater formation of two bubbles, no entry to the manhole possible. Inspection, testing and evaluation cancelled.
³ Robustness to point defects in substrate preparation: simulation of inadequate pretreatment, as can occur in practice.
⁴ Impression made at on-site acceptance inspection: entry to manhole and video evaluation by members of the steering committee.
⁵ Protective action against aggressive environmental conditions: is considered demonstrated provided the relevant environmental conditions are met, e.g. DIBt approval. Grades awarded on the basis of pH class and, where appropriate, passing of random-sampling test.
⁶ The in-situ work was performed by Schulz Bau GmbH, since Aarsleff Rohrsanierung GmbH declined to perform rehabilitation.
⁷ **System failure after 8 days of short-term exposure to groundwater: formation of two bubbles, no entry to the manhole possible. Inspection, testing and evaluation cancelled.**
IKT Comparative Test "Manhole Rehabilitation"

Task: Rehabilitation of an approximately 5 m high DN 1000 concrete manhole in which defined defects had been installed, against a rising groundwater table.

- 4x "area damage": nine drilled holes of 5 mm dia. in a 20 cm x 20 cm area, with simulation of point defects in substrate preparation (mould release agent)
- 4x "leaking ring joint": ring joint with four 6 mm dia. drill holes

Source:
- Source One: Environmental UK (S1E)
- SEKISUI SPR
- Remmers
- Baustofftechnik GmbH
- MC-Bauchemie Müller GmbH & Co. KG
- FSB Bautechnik GmbH
- SMG Bautenschutztechnik für Bauwesen GmbH
- Heikaus KS Kanalsanierungen GmbH
- BSG Beschichtungs GmbH
- SMG Bautenschutztechnik für Bauwesen GmbH

IKT test results *

<table>
<thead>
<tr>
<th>System tests (85 %)</th>
<th>Source One Environmental UK (S1E)</th>
<th>Remmers Baustofftechnik GmbH</th>
<th>SEKISUI SPR Germany GmbH</th>
<th>Remmers Baustofftechnik GmbH</th>
<th>MC-Bauchemie Müller GmbH &amp; Co. KG</th>
<th>FSB Bautechnik GmbH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infiltration water tightness (40 %)</td>
<td>Good (2.5)</td>
<td>Satisfactory (2.8)</td>
<td>Satisfactory (3.5)</td>
<td>Satisfactory (3.5)</td>
<td>Sufficient (3.6)</td>
<td>Not evaluable</td>
</tr>
<tr>
<td>Short-term exposure to groundwater, in increments up to 5 m, holding time: 17.5 days per load level (20 %)</td>
<td>3.8</td>
<td>1.8</td>
<td>4.5</td>
<td>4.5</td>
<td>2.6</td>
<td>Not evaluable</td>
</tr>
<tr>
<td>Long-term exposure to groundwater, constant at 5 m. holding time: 67 days (20 %)</td>
<td>3.8</td>
<td>1.9</td>
<td>4.5</td>
<td>4.5</td>
<td>3.3</td>
<td>Not evaluable</td>
</tr>
<tr>
<td>Load-bearing capacity (20 %)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Robustness** (20 %) to point defects in substrate preparation</td>
<td>1.0</td>
<td>6.0</td>
<td>1.0</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Acceptability of completed work *** (15 %)</td>
<td>2.2</td>
<td>2.5</td>
<td>3.7</td>
<td>2.6</td>
<td>3.2</td>
<td>Not evaluable</td>
</tr>
<tr>
<td>Protective action**** (5 %)</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>2.8</td>
<td>2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Quality Assurance***** (15 %)</td>
<td>Adequate (4.5)</td>
<td>Satisfactory (3.5)</td>
<td>Inadequate (6.0)</td>
<td>Satisfactory (3.0)</td>
<td>Very Good (1.0)</td>
<td>Good (2.5)</td>
</tr>
<tr>
<td>Method description (20 %): Method description (10 %). Technical note sheets (10 %)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Training provisions (20 %): Training of rehabilitators (10 %). Manufacturer’s training courses (10 %)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Test certificates (20 %)</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Third-party supervision (20 %)</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>* Particular abnormalities (20 %)</td>
<td>In situ: Drying of reprofiling mortar using hot air blower (o) no abnormalities (+) Quality Assurance: no need on inquiries and requests (-) no abnormalities (+) no abnormalities (+) no abnormalities (+)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>** Additional information (with no grading):</td>
<td>Table 1 System MAC stiffness (intact system = 100 %)</td>
<td>after rehabilitation 100 - 150 %</td>
<td>after rehabilitation &gt; 150 %</td>
<td>after rehabilitation 100 - 150 %</td>
<td>after rehabilitation &gt; 150 %</td>
<td>after rehabilitation &gt; 150 %</td>
</tr>
<tr>
<td>Static system</td>
<td>1 - 18 access systems</td>
<td>3 - 18 access systems</td>
<td>2 - 18 access systems</td>
<td>1 - 18 access systems</td>
<td>1 - 18 access systems</td>
<td>not evaluable</td>
</tr>
<tr>
<td>Surface preparation: Implementation and time required (approx.)</td>
<td>Manual high-pressure-water jetting with 250 bar, (1h)</td>
<td>Manual high-pressure-water jetting with 250 bar, (1h)</td>
<td>No surface preparation</td>
<td>Mechanical high-pressure-water jetting with granulates (approx. 20 min)</td>
<td>Mechanical high-pressure-water jetting with granulates (approx. 20 min)</td>
<td>Manual high-pressure-water jetting with 500 bar, (1h)</td>
</tr>
<tr>
<td>Rehabilitation: Implementation and time required (approx.)</td>
<td>Hand-held spray gun, 1 Std.</td>
<td>Hand-held (mat-by-mat), 2 Std.</td>
<td>Hand-held (mat-by-mat), 2 Std.</td>
<td>Hand-held spray gun, 4 Std.</td>
<td>Hand-held spray gun, 3 Std.</td>
<td>Hand-held spray gun, 2 Std.</td>
</tr>
<tr>
<td>Total working hours (approx.): days on site</td>
<td>10 h/3 days</td>
<td>7 h/2 days</td>
<td>7 h/2 days</td>
<td>9 h/1 day</td>
<td>7 h/2 days</td>
<td>9 h/1 day</td>
</tr>
<tr>
<td>Filling level test after Rehabilitation</td>
<td>Passed</td>
<td>Passed</td>
<td>Not passed</td>
<td>Passed</td>
<td>Passed</td>
<td>Passed</td>
</tr>
<tr>
<td>Costs, not including VAT</td>
<td>5,040 EUR</td>
<td>1,940 EUR</td>
<td>3,770 EUR</td>
<td>2,240 EUR</td>
<td>5,500 EUR</td>
<td>3,670 EUR</td>
</tr>
</tbody>
</table>

* Note calculation is based on non-rounded values

** System failure after 8 days of short-term exposure to groundwater: formation of two bubbles; re-entry into the manhole impossible. Imposition, testing and ex-vacuo sampling cancelled.

1 Robustness in point defects in substrate preparation: simulation of inadequate pre-treatment, as can occur in practice.
1.1 Method description (20 %): Method description (10 %): Technical note sheets (10 %): is considered demonstrated provided the relevant documents can be submitted, e.g. DIBt approval. Grade awarded on the basis of price class and, where appropriate, passing of random-sampling test.
1.2 Training provisions (20 %): Training of rehabilitators (10 %): Manufacturer’s training courses (10 %): is considered demonstrated provided the relevant documents can be submitted, e.g. DIBt approval.
1.3 Test certificates (20 %): is considered demonstrated provided the relevant documents can be submitted, e.g. DIBt approval.
1.4 Third-party supervision (20 %): is considered demonstrated provided the relevant documents can be submitted, e.g. DIBt approval.
1.5 Particular abnormalities (20 %): In situ: Drying of reprofiling mortar using hot air blower (o) no abnormalities (+) Quality Assurance: no need on inquiries and requests (-) no abnormalities (+) no abnormalities (+) no abnormalities (+) no abnormalities (+)

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

IKT
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.

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