

## Manhole Coating: An Alternative Renovation Method?

For the renovation of manholes, coating methods are considered a competitive alternative to the renewal of the manhole. But are they really an alternative? So far there has hardly been evidence regarding limitations of use, influences on quality and the durability of the methods offered. The IKT has lightened the dark: in an extensive practical survey 42 manhole coatings were monitored and investigated at twelve sewage network operators.

### Renovation, but how?

Besides the renewal of the manhole lining and coating methods can be employed for the renovation of large-area damages or leakage. A specific pressure to act is apparent for operators in North Rhine Westphalia (Germany): here the *Selbstüberwachungsverordnung Kanal (SüwV Kan)* (self-monitoring regulations for sewer systems) require the inspection and, if necessary, the rehabilitation of manholes. According to estimations by public sewage network operators, around twelve per cent of the approximately ten million manholes in Germany are basically suitable for rehabilitation with the coating method. The resulting possible market volume for coating methods of around 2.7 billion Euro is immense! Until today, however, there have been large uncertainties regarding the limitations of use of the offered method and the durability of the results of the renovation.

### The Quality Components

The IKT chose a very practically-oriented procedure to find out the essential influences on quality when carrying out coating measures. At the same time they intended to sound out the possibilities or limits of use of each methods.

During the two years of the project the following working program was completed:



Grout coating in the spray lining process



Polyurethane coating in the gunite lining process



Manhole coated with mortar



Manhole coated with polyurethane

### 1. On-site Measures

42 coating measures in the drainage networks of altogether twelve network operators were monitored. Extensive quality test were carried out over a period of several months. Grout coatings and coatings of polyurethane were used by considering all cleaning- and application methods that are relevant for the market. All renovations were carried out by specialty firms that had only received instructions regarding the coating material and application method. Comments on the renovation procedure were deliberately not made in order to be able to identify the routine working processes, the actual quality of the renovation as well as possible sources of errors and improvement potentials under realistic circumstances.



Figure left: Documentation of the conditions on the construction site and the renovation  
Figure right: Quality check of the renovations carried out

# Manhole Coating

## 2. Laboratory Experiments

To complement these on-site measures, experiments were carried out in the IKT-laboratories and test facilities. In this way, for instance, the effects of intensive traffic loads on a coated manhole could be simulated or the bonding behaviour of coatings on water-saturated concrete surfaces could be investigated further.



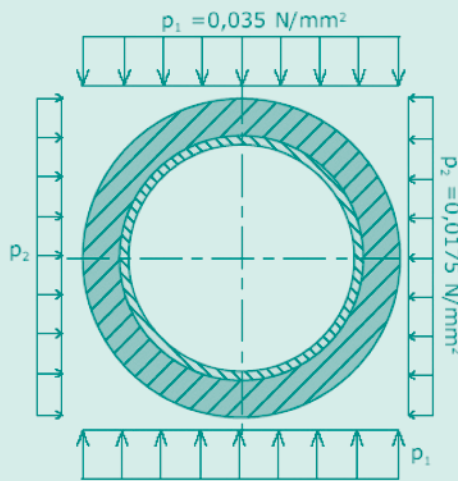
Dynamic load of a coated manhole



Water saturation of manhole elements

## 3. Special Questions

Further questions raised from the results of the investigations and the laboratory experiments: What are the minimum adhesion tensile strengths of coating? What are the effects of alternative pre-treatment techniques? How does the external climate influence the hardening of grout coatings? How well can the transition to other materials can be created in the joint areas? These questions were followed in additional investigations.



Load case for the numeric calculations of the minimum adhesion tensile strength



Investigation of alternative pre-treatment techniques

### Manhole Coating: an alternative! But...

The results of the research project show: the coating methods analysed can basically be helpful to recover the functional capability of brick-built and concrete manholes. Especially with difficult geometries and numerous inflows renovating manholes by coating seems to be an alternative to the new construction of the manhole.

The quality of the renovation, however, was low in the majority of the analysed cases: in 16 of the 26 grout coatings that were analysed visual lacks such as cracks, hollow spots, imperfections or leaks were registered. Only in seven grout coatings an adhesive bond to the old manhole wall could be measured that met the requirements of the relevant regulations. Especially grout coatings in concrete manholes showed a very low bond to the subsurface.

Also among the polyurethane coatings nine of the 16 analysed cases showed visual lacks such as hollow spots, bubbles or imperfections. In twelve cases a sufficient adhesive bond to the subsurface could be found. Only very wet surfaces seemed to cause problems.

Inaccurate application of the coating, in particular, could be identified as a main reason for the poor renovation quality. Furthermore, the preparation of the subsurface was insufficient in many cases. Generally, the preliminary cleaning of the manhole with water pressure, which is very common today, only seems to be suitable to a limited extent for preparing the coating measure. It can be recorded that the current measures for quality assurance – especially when looking at the usual practice – urgently need improvement. This is why IKT – starting from the experiences made – develops help guidelines for quality assurance, which can be used by the sewage network operators for tendering, construction monitoring and final acceptance of renovation measures using coating methods.



High-pressure water cleaning of a manhole wall with a hand lance



## Material Behaviour and Application Limits:

### Present Cleaning Methods hardly suitable

To keep a sustainable subsurface and the pre-conditions for a good bond of the coating, first of all dirt, coverings and glaze as well as damaged material have to be removed from the manhole wall. For this purpose, usually high-pressure water cleaning is used.



High-pressure water cleaning of a manhole wall with a rotating cleaning nozzle

In the IKT experiments showed that this method is only scarcely suitable: often coverings and glazes could not be removed from bricks. Also cleaning out brickwork joints in an adequate depth nearly always proved to be difficult. In concrete manholes there is often the problem that the subsurface cannot be roughened adequately to ensure a sufficient hold of the coating grout with the surface.

As a test some manholes were cleaned with high water pressure by mixing in sand. The results of the cleaning were clearly better. However, the working conditions for the executive technician were catastrophic: not only was he forced to protect himself against the rebound of water, but in addition against the rebound of sand.

## Automatic Application is not necessarily an Advantage



Pre-coating of a brick-built wall with severe joint corrosion

Brick-built manholes with strong joint corrosion and concrete manholes with advanced concrete corrosion have a very uneven wall surface. Before these manholes can be coated by spray lining, the surface needs to be flattened manually with a pre-coating of mineral mortar first.



Completely pre-coated brick-built manhole

These manual works often comprise a major part of the total work effort. This pre-coating also presents – depending on the layer thickness – a complete coating of the manhole. By the subsequent mechanical application of a main coating, the compound strength of the pre-coating cannot be increased any further.

## Polyurethane: Big Differences between the Products



Bubbles in a polyurethane coating with high surface moisture

The laboratory experiments clearly show big differences between the single products offered on the market. Especially the sensitivity towards moisture differs: while one of the PU-products analysed reacted to a high level of moisture, another PU-product showed no visually noticeable reactions.



Flawless polyurethane coating also with a high surface moisture level

⚠ Polyurethane is not like polyurethane.

⚠ Here the industry seems to be in demand: a new cleaning device, similar to the already available rotating cleaning nozzle, is needed in order to apply water and sand mechanically to the manhole wall.

⚠ In these cases the question has to be asked why the spray lining method has to be applied for renovation additionally after all and why the entire coating thickness is not applied manually in the first place?

# Manhole Coating

## Polyurethane: Caution when coating very moist Brick-built Manholes

All polyurethane products analysed did not adhere well on moist surfaces. Especially on PU-coatings which were applied to soaked brickwork, the IKT testers measured only a slight bond with the surface. In exceptional cases also debonding was observed.



Drying of a manhole in the run-up to a polyurethane coating

Often renovation contractors use mobile heating equipment to dry the brickwork before it is coated. But even after drying, in some cases the surface moisture was still too high.

Thus, the use of polyurethane for coating very moist brick-built manholes seems not recommendable.

## Requirements of Mortar vs. Requirements of Polyurethane

Generally, there is a difference between the requirements of a (pre-coating) mortar and those of a polyurethane. While, if possible, the mortar should be kept rather moist during hardening, for coating with polyurethane a dry environment is an advantage.

This different requirements can become critical if both materials are used in combination. This is the case, for example, if a manhole is pre-coated with mortar to even the surface and is to be coated with polyurethane afterwards. To achieve the lowest possible moisture of the surface for applying the polyurethane here coating contractors often like to use mobile heating guns, by

means of which the manhole – and thus the grout layer – is dried.

Using these heating devices can influence the hardening since it forms the subsurface for the polyurethane coating.

Thus, our recommendation: wait with the polyurethane coating until the mineral pre-coating has enough residual moisture. Do not use mobile heating equipment for drying.

## Preparation of the Renovation

### Clever Inspection before the Acceptance of bid!



Damaged manhole

In the phase of preparing the renovation the manhole to be renovated should be visually inspected in detail. Ideally, the inspection should be carried out with a high level of groundwater in order to be able to notice leakage in the manhole body.



Leaking annular joint inside a manhole of concrete components

Here, also the condition of the vicinal sections as well as the other branches in the manhole wall are to be documented. If damages or leaks are noticeable in the vicinal sections, in the ideal case the renovation of the manhole should be integrated in the rehabilitation of the entire system.

## Where are the Damages?



Leakage in the channel in the area of the discharge

Nearly all manholes showed severe damage in the lower area of the manhole body, in many cases the berms, channels and connections to the outgoing sewers also needed renovation.



Transition area of a rectangular brick-built manhole/round concrete cone with horizontal ledges in the manhole wall.

If branches were integrated in the wall, they were leaking or damaged in nearly all cases. In the transition area of brickwork to concrete often leakage and transverse displacement were found, which can complicate a renovation with the coating method.



### Plan Preparatory Works!

Damaged branches inside the manhole wall are to be renovated before starting the coating. Step irons should be demounted before coating. After the coating is completed, the use of a ladder is particularly recommended as then the body of the coating has only to be broken through at a few spots.



Formation of spray shadows next to a step iron caused by grout coating with spray lining

With grout coatings by spray lining as well as with polyurethane coatings by the gunite lining process, spray shadows develop at the step rings. In addition, these areas have to be prepared manually or have to be re-worked.

In brick-built manholes and manholes of pre-fabricated concrete components with corrosion usually a comprehensive mechanical preparation of the surface is necessary. In manholes consisting of prefabricated concrete components without corrosion preparatory works are normally limited to annular joints.



Sealing of a brick-built manhole with filling jointing grout

Before coating, in many cases the manhole wall needs to be sealed. In manholes of pre-fabricated concrete components good results can be achieved with injections like polyurethane resins, for example. Sealing by means of injection in brick-built manholes is more laborious. If there is no in-situ groundwater that pushes, here especially quickly setting repair grout is helpful.



Injection material entering through leaks inside an annular joint of a concrete manhole

In brick-built manholes with joint corrosion normally laminar pre-coatings with mineral grout are necessary before the coating is applied mechanically (grout and polyurethane).

### Construction monitoring

Generally, the following applies: the present practice under the special conditions in manholes seems to have a strong impact on the results of the renovation. Here in particular:

- procedural weaknesses in the preparation of the surface,
- manufacturers not meeting the requirements and the essential regulations during the entire renovation process and
- the lacking control of the rehabilitation success

are to be mentioned.

Manual processing on site, slow hardening of the material and the high requirements of the re-working are becoming more serious when using mortars. A more intense construction supervision compared to present practice is definitely recommendable!

Looking at a couple of essential points during renovation can increase the probability of a successful renovation enormously:

❗ Control the tidiness of the manhole wall.



Dirt residues on the wall after cleaning

In practice, insufficient preparatory cleaning can occur. This is why after completed cleaning dirt residues can be found on parts of the wall. A finishing check of the manhole wall before applying the coating is not carried out in all cases.



Applying the grout onto a „dirty“ wall

Thus, before applying the coating, a detailed inspection of the cleaned manhole wall should be carried out to be able to notice dirt residues, coverings or a too low material removal and to introduce further measures if necessary.

# Manhole Coating

## Check the material used

In many cases inadequate materials, especially for pre-coating, are used. For example, for concrete manholes with severe corrosion only grout products are suitable, which were developed especially for the use in very aggressive sewage.



Green-black colouring of the pre-coating inside a manhole with strong impact of sulphuric acid

Thus, check the materials used by the contractors whether they are really suitable for the application.

## Mortar: urge the observation of manufacturer requirements

To improve the mortar's processing characteristics for manual application, in practice the requirements by the manufacturers are interpreted in a very creative way. For example, it could be possible that slightly hardened mortar is again mixed with water and is used for coating.

Thus, already in your call for tenders point at the requirements of the manufacturers and the observation of processing regulations and randomly check the construction works during the building process.

## Finishing treatment is highly important

The moisture level of the surface before applying the mortar as well as the drying of the mortar have strong impact on the tensions occurring in the mortar coating as well as in the environment of the connection joint. These tensions can lead

to debonding and to cracks in the coating. For this reason care should be taken of a moist surface, of keeping the mortar moist during application and especially of preventing early drying during the hardening process.

In addition, if, while applying the coating, the single, already dried layers are not roughened before applying a new layer, a bad result of the renovation can be the consequence. Principally, the grout coating is to be protected from direct insolation especially in the cone area. By applying a finishing treatment medium to



A finishing treatment medium can be of great help

the mortar coating directly after the renovation works, it seems to be possible to prevent too quick drying of the mortar. Sealing the manhole cover with an awning to prevent incoming air does not seem to cause great advantages as a single measure. For polyurethane coatings comprehensive finishing treatment does not seem to be necessary. Here it is advisable, however, to inspect the entire coating cover visually in detail after applying the coating. So imperfections in the coating can be registered and can be removed immediately.



Sealing the manhole cover simply does not suffice

## Polyurethane: check coating immediately after application



finishing treatment of a polyurethane coating

## Acceptance of the Construction

Principally, it can be observed that the measures suggested in guidelines and progress reports are only suitable to a limited extent for testing the quality of a manhole coating in a sustainable way and especially with adequate effort. The following measures for quality checks have turned out to be reasonable:

## Approval of the construction after several months

Weaknesses in the polyurethane coatings normally showed directly after applying the coating or at the latest after an ascent of the groundwater level. In many grout coatings numerous deficiencies could only be observed during an inspection several months after the coating measure. This might be due to the fact that the tensions in grout coatings, which are responsible for the formation of cracks or debonding of the coating, only develop after a few days or weeks from a mathematical point of view.



Cracks often become obvious after a couple of months

Therefore, it is advisable to carry out the construction measure after a couple of months and ideally with higher groundwater levels.





Areas with bad bonding can be noticed after an ascend of groundwater at the latest

**A detailed visual inspection is an adequate measure here**

A detailed visual inspection under high groundwater levels including tapping the coating is particularly suitable for an acceptance of manhole coating measures. Lacks in quality such as cracks and leaks can usually be noticed rather well: due to the typical sound when tapping the coating also hollow spots behind the coating can be registered.



A detailed visual inspection is great help when assessing the quality of a coating

However, great care should be taken of the fact that the condition of the coating is acquired during a visual inspection of the entire manhole construction. It should include the connection area, channels and step irons and should be documented by photos. The simple examination through the opened manhole cover does not suffice!

**leaktightness testing does often not suffice**

A water tightness test inside the manhole does not always give reliable statements with regards to the success of a coating measure.



A leaktightness test of a manhole does often not suffice to assess the quality of a coating measure

Often the test results cannot be used due to circular seepage in the area of sealing bubbles, for instance. The costs are often out of all proportions to the usage. In extreme cases (e.g. strong volume stream, large cross sections, corroded sewers) the costs for the final leaktightness test can exceed the costs of the actual renovation measure.

Only if also the invert area including the channel as well as the connecting sewer sections were rehabilitated, a test with water can lead to a successful result in individual cases. Generally, then a water leaktightness test according to DWA-M 143, Part 6 seems to be reasonable in combination with a comprehensive visual inspection of the upper manhole body.

**Question the adhesion tensile test**

As a criterion of acceptance, in general, the current minimum demands on adhesive tensile strengths of the coatings, influenced by the requirements of structural engineering and bridge



Mortar: adhesion tensile test of a coating

building, as well as the importance of adhesion tensile tests are to be questioned. Numeric analyses showed that adhesive tensile stresses in grout coatings, developing under these conditions in a manhole, are below the requirements of the essential guidelines.

And although in many cases the demands on the adhesive tensile strength were not fulfilled, a loosening of the coating could only be noticed in single cases. In the cases in which extremely low adhesion tensile values of only 0 N/mm<sup>2</sup> to 0.2 N/mm<sup>2</sup> were measured in the final adhesion tensile test, the IKT testers had already noticed cracks in the coating and hollow spots by tapping the coating.

Against this background, the result of an adhesion tensile test should only be considered an additional hint on the renovation quality and the visual inspection including tapping the coating should be focussed on.

#### To be continued

As the article shows, basic findings regarding the influence of quality and limits of application of coating measures are now available. In the present research project „manholes – monitoring, testing and renovation“ further questions are to be answered. It aims at the comprehensive analysis of the entire manhole body and the corresponding operation processes. In laboratory and in-situ applications various renovation processes are analysed in comparison.

Sources: IKT-eNewsletter April to September 2005

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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:

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