Methods for detection and condition assessment of domestic sewer systems

The present methods for detection and condition assessment of domestic sewer systems serve to record the characteristics of the network and pipes. The reason for such recording can be either acute impairment of the functionality through blockage, for example, or the indirect strain on the public network (extraneous water) or legal specifications involving testing for leaks in private networks [1], [2], [3]. There is a great need for reliable knowledge about the use of the methods available for detection and condition assessment in the domestic sewage system, because on the basis of the results of the investigation founded declarations should be made about the condition of the system including the exfiltration potential, the infiltration potential and functionality, as well as for a meaningful rehabilitation planning.

The following summarises current experience with the detection and condition assessment of domestic sewer systems and describes the need for action derived from this. The content is based on the knowledge that was investigated during the IKT- research projects " *Testing of tightness on house connections and base lines – limitations of use, methods, testing criteria*" [4] *as well as „Basics for the planing of rehabilitation on house connections and base lines"* [5].

Domestic sewer systems

Domestic sewer systems are used for estate drainage. They should guide domestic waste water without loss to the public sewage system. The term "domestic" is used here to refer to the whole area of the pipe network on the estate to the point of connection to the public sewage system.

The characteristics of these domestic pipe networks cannot be compared with the public sewage system, or only to a certain extent. They are usually far more complex: Draining possibilities for wastewater have to be provided in many places in the building, e.g. for showers, toilets or technical appliances such as washing machines or dishwashers. Pipes for surface water can also be connected. The waste water is guided through vertical pipe runs - which are usually embedded in the walls - into the cellar and mostly under the basement slab of the house. From here the vertical pipe run join the horizontal base lines which usually carry the water into an inspection shaft. From this inspection shaft the water then flows through the house connection into the public sewage system.

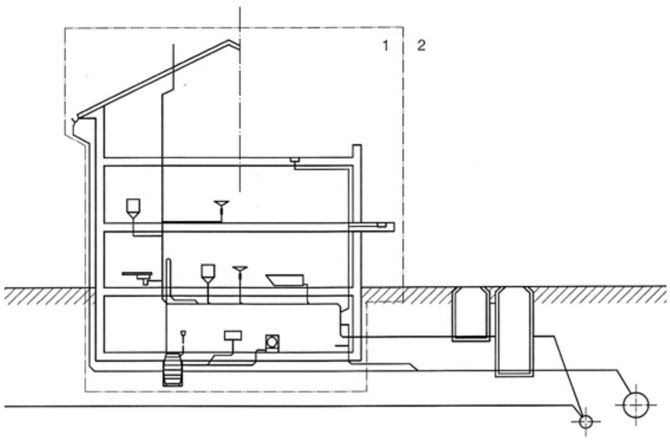

Fig. 1: Range of validity of DIN EN 12056 (1) and DIN EN 752 (1) (acc. to [6])

Since the introduction of European standards, a distinction has been made between inside and outside the building. For the area inside the house, the standard EN 12056 [6] has been valid since June 2000. Drainage systems outside buildings are governed by EN 752 [7]. In German national DIN standards, a distinction was only made previously between private and public pipes. The pipes in the private area are described as base lines, those in the public area as house connections. DIN 1986 [8] is valid for the private area. The distinction between private and public pipelines is laid down in the statues of the individual local authority districts. Figures 2 and 3 show two different possibilities as examples. Fig. 2 shows a case where all pipes within the private estate are regarded as private pipes. In Fig. 3 the inspection shaft is defined as the point of transition. In rare cases all pipes including the connection to the main sewer are defined as private.

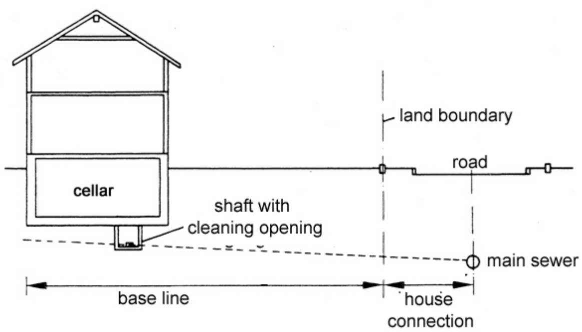

Fig. 2: Land boundary as separation between the base lines and the house connection [9]

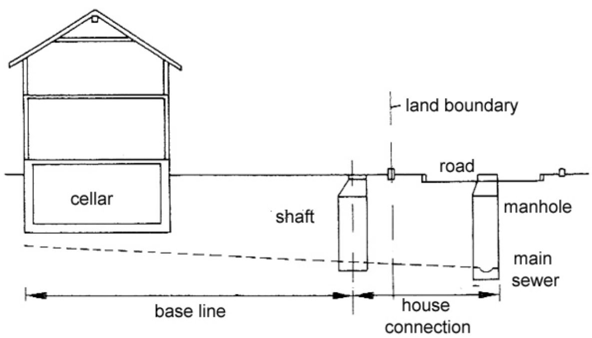

Fig. 3: Inspection shaft as the separating element between the base lines and the house connection [9]

Access to the private network is often possible via the inspection shaft or the public sewer. From a technical point of view it makes sense to consider the many-branched network in the base line area and the house connection between the inspection shaft and the sewer separately. The latter usually guides the waste water collected to the public sewer without branching off and usually follows a comparatively straight course. This house connection can be compared with the public sewer in principle as far as the operational requirements are concerned, just the inside diameters from DN 150 to DN 200 deviates from the usual values in the public sector.

The pipe network between the inspection shaft and draining objects in the building, however, is characterised by branches and bends, limited or no access possibilities and smaller pipe diameters.

There are often multiple branches in this part of the sewage network, i.e. a pipe branches off from the main pipe and then divides again. Bends up to rectangular can be find, even if this does violate valid guidelines (cf. [8]). Good access possibilities through shafts within the building are very rare, these are usually outside the building. Access to part areas of the base line network is often only possible via inspection flaps on the vertical pipes. If there are no flaps or if they have been plastered over, access can only be obtained through the sanitary system or perhaps through floor drainages. In some cases this is not possible either, for example if floor drainages have been fitted with an odour trap to prevent smell or an antiflooding valve. In the end the walls have to be forced open or an inspection flap must be built in or the floor drainage must be removed. The pipe diameters used are between the dimensions DN 50 and DN 150. Pipes with diameters of DN 100 – DN 150 are usually used as base lines. Smaller PVC pipes up to DN 70 are also used, however, or even DN 50 pipes for wash basin etc.

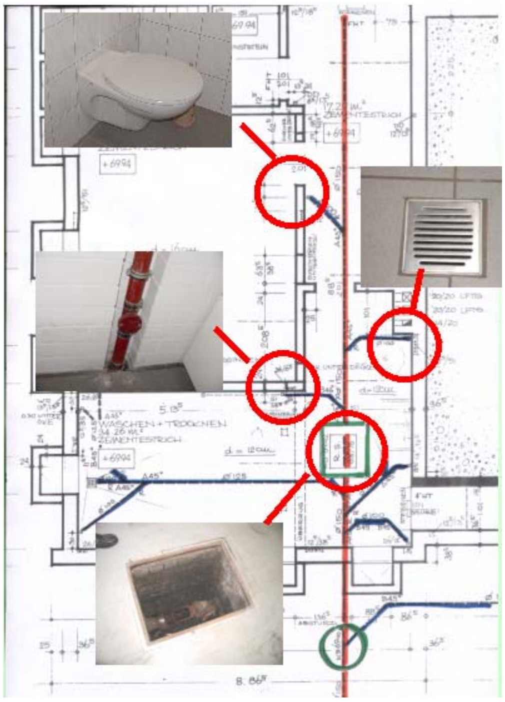

Fig. 4: Example of the waste water network inside a building

In the base line area, the pipes below the basement slab are particularly difficult to access. Laying these pipes bare is always complicated and cost-intensive. For this reason it is better to plan in such a way that these pipes are not laid under the basement slab but rather on the ceiling of the cellar or on the walls. Lower draining points can be drained using central pump stations or smaller pumps. Chopping units included allow wastewater to be pumped from lower toilets through small pipes.

Fig. 5 Example of a central pump station

Fig. 6: Example of a pump with chopping unit

Experience so far has shown that domestic sewage systems often deviate from the draining scheme or that there are no such draining scheme even available. Sometimes the drainage objects marked in the plan do not exist or additional drainage objects have been installed without being marked in the draining scheme.

Methods for detection and condition assessment in the domestic sector

The special situation described in the domestic sewer system requires a special proceeding for detection and condition assessment. Before method and equipment are selected, a comparison should be made between the actually existing drainage objects and the planning documents. A site survey is necessary to estimate which possible methods can be used. The existing draining scheme should then be updated if necessary. This reduces later investigation costs. Fig. 7 shows a section of a building drainage plan before (left) and after (right) updating as a result of a site survey.

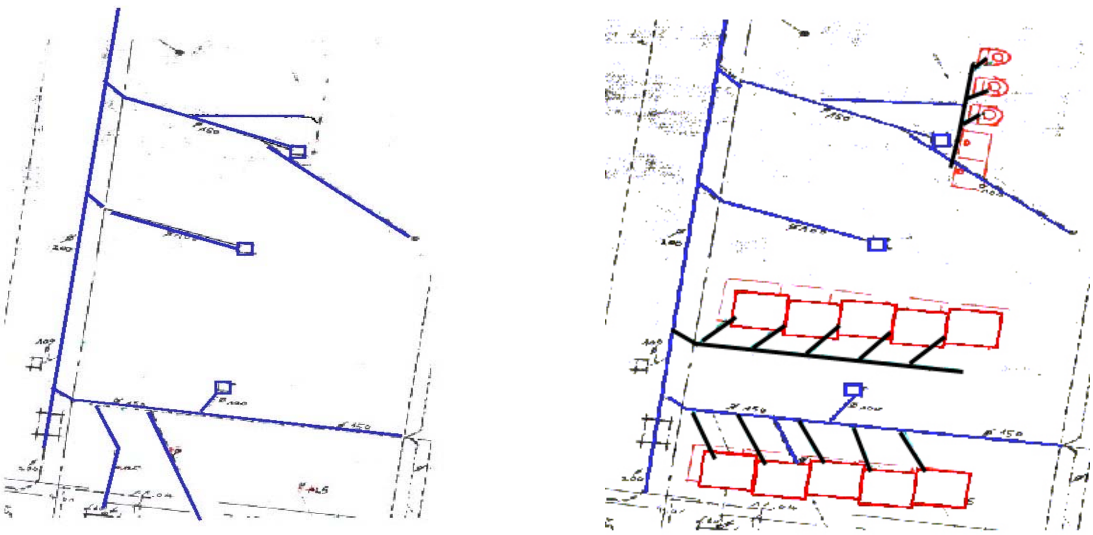

Fig. 7: Section of a plan before and after updating following a site survey

Foremost when the drainage situation has been clarified, suitable methods for detection and condition assessment should be selected. The most common method for condition assessment of pipes is the optical inspection. With this method the condition of the pipes is recorded from inside using cameras. Fig. 8 shows a summary of the different techniques of optical inspection used.

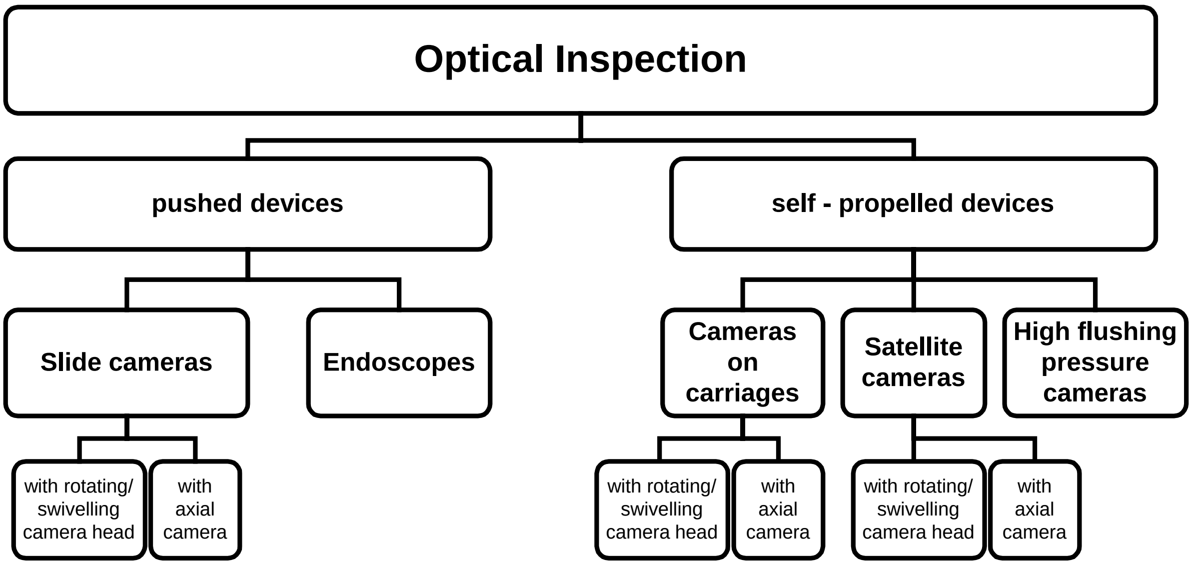

Fig. 8: Summary of the methods used for optical inspection

Slide cameras have been designed mainly for use in small diameter pipes. Some models can even be used to inspect pipes DN 40, e.g. from a wash basin drain. The cameras are pushed forward by hand during inspection using flexible poles. Camera heads that are rigid as well as camera heads that can be rotated and swivelled are available. This latter type is hardly ever used for manual propulsion due to the danger of damage, however. Deposits in the pipe can lead to dirt particles pushed along by the camera being accumulated in front of the camera lens. For this reason, most models can be fitted with spacers which are designed to centre the camera head in the pipe. The possible uses are limited, however, due to the increase in cross-section of the camera head.

Endoscopes were originally designed for special investigations, e.g. the inspection of air-craft turbines. During the IKT investigations, an endoscope consisting of a 7 mm wide, cable-like tungsten braid with a camera lens only a few millimetres in size at the endoscope head was used to inspect a domestic sewer system. The last 4 cm of this endoscope could be moved in all directions by a remote control. This model made it possible to carry out an inspection even on the pipes behind the sieve inlet of a wash basin or the odour trap of a floor drainage. The image quality of the camera was excellent, a special camera made it possible to measure even the tiniest cracks in the millimetre range with the use of the photogrametrie principle. Disadvantages are the high procurement costs of these devices and their complex operation which requires appropriate specialist knowledge.

Cameras on carriages can be used particularly in the house connection sector and perhaps in the base line sector if access is guaranteed via a shaft and the minimum diameter of the pipes is DN 125 and the maximum bend of the pipe is 45°. Use in branched pipes smaller than DN 125 is not possible.

The carriage means that the camera is centred approximately in the centre of the pipe so that all areas of the pipe can be inspected equally well. The use of swivelling camera heads is an advantage, since these can be used to inspect damaged spots in more detail and to have a look at side branches.

Satellite cameras supplement cameras on carriages by an additional camera head which can be deflected into side branches and pushed forward mechanically. Most models available on the German market at the moment require a minimum pipe diameter of DN 200. This is rarely the case in the domestic sewer sector, even for house connection pipes. In tests of the IKT, a model which according to the manufacturer was suitable for use in DN 200 pipes could not be used in the house connection pipe DN 200 even through a shaft on account of its size (see Fig. 9). There are only two models available in Germany which are specified for use in DN 150 pipes. With the smaller one it was possible to run in pipes DN 150. The premise of a use is, that there are absolutely no bends in the pipe. If offsets of sockets are present in the pipe, great knowledge and experience of the inspector is necessary. The use through the cleaning opening in the inspection shaft was not possible. A satellite camera is currently being developed in Holland which is said to be suitable for use down to DN 135 (see Fig. 10). A use through the cleaning opening in the inspection shaft will not either be possible with this model, belonging to its long design (87 cm overall length)

Fig. 9: Attempt to use a satellite camera through a shaft in a DN 200 pipeline

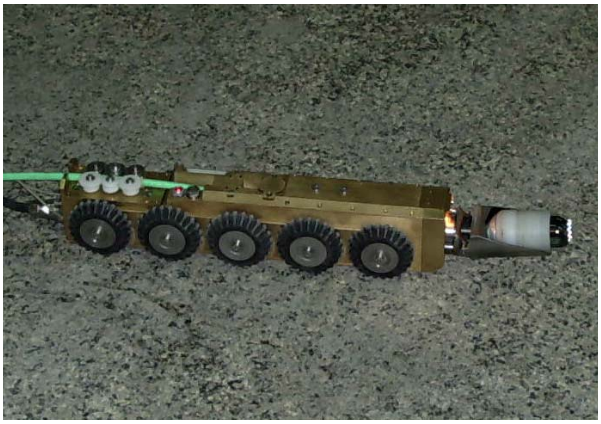

Fig. 10: Prototype of a satellite camera for use in pipes up to DN 135

High flushing pressure cameras are pushed forward through high water pressure. The camera is at the end of a high flushing pressure hose. The water can escape through openings at the rear edge of the camera housing under high pressure at an angle of approx. 30°. This means that the camera acts as a cleaning nozzle at the same time.

The use of the high flushing pressure camera in sewage networks of schools and multiple dwellings allowed large pipeline sectors to be recorded for the first time that were not able to be recorded during previous inspections. The maximum inspection length was only limited by the length of the cleaning hose (approx. 85 m). Moving into horizontal side branches of pipes up to DN 100 was possible by turning the hose. The video image was clear and meaningful even at full water pressure. The possibility of visual control during cleaning also made the loosening of hardened deposits easier which could be deliberately shattered and transported away by the partial vacuum produced by quickly retracting the hose.

Fig. 11: High flushing pressure camera

Beneath the optical inspection there are more methods for detection and condition assessment of domestic sewer systems. Fig. 12 shows a summary of the possibilities. A distinction is made between leak location and methods used to determine position. Some of the methods are suitable for both purposes.

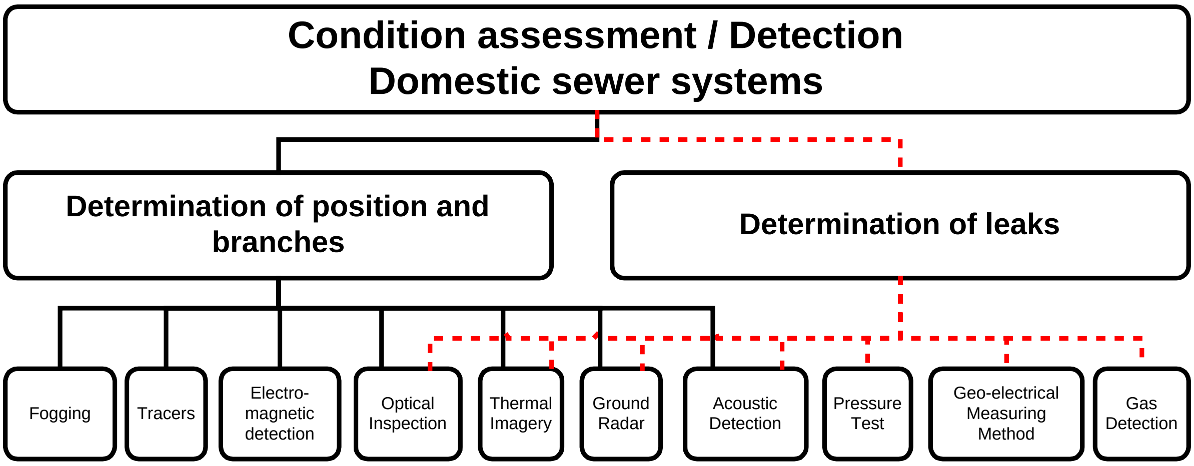

Fig. 12: Summary of methods for detection and condition assessment of domestic sewer systems

Fogging

Fogging is a simple possibility of finding false connections. A fog machine is used to blow smoke into the domestic sewer system. This then escapes at all open drainage points connected to this network. This method is used in particular to determine false connections to the wastewater network, such as. e.g. roof drainage or ground drainage [10]. It is not suitable for more detailed recording of the network structure or recognising leaks, however.

Tracers

Tracer are dyers such as uranine which are added to the water to be able to follow its flow behaviour. Tracer additives can be used during the site survey through wash basins and toilets to assign the individual drainage objects to the respective part networks. This is particularly recommended for drainage objects which are not included in the drainage plan. Used together with an optical inspection, tracers can also serve to assign branching.

Electro-magnetic detection

With electro-magnetic detection, a distinction has to be made between the detection of metal and non-metal pipes. Metal pipes such as cast-iron vertical pipe runs, for example, can applied with an electro-magnetic field directly which can then be detected by the relevant receiver devices. In the case of non-metal pipes probes have to be inserted into the pipes which then produce a detectable electro-magnetic field. A distinction can be made again with these probes between probe heads where a spot can be detected exactly and probe rods which emit an equally strong signal over their whole length. Detection using probe rods has only revealed very inaccurate estimations of the course of pipes. Better detection results are provided by the use of a probe head. Staff with appropriate training can read off position, depth and direction of the pipes on the receivers. If there are further electro-magnetic fields in the area of the pipes, these can have an interfering effect. Power lines in particular prevent reliable detection.

Thermal imaging

With thermal imaging the temperature of the surface is recorded using a heat picture camera. Differences in temperature of up to 0.1° can be detected. Using the method of thermal imaging it was not possible to detect the course of base lines nor leaks in the pipes that had proved to be leaking during the tightness tests before. The pipes had been filled with 70°C hot water before the investigation. By continuously refilling the pipes with hot water a temperature of approx. 50°C was maintained for around two hours. Increases in ground temperature were established neither in the building nor in the outside areas, thus neither the course of the pipes nor leaks could be determined.

Fig. 13: Thermal imaging investigation of base lines

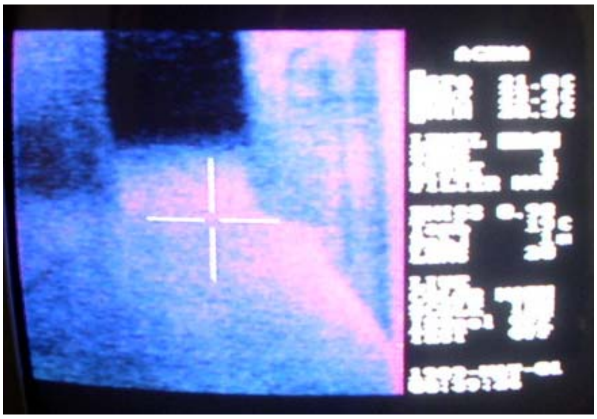

Fig. 14: Heat picture at floor sector of a corridor, without identifiable course of base lines

Ground radar

With this method, electro-magnetic impulses are radiated into the soil via an antenna, spread out there as waves and are then reflected or broken at layer boundaries and deflected or diffracted at obstacles. The penetration depth of the waves depends on the conductivity of the soil. The wave fields measured can be processed into images of the soil. The extent to which this method can be used to identify the courses of pipes or leaks in domestic sewage systems has not yet been clarified.

Acoustic detection

Acoustic detection can be divided into **flow noise measurement** and **the detection of acoustic test signals.** Both methods can be used successfully for detecting pressure pipes. In the case of flow noise measurement, noise coming from water streaming from a leak is searched for. With this method it was not possible to make statements about where leaks are situated in water – filled ground lines. There could not be heard any flow noises even though the pipe sector was tested as leaky before.

Detection with acoustic test signals is also used for detecting leaks. A transmitter applies sound waves to the pipes. The water reflects the sound waves which can then be detected by a receiver. A detection can just be made at a distance of approx. four meters from the transmitter because otherwise there is the danger that the sound waves which are emitted directly from the transmitter warp the resulting of the detection. Just for this very reason a use of the method is not recommended in many cases inside the building. The result from measurements outside the building showed that the received signals were too weak for a based statement about the course of the pipes.

Pressure test

In pressure tests a pipe is filled with water or air pressure. Statements about the tightness of the pipes can be made on the basis of the measurement of the amount of pressure or water lost.

A pressure test using air or water in compliance with the criteria of DIN EN 1610 [11] or ATV M143 [12] where a certain pressure has to be built up, is economically sustainable in the domestic sector just if the pipes are straight without any branching off. The pipes must be accessible from at least one side via a shaft. Compared with this a water level test with the criteria of DIN 1986 [8], which is essentially easier to handle, can be used in base line net-works with branching. For this, the pipe system is blocked off and flooded with water to the deepest drainage object. Then the level is held over a fixed period of time and the loss of water can be measured. A statement about the exact point of leakage is thus hardly possible.

In all cases of pressure test the dewatering in the wastewater sewer during the testing phase is necessary. In larger buildings in particular, numerous auxiliary measures must be undertaken to secure the dewatering. In this context it is often only the inspection flaps in the vertical pipe runs – often more than ten in larger buildings – that provide access to the pipe system to install the dewatering pumps.

Geo-electrical measuring method

With this method, a probe emitting a current (current-emitting electrode) is drawn through a waste water pipe completely filled with water. A further current-collecting probe is earthed and the current flow from the probe to the opposite electrode is recorded. Wherever there are damaged spots in the pipe, the electrical resistance is reduced and the current flow increased, since the current can spread through the water escaping from the leak. This allows conclusions to be drawn about damage to the pipes. This method can only be used with non-conductive or poorly conductive pipe materials such as concrete, clay and plastic.

One device based on this geo-electrical measuring method is the sewer probe AMS-4S20 from Seba-Dynatronic. The prototype of this device, which has been especially developed for sewage pipes with a small diameter, has also been used for investigating tightness and renewal of estate drainage pipes [13]. It was not always possible even for experienced staff to interpret the fluctuations of the current flow correctly. Changes in resistance are caused not only by leaks, for example, but can also be caused by changes in the types of soil, pipe materials, diameters and branches. Damage detection is basically possible using this method, but the possibilities of false interpretation are immense.

Gas detection

In the case of gas detection, the pipes are blocked and filled with a tracer gas (e.g. a hydrogen-nitrogen mixture). This escapes through leaks and makes its way to the surface where it can then be detected using a gas detector. The Investigations by IKT showed that this method is not suitable for detecting leaks in the domestic sewer system. The gas cannot penetrate sealed surfaces such as the basement slabof a house or an asphalt layer. If openings cannot be made at regular intervals, through which the gas can escape, this method cannot be used. Depending on the number of openings available it is only possible to narrow down the area where there is a leak, since the gas creeps further under the sealed surface and can only escape at the nearest opening. Inside a building the gas is dispersed so quickly on the floor of the rooms that gas concentration can be measured everywhere. When used in pipes that have not been laid under a sealed surface, the measured values fluctuated so much that it was impossible to make a statement about leaks on the sewage pipe.

Combination of the methods

The combination of the methods of electro-magnetic detection with those of optical inspection and the use of tracers is recommended as particularly effective. In this form it is possible to determine the position, assess the condition and assign the inlet points and branches in one single working process. If a high flushing pressure camera is used, the pipes can be cleaned at the same time.

After the implementation of the optical inspection it is recommended to make a pressure test for a review of both the ex- and the infiltration potential if the pipes are in good optical condition.

Fig. 15 shows a pipe network that has been investigated using different methods. The use of a satellite camera was ruled out due to the small pipe diameter. The pipes marked with the interrupted line were able to be investigated using a camera carriage, whereby the use of a sliding camera or high flushing pressure camera would also be conceivable. The pipes marked with a continuous line could be investigated only using a high flushing pressure camera. Pipes marked with dots could only be recorded using a slide camera. The detection and condition assessment of the pipes marked by a broken line and those marked by a question mark could not be carried out. This would only have been possible at considerable expenditure e.g. by setting drill holes. Tracers were used to assign most of the branches and pipes which could not be inspected to the drainage spots. Using electro-magnetic detection it was possible to record the exact course of the pictured pipes in terms of position.

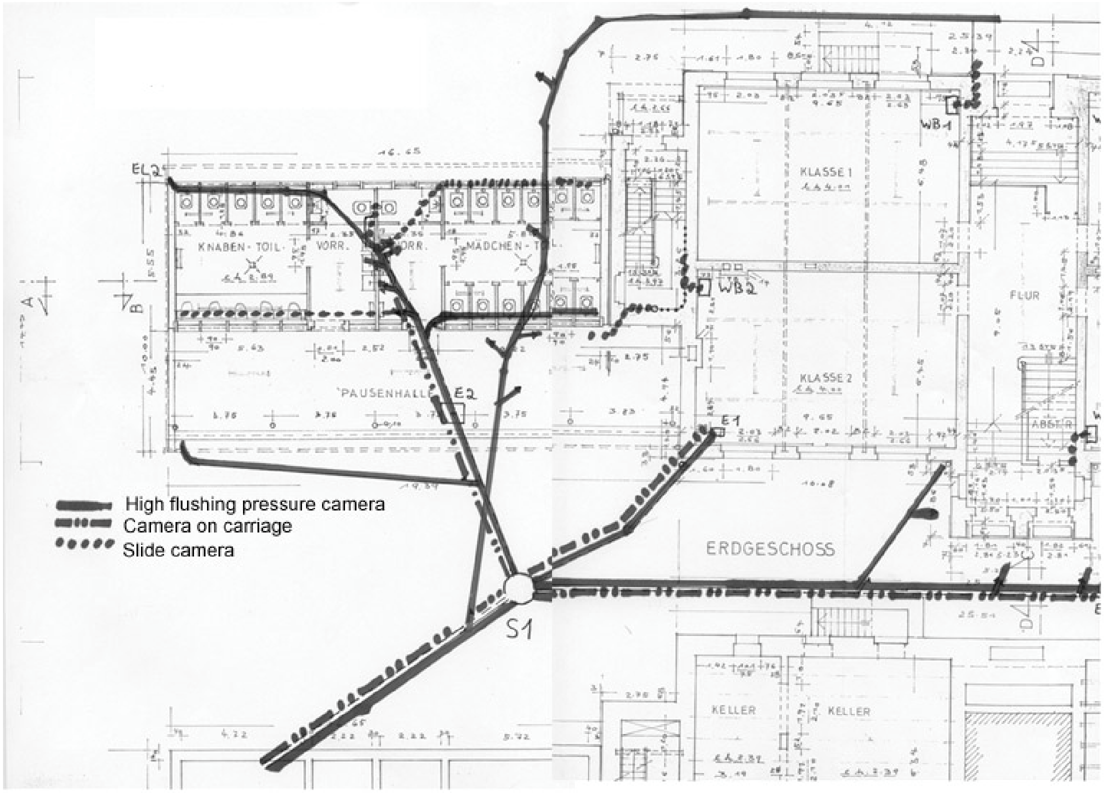

Fig. 15: Comparison of the inspection results of high flushing pressure camera, camera on carriage, sliding camera

Evaluation

The experience described shows that the circumstances from the public sewers cannot be transferred to the domestic sewer system. The abilities and experiences of the inspectors are of special importance for the investigation of the domestic sewage pipes. Depending on the local conditions, the inspector must choose a sensible combination of the methods presented in order to be able to answer the decisive questions. The meaningfulness of many of the methods depends to a large extent on the competence of the inspector. For example, during a pressure test the pneumatic pipe plugs must be set in such a way that the pipe is completely sealed even under difficult conditions. The receivers for electro-magnetic detection must be read off carefully by specialists to avoid detecting the signal of electrical sources as the position of a probe. Quite often, the use of unconventional aids is necessary to detect or inspect parts of the pipe network reliably.

Fig. 16: Insert wedge used as an aid for condition assessment by optical inspection

Thus it was only possible to inspect a wastewater train branching off from the main pipe by using a plastic wedge (Fig. 16). The wedge was inserted past the branch, blocking the camera's path, so that it could be diverted into the branch pipe. The Investigations carried out by IKT with a total of eight companies commissioned revealed that only two companies were properly prepared for the conditions in the domestic sewer system with respect to staff qualification and instrument technique. This is an indication of the acute need for training inspectors and the need of advice of firms concerning the selection of sensible methods and instruments.

None of the investigated methods for the determination of leaks was found to be reliable. Although it is possible to detect defects in the pipe system through the optical inspection, a based statement about both the ex- and the infiltration potential with apparently intact pipes is just possible with the application of pressure tests. However, due to the special conditions of domestic sewer systems, tests with this method are sustainable only for relatively large pipe sectors in most cases. With the use of this method a detailed zoning of leaks is often neither possible nor meaningful under a technical or an economic scale especially in the many-branched base line network.

Premises for meaningful results of this test method are attainments about the course and branches of the pipes, the lengths of the pipes as well as the nominal sizes of the pipes. Just with these data the required allowable value of the water loss can be calculated correctly. The difficulties to get these data indicate a need for the development of new or modulated test criteria for the pressure tests in the base line network.

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