Stability of Manholes - a new application for the MAC System?

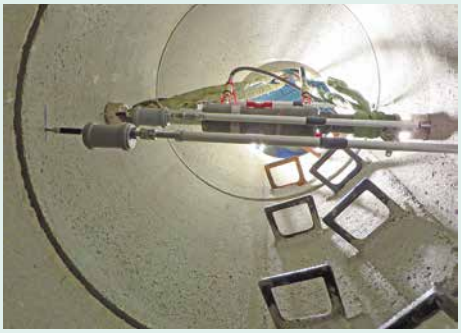
The MAC system has been further developed by IKT for semi-automatic deployment in pipes above DN 1000.

The MAC system has been designed to non-destructively assess the stability of man-entry, horizontally laid pipes. However, IKT has been considering whether this system could also be used in vertical situations? So, our developer team is examining whether it can also be used in manholes. Initial tests have already been carried out and the results show it works.

The large pipes under our streets are the 'autobahns' of the sewage system. They are in operation 24 hours a day, so everything must flow continuously. Consequently, expensive and wide-ranging repairs or replacements of pipes are usually put off for as long as possible. Therefore, the MAC system (Mechanical Assessment of Conduits) was developed to determine how a pipe needs to be overhauled so that it can remain in operation for many more years. Its measurements allow inferences to be made about the status of the pipe-soil system and to indicate suitable upgrading measures.

However, many millions of manholes are also connected with sewer networks. These are also subject to ageing processes and do not hold up forever. Can manhole constructions be checked in the same way and using the same methods as horizontally-laid pipes? IKT is currently looking into this question.

Of course a manhole should not to be equated with a wastewater pipe. In particular, completely different loads occur. However, the test principle remains the same: with its strong pressure cylinders, the MAC system can press the manhole wall outwards. This sounds more like the use of brute force than it actually is. Certainly, very high forces are sometimes applied, but the deformation required for the measurement is only a few tenths of a millimetre. Consequently the test does not cause any damage to the manhole as only sufficient force is applied to achieve this minimum deformation. Currently IKT is examining how the MAC system can be employed in manholes, how the measurements can be determined and whether the measurement data is usable.



IKT researchers use the measurements from the MAC system to determine the status of a manhole and the bedding ballast.

Normal deployment of the MAC system

It has been a long road to the point where the MAC system can be considered for use in manholes. However, this does not mean that the MAC device has the time to rest. It has been in routine use for testing pipes since the spring of 2015, following a long period of development and an intensive testing phase. The overall stiffness values of pipe-soil systems have been reliably determined in varied pipe situations in several German cities. The IKT MAC team is well experienced and trained for the job. Thanks to the 'tool-free' assembly and dismantling of its compact modules, the installation and recovery of the device on site is rapid. This provides more time for taking measurements during a deployment.

The modular construction of the MAC System means it can be lowered into a manhole in several parts and assembled below without using tools.

IKT is developing the MAC system further

The MAC system was invented by Eau de Paris, the water supplier to the French capital, and has been further developed by IKT. With the aid of this system, appropriate upgrading strategies can be prepared. Its use offers advantages, not only for the stability evaluation of large diameter pipes and manholes, but also for the quality control of completed upgrading work.

In France, the MAC system has been successfully employed since 1989 in large diameter pipes above DN 1500. IKT has adapted the system, in close cooperation with Eau de Paris, for employment in smaller pipe diameters above DN 1000 and has further developed the measurement and control engineering for semi-automatic operation.

Meanwhile, the Paris water supplier has ordered its own model of the more advanced MAC system from IKT. This is currently in construction and should be supplied to the cooperation partner shortly. IKT will train the team in Paris in the handling of the new MAC system and will accompany them during operational commissioning.

How the MAC system functions

Regardless of whether it involves a pipe or a manhole, the functioning of the MAC system is very similar in both situations. The MAC system has a powerful pressure cylinder which presses simultaneously against opposite walls of the pipe in a controlled manner, to move them apart from each other by a few tenths of a millimetre. Fine sensors measure the deformation arising in the area of the pressure plates and at a distance of approximately a metre in front and behind these points. The very small deformation that results is sufficient to calculate the status of pipe and surrounding soil, from a combination of the deformation detected and the force applied. The pipe is not damaged by the minimum deformation, despite the high forces applied, as automatic control of the pressure cylinder prevents any overloading of the pipe.

The measurements that are generated allow the stability of the pipe-soil system to be determined. Weak points can be quickly identified and further detailed information then derived through drilling cores and subsequent finite-element analysis.

Quantifying stability risks

After wall thickness values and strength properties have been determined through drilling cores, a static verification can be undertaken according to DWA A 143-2. If this verification is not sufficient, three-dimensional calculations according to the finite-element method (FEM) can be undertaken, which allow inferences to be made about the pipe and bedding ballast condition. On the basis of these calculations, it is possible to locate weak points in the pipe wall and loose zones or hollow spaces in the bedding ballast beyond.

Objectives for stability assessments

There are a range of objectives concerning the identification and elimination of stability problems that the MAC system can assist in meeting.

Finding the weak point - with the MAC system

In case of one survey in a German city, the IKT team did not expect any particular difficulties following the first inspection of a circular brickwork pipe. However, the MAC system indicated stability values which were completely unexpected and alarming. The problem was quickly identified during subsequent drilling core investigations, which found that the inner of three layers of brickwork comprising the pipe no longer had any connection with the external layers. This

The MAC system sees more than the naked eye. In this pipe it indicated some alarming values - the inner brickwork had detached from the surrounding brickwork.

was far less dramatic than initially feared, but could not be identified by eye. Further investigations are ongoing to provide a basis for decisions on suitable remedial measures.

In a medium-sized city in North-Rhine Westphalia, the MAC system helped in finding the correct positions for drilling core extractions in a brickwork profile. In this case the stability of the pipe-soil system could be subdivided into zones of similar stiffness from which targeted drilling cores were taken. With the MAC system the selection of drilling core sites longer needs to be

With the aid of the MAC system the correct positions for drilling core extractions can be determined in unusual profiles.

undertaken randomly, improving the information coring can provide.

Identifying the repair system - with the MAC system

The results of the measurements with the MAC system, in combination with the FEM calculations, give indications as to whether problems should be looked for in the bedding ballast or in the pipe. Assumptions can then be verified by means of drilling cores. Based on the results of an initial optical inspection, the first MAC test and the drilling core investigations, the objectives for remedial action can be determined. The entire pipe-soil support system can be divided into different upgrading zones. Specific objectives can be set for each, for example sealing, hydraulics or substrate improvement.

That then determines selection of the upgrading procedure, targeted at the weak points. For example, air-placed concrete linings for the static upgrading of the pipe or ground injections for the improvement of the bedding ballast. So, process selection not just based on an optical evaluation from inside the pipe and drilling of random cores. The stability evaluations provided by the MAC system are far more detailed and considerably more reliable.

Furthermore, considerable financial advantages can result. If, with the aid of the MAC system, it is possible to locally define a weak point, then any intervention can also be localised. Thus it is not necessary to upgrade the whole support system, as a precaution, simply because the precise location of damage is not known. Once the weak points are identified, they can be eliminated with targeted measures.

There are further applications that the MAC system can be used for on completion of upgrading work.

Checking the success of repairs - with the MAC system

Following upgrading work in a capital city on brickwork and egg-shaped pipe sections, there was a need to determine whether the work was successful. Therefore, a before-after comparison was made by the IKT team running through twice with the MAC system - once before the upgrading and once after. The measured values confirmed that the upgrade had achieved a significant improvement in the stiffness of the pipe.

This deployment showed that the MAC system is well suited to the quality assurance of upgrading work or to repeat control-checks of statically critical areas. Direct before-after comparisons

In this deployment space was confined, but the operators could still fit into the pipe.

and also time-related changes can be technically measured. Thus, the effectiveness of upgrading measures, such as ground injections or air-placed concrete linings, can be determined using the MAC system.

Verifying the long-term effect - with the MAC system

In addition to determining whether upgrading work has initially succeeded the MAC system can also be used to determine how long the effect lasts. By repeating MAC tests at stipulated intervals, comparisons of performance can be made over the long-term.

Ensuring quality of new construction - with the MAC system

The MAC system can even be used on new pipeline construction. With its assistance, the

The MAC system applies pressure on the pipe walls with its powerful hydraulic cylinder. The force required and the deformation are measured.

installation and bedding ballast relationships can be checked. Special advantage: As the planned boundary conditions are already known, „set point values" can be stipulated for later testing when the new construction is in operation.

Ensuring quality in production - with the MAC system?

And what of future developments? Having determined that the MAC system can be effectively employed for quality assurance after upgrading and with new pipeline construction, the possibility exists for using it to test new pipes in the factory. Its employment for the quality assurance of concrete pipes appears conceivable. Here considerable costs could be saved in the testing of large pipes, if the testing of the pipes from inside enables reliable statements to be made about the concrete quality and the reinforcement. Initial investigations of this application that have been carried out this year by IKT are promising. Here our developers see a still untapped potential for the MAC system.

Expenditure and costs in outlook

Finally there is the question of the cost of deploying the MAC system and undertaking the subsequent FEM calculations.

MAC System test costs

If the results of an existing visual inspection are available, IKT analyses these to determine the programme for the MAC test. It then agrees with the client the locations of the sections of pipe to be examined, together with the measurement intervals needed for each section. On the day before the test, it is recommended that the measurement points are identified and marked in the pipe. On the day of the test itself, the MAC system is assembled within the pipe and the measurements can begin.

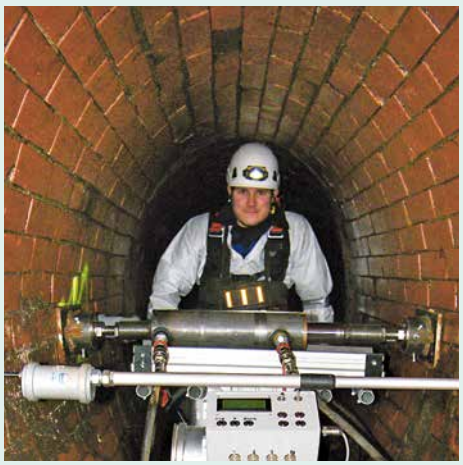
The installation and dismantling of the MAC system each take approximately 1.5 hours. With a measurement interval of every 10 m, about 100 to 200 m can be surveyed per day. Where feasible, the MAC system can be left in the pipe overnight in order to save on dismantling and setup times, thus increasing the daily survey performance.

Experience from tests on pipes of about 1,000 metres length indicates that the costs are approximately 10 to 15 Euro/m on average, for the first MAC test. The costs per pipe meter are particularly dependent on the investigation intervals which determine how many measurements need to be taken. Other factors that affect the price are the size and the structural status of the pipe, the access via manholes, the time that is available for working on site and the water level during testing. It is possible to use the MAC system up to a maximum water depth of 40 cm.

These prices do not include the costs of traffic safety measures, the guarantee of safe access to the conduit (cleaning, shut-off, ventilation etc.) and the drilling core extraction.

Costs of calculations of stability characteristics

On the basis of the test results, planning documentation and drilling core investigations,



Regardless of whether it involves a circular or oval section, a mouth or box - the MAC system can be employed everywhere.

calculations of the stability of each pipe section are undertaken using FEM to identify the weak points (in pipe or bedding) and to determine ground stiffness according to the applicable specifications. Experience indicates that these costs are approximately 8 to 10 Euro/m for 1,000 metre sections of similar cross-section and material type.

This rough overview illustrates clearly that the costs of a MAC test, including the static calculations, are below the annual costs for large pipes using the replacement value approach. With assumed building costs of approximately 1,500 Euro/m and a depreciation over fifty years, the annual cost is 30 Euro/m. The MAC test of a 1,000 m long pipe/soil system and the subsequent calculations together represent a one-off cost of approximately 18 to 25 Euro/m.

Identifying advantages

In comparison with conventional survey methods, far more information about the pipe-soil system can be acquired with the MAC system, without increasing the number of cores taken from a pipe or the surrounding soil. This is because more detailed, targeted investigations relating to the quality and geometry of the pipe

Profile? Material? Nominal diameter? Between DN 1000 and DN 3000, the MAC system can operate in all pipes.

can be undertaken. Furthermore, static calculations about the load distribution between ground and pipe can be implemented on the basis of the measured data and the results of drilling core. In this way, upgrading measures can be aligned to specific weak points. The selection of remedial procedures is therefore based on a more sound foundation.

In addition, the MAC system can be employed for the quality assurance of completed upgrading works through before-after comparisons or for repeat control checks of statically critical areas. In addition it can be used for checking of the pipe installation and ballast relationships in new pipeline construction. Perhaps, in future, the MAC system can also be used to assess manholes and new pipe production in the factory. The costs for such deployments of the MAC system may justifiable given the value of the information that can be provided on static load-bearing capacity.

Extending service life

As has been indicated, not only pipes but also manholes can be examined with the MAC system. If the investigation of both can enable localised repairs to be made to weak points in the network, then the expensive replacement of a large waste water 'autobahn' can be postponed.

The authors are glad to remain available in case of any concrete questions relating to the MAC system, its employment in conduits, the calculations and proof of structural stability.

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IKT – Institute for Underground Infrastructure

neutral
independent
non-profit institute

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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 130 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 70 companies. They hold together 33.3% of IKT.

You can find information on projects and services at:
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