PE-80 Pipe Systems: 17 Years of Successful Application in the Public Sewer Network of Göttingen

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ABSTRACT

The city of Göttingen is located in central Germany, directly on the highway connecting Hannover and Kassel. With its 130,000 inhabitants, Göttingen is one of the 60 largest cities in Germany. In 1988 Göttingen started to systematically investigate its 700 km long sewer network (350 km sewerage lines and 350 km rain water drainage lines). Failure pictures from TV-inspections were evaluated and simultaneously a sewerage rehabilitation concept was drafted. The rehabilitation programme with its focus on PE-80 piping is planned to last until 2011. The municipal sewerage system in Göttingen has been operated independently since 1997. It is one of the few sewage municipalities to be granted ISO 9001(1). The “Stadtentwässerung Göttingen” was certified in 2001. The annual investment in the sewerage system construction equals approximately EURO 16 mio.

THE „MODEL OF GÖTTINGEN“

Sewer system rehabilitation is a challenge for our present generation. Inspections with cameras and additional tightness tests show that former pipe systems can not meet today’s high tightness requirements. The engineers have to face the challenge of building new well functional systems from the old network by means of rehabilitation. In this it is important to not only consider our own area of influence but to push all infrastructure stakeholders into joint actions.

THE GÖTTINGEN SEWER REHABILITATION MODEL IN HEADLINES

Co-operation with all network administrators and the road construction authority
65 of 70 construction measures in 2003 were carried out in co-operation with other authorities.

Consideration of the total network including private lines
The sewage municipality of Göttingen offers the service of examination of private sewer pipelines inside the private property border. This service is carried out by 8 appointed engineers, who also follow up on the rehabilitation. So far approximately 8,000 of 22,000 private property lines have been inspected and repaired where necessary.
Implementation of quality management
The sewage municipality of Göttingen has been ISO 9001 certified since October 2001.

Use of advanced construction methods
Without the use of modern rehabilitation techniques sewer network rehabilitation is not affordable. This includes relining, the use of robots, burst lining and drilling.

Selection of piping materials
The high failure frequency of the existing sewer system was the reason to look for more durable materials with better leak tightness characteristics. A range of different piping materials, namely ductile iron, fibre cement and PE-80 was tested. Conventional clay and concrete piping was excluded due to the high failure rates in the past. PE-80 emerged as the winner and has been used in Göttingen for 17 years. Due to their excellent track record PE-80 pipes have been for the last 5 years the only pipe material specified for drainage and sewerage pipes in Göttingen.

EVALUATION OF THE TV-INSPECTIONS ON EXISTING SEWER PIPELINES

The failure mechanisms of all the inspected sewer pipelines have been evaluated. When replacing pipes using the open trench method, damaged sections were carefully opened in order to investigate the cause of failure. In more than 75% of failures the reasons were shortcomings in the installation process. With the pipe materials used in the past (75% clay and 10% concrete pipes) the most frequent cause for failures are installation faults in the jointing section, which resulted in axial or horizontal displacements. These displacements are the cause for leakage and for subsequent infiltration, exfiltration and roots penetration. The second largest group of failures are poorly post-connected lateral pipes. A third group of failures relates to insufficient backfilling, which leads to cracks and pipe breakages. Based on the analysis of failure pictures and the general bad state of the sewer network, Göttingen decided to stop using “old generation” pipe materials and instead use PE-80 piping wherever possible.

REQUIREMENTS FOR PIPING MATERIALS

We have to accept that in the future as in the past it is not possible to completely eliminate installation shortcomings. Therefore it is necessary to re-define the requirement profile for the selection of new pipe materials. The reduction in number of joints by the use of longer pipe sections and the flexible adjustment to alternating load conditions has to be considered. It is important to make available product systems which include pipes and inspection chamber connections as well as a sufficient range of fittings for lateral connections. Any system is only as efficient as the weakest link in the chain.
SELECTION OF PE-80 PIPES

The aim was to select pipe materials, which are able to withstand all the causes of failures observed in the TV investigations. The PE-80 pipe was able to fulfill the requirements in most aspects.

Therefore the pipe material PE-80 was increasingly specified in tenders for sewerage building projects as an alternative to clay pipes. In most cases the price difference between the two systems was not large. Besides the fulfillment of above requirements it was the acceptable price and the good experience in the gas and water industries which made PE-80 an attractive option. The PE-80 pipe has a smooth inner wall and therefore excellent abrasion resistance.

The pipes are flexible and thus adjust easily to ground movements. Due to the flexibility of PE-80 pipes the load can be carried by the surrounding soil. Damage due to storage and brittle failures can be avoided. The welded pipe connections are resistant to root penetration. However there were further requirements that needed to be solved before the material could be fully accepted: namely the fittings to connect to the inspection chambers. The municipality was interested in improving the chamber connections and started to seek potential co-operation partners. In this Friatec AG gave positive signals for joint developments. In the following the co-operation between Friatec and the municipality turned out to be very successful. First the requirements for inspection chamber connections and the timeframe for realisation were defined. Simultaneously two welding technologies for the sewerage application were tested.

WELDING OF PE-80 SEWERAGE PIPES

The polyolefin PE-80 is weldable. A welded pipe connection is leak tight, homogenous, axially strong and resistant to root penetration. Heated tool butt-welding and electro fusion methods were investigated in particular. Göttingen favours electro fusion fittings because of the better hydraulic performance due to the lack of internal beads.

Welding requirements

At the beginning the selected construction companies made use of subcontractors as in gas and drinking water pipeline installation. However sewage constructions are generally much shorter in duration and this leads to high costs of using subcontract labour.

Therefore the sewage construction companies developed their own professional workforce to deal with these special tasks. The basis for the education of pipe welders is the DVGW Guideline GW 330 and GW 331 (2). PE welding seminars are held by commercial associations on province level. The courses last for 1 week and only welders who hold the GW 330 certificate and companies that are GW 301 (3) certified are allowed to work on the construction sites in Göttingen.
PE-80 SEWERAGE SYSTEM – PRODUCT OFFER

During the stage of market research in the late 1980’s it was only possible to utilise the fittings range developed for gas and water supply.

After the development of a requirement catalog for sewer systems main needs for the optimisation of the system were defined as follows:

- Better inspection chamber connection solutions
- Non-pressure sewer sockets
- A tapping unit for retrospective house connections
- Supply of pipes with a bright inner wall

These developments have been completed with Friatec AG and several PE-80 pipe suppliers. Today a broad product range for the sewerage applications is available in the marketplace.

Sewage inspection chamber adaptor (ASF)
The sewage inspection chamber adaptor is the connection element between the concrete inspection chamber and the sewage insert sleeve (AEM). It is made of PE-80 (PE100) and therefore very corrosion resistant. Lock-in ribs ensure the stable connection to the concrete structure. An elastomeric center section accommodated the deflection (up to 5°) of the installed pipes. The sewage inspection chamber adaptor is installed according to DIN 4034 (4) and secures a tight connection (inside and outside) to the concrete inspection chamber.

Sewage insert sleeve (AEM)
The sewage insert sleeve is used for the connection of PE-80 pipes into concrete inspection chambers according to DIN 4034 in conjunction with the sewage inspection chamber adaptor. The sewage insert sleeve can be welded to PE-80 sewer pipes according to DIN 8074/8075 (5/6) and DIN 19537 (7). Heating spirals are placed on the inside of the socket. On the outside of the insert sleeve two sealing rings and an additional water swelling sealing ring are fitted. The sealing rings secure the optimal connection of the sewage insert sleeve to the inspection chamber adaptor. The elastomeric sealing ring allows optimum anchoring against the inspection chamber adaptor. Each insert sleeve is equipped with a bar code for automatic welding.

Sewage saddle
The saddle replaces the junctions used earlier. Formerly the junctions had to be welded to two sewerage sockets. The saddle enables subsequent lateral connections to the existing system at any location. Similar saddle connections have been a standard in the gas and water supply systems. The sewage saddle is fitted to the pipe using a clamping device and is available for dia 225 – 450 mm pipes and laterals up to dia 160 mm. The drilling takes place in pressureless condition with commercially available drilling tools. The drilling section is free of heating wires.
Pipes with bright (grey) inner walls
The experience with TV inspections of the newly installed black pipes lead to the request for pipes with a brighter inner wall to ensure easier failure detection. A continuous observation of the black pipe wall is very exhausting to the inspector. The alternative of white inner walls was rejected due to the disturbing reflections at the TV inspection. The requirement for pipes with a bright inner layer was communicated and soon after marketed by the company Egeplast. This development significantly improved the quality of TV inspections.

STATICS AND DEPRECIATION TIME

The required wall thickness of buried non-pressure sewage pipelines has to be determined according to the external load caused by soil pressure and traffic load. The specific characteristics of the visco-elastic pipe material PE-80 have to be considered. The usual calculation methods used for rigid pipes (clay, concrete, fibre cement) or elastic pipes (steel) are not applicable. It is also recommended that the soil surrounding the pipe has to be compressed according to DIN 1610 when using rigid old generation sewer pipes.

Calculations showed that PE-80 pipes according DIN 19537 series 2 (PN3,2) would be sufficient for general use and pipes from series 3 (PN4) for specific projects. However in Göttingen only PE-80 pipes of series 4 (PN 6 or SDR 17,6) are used. Taking the additional reserves into account, the PE-80 pipes in Göttingen are depreciated over 70 years. The actual lifetime of the pipes is expected to be significantly longer.

DEFORMATION MEASUREMENTS

In order to gain additional information, various pipes of different pressure classes were subjected to deformation measurements. The deformation was measured on pipes which have been buried for more than one year. The pipes of pressure class PN 3.2 had a deformation of 6% - exactly the rate which was calculated before installation. The pipes of pressure classes PN 6 (SDR 17,6) did not exhibit any deformation.

EXPERIENCE WITH PE-80 PIPES IN GÖTTINGEN

In Göttingen PE-80 pipes have been used since 1988 for following applications:

Open trench installation (PE-80 SDR 17,6, dia 225 – 560 mm)
- 25 km new sewer pipelines (with 2.000 lateral connections)
- 35 km sewer rehabilitation lines (open trench installation with approximately 2.500 lateral connections)
- 13 km leachate transport pipelines (connection between 2 landfill sites)

Open trench installation (PE-80 / PE 100 “Wickelrohre” dia 700 – 1500 mm)
- 4 km Wickelrohr
No-dig installation method with PE 80 SDR 17.6 and SDR 26
- 2 km Short pipe relining
- 18 km U-liner (2,500 lateral connections)
- Burst lining (10 mainline sections, 50 lateral connections)

All constructions were commissioned without any problems. All connections were subjected to tightness tests – no pressure loss was registered.

The water authority in Göttingen compulsorily specifies the use of PE-80 pipes in water protection zones II, IIIa and IIIb according to ATV Guideline 142 (9).

The system solutions for pipes and inspection chambers which were jointly developed by the sewage municipality of Göttingen and the company Friatec AG have in the meantime also been used in Munich („Oktoberfestwiese“), Berlin and several other cities, communities and sewage associations.

SUMMARY OF MEASURES TAKEN IN GÖTTINGEN

The serious damage and failures, which were detected through TV-inspections and the related failure analysis lead to the reconsideration of piping material selection.

The municipality of Göttingen conducted a market survey in the late 1980’s in which ductile iron, fibre cement and PE-80 pipe solutions were investigated. Conventional clay and concrete piping was excluded due to the high failure rates in the past. The market survey also included information from the gas and water markets as well as relevant data from abroad. The survey then lead to the conclusion that PE-80 was the best material for the requirements in Göttingen.

The system was completed by product innovations (Friatec AG) and with the newly invented fitting types, especially the inspection chamber connections, the PE-80 system comprises all elements needed for an effective sewerage system. Due to hydraulic and maintenance requirements only electro fusion connections have been applied in Göttingen.

By today more than 60 km main sewer lines and 20 km lateral connections have been installed and are in operation without any failure. More than 2/3 of the pipelines have been buried for more than 5 years. The necessary guarantee examination procedures were also passed without any failures.

Initial concerns about connection techniques and deformation behaviour were proved to be unfounded based upon practical experience. PE-80 pipes are therefore now exclusively used by the municipality of Göttingen for all sewer lines up to dia 560mm and were recently also specified for rain-water drainage lines up to dia 560 mm.
ADDITIONAL COST SAVINGS & OTHER BENEFITS

The use of PE-80 in sewerage pipeline construction opens new perspectives and cost saving potentials. During the last 12 months several new measures were implemented in Göttingen:

Installation cost benefits
In narrow sections the installation of drainage pipes under three roads was for the first time ever designed to fit the line of other supply pipelines. Sewer pipes were installed including the use of bends in parallel to the existing water and gas pipelines. The new installation method made the otherwise required installation of 10 inspection chambers obsolete. A side effect was the significantly reduced maintenance effort in relation to inspection chamber covers. The measures produced savings of circa EURO 20,000, an amount equal to 6% of the total construction work expenditures.

Reduced building costs
Due to the availability of saddle connectors it is now possible to install the main sewer line without lateral connections in new housing areas. In the past changes in the development plans have resulted in some 20 – 33% of lateral connections being misplaced and becoming breeding places for rats. In addition it created unnecessary construction costs. The cost savings potential in this case equals another 6% of the building sum.

Establishment of a “sustainably tight sewer network”
The municipality of Göttingen has decided to establish a “sustainably tight sewer network”, a decision which became effective on 1st Oct 2003. The quality management catalogue of the municipality of Göttingen requires that all rehabilitation constructions have to be subjected to tightness tests. When rehabilitating pipe sections with new lateral connections made of rigid old generation materials it was impossible to carry out such tightness tests. Through the use of PE-80 pipelines and saddle connectors with shut-off facilities at the property border this requirement can be fulfilled easily. – Therefore an important step to quality insurance was secured.

Cost savings in guarantee examination
Due to the absolute failure-free operation of all PE-80 pipelines it became possible to use selective methods in the guarantee examination. This means that after a guarantee period of 5 years only ¼ of the area is subjected to examinations. The rest of the pipelines are investigated during routine inspections, which take place every 10 years. The cost saving in a relatively large construction area is around EURO 17,500. It is expected that in the future the cost saving will become as high as Euro 75,000 – 100,000 per year (equal to approximately 40% of the costs for guarantee examinations).
Welding experts
The welding of pipes is performed exclusively by expert personnel holding the welding certificate GW 330 and GW 331. The involved construction project managers of external companies and the municipality’s own installation personnel are obliged to attend welding courses and introduction sessions to quality insurance.

PE-80 exceeds rigid old generation piping solutions by the factor 42
In order to estimate the potential failure frequency of pipelines a comparison between gas / water supply lines and sewerage pipelines was conducted.

Water and gas supply companies calculate according to failures / km per year. The average value for PE-80 pipes is 0.03 failures / km per year. \(^{(10)}\)

Sewage service organisations do not use such calculation methods. It is however estimated that at 50 failures / km and approximately 40 years old sewer lines the following average value is valid: Failure rate of old generation rigid pipes is 1.25 / km per year. \(^{(11)}\)

The factor 42 explains very clearly, that municipalities and sewer network operators should for their own benefit consider PE-80 as material option for their pipeline systems.

CONCLUSIONS

The sewage municipality in Göttingen has the strong believe, that the future in non-pressure sewage pipeline construction is to use PE-80 materials. \(^{(12)}\)

If 50% of sewage network operators in Germany changed to the use of PE-80 piping, the newly generated market potential would be around 5,000 km / year in the diameter range 280 – 560 mm and 3,000 km in the dimension 160mm.

The path to the realisation of such attractive market potentials however requires a joint approach of the industry combined with very intense education and public relation activities – at present neither of these are being carried out sufficiently.

REFERENCES


2. DVGW Richtlinie GW 330: „Schweißen von Rohren und Rohrleitungsteilen aus Polyethylen (PE 80, PE 100 und PE-Xa) für Gas- und Wasserleitungen; Lehr- und Prüfplan –Arbeitsblatt“, 11/00

DVGW Richtlinie GW 331: „Schweißaufsicht für Schweißarbeiten an Rohrleitungen aus PE-80 für die Gas- und Wasserversorgung; Lehr- und Prüfplan –Merkblatt“, 10/99
3. DVGW Richtlinie GW 301: „Qualifikationskriterien für Rohrleitungsbauunternehmen – Arbeitsblatt“, 07/99

4. DIN V 4034-1: “Prefabricated concrete manholes, unreinforced, steel fibre and reinforced for drains and sewers - Type 1 and Type 2 - Part 1: Requirements, test methods and evaluation of conformity”, 2003

5. DIN 8074: “Polyethylene (PE) - Pipes PE 63, PE 80, PE 100, PE-HD – Dimensions”, 1999

6. DIN 8075, “Polyethylene (PE) pipes - PE 63, PE 80, PE 100, PE-HD - General quality requirements, testing” 1999

7. DIN 19537-1: “High density polyethylene (HDPE) pipes and fittings for drains and sewers; dimensions”, 1983

DIN 19537-2: “High-density polyethylene (HDPE) pipes and fittings for drains and sewers; technical delivery conditions”, 1988

8. DIN EN 1610: “Construction and testing of drains and sewers; 1997


10. DVGW-Nachrichten 4/96


12. The „Stadtentwässerung Göttingen“ organises knowledge exchange seminars twice per year, titled „Göttinger Abwassertage: Aus der Praxis – für die Praxis“. For further details please check the homepage www.goettinger-abwassertage.de