

PE sewer piping systems

By Robert Eckert

SUMMARY: “Broken pipe” and “defective connections” by far represent the most common damages in sewers. These are typical for rigid, brittle pipe materials. Plastic pipes respond to loads with flexibility: Flexible pipes can deform without compromising their performance. Plastic piping systems also offer a reliable method for joining technology. Already in 2002 a fusible PE sewage saddle was best in test of the Institute for Underground Infrastructure’s product test [1].

For PE sewage pipes, electrofusion technology offers a reliable joining technology. Manhole connection, domestic sewer and pipe joints can be implemented with a fitting range specifically developed for non pressure sewage systems. The consideration of the material selection for the sewer should focus today more than ever before on sustainability, economy, and reliability: arguments in favour of PE.

THE SELECTION OF THE PIPE MATERIAL IN SEWER CONSTRUCTION

Sewage pipes are subject to complex stresses which consist of external and internal loads. External loads are primarily mechanical loads caused by static earth load, often in connection with dynamic traffic loads. Given large installation depths and a high groundwater level, collapse resistance and resistance to buckling pressure are required. Because of the sewage water, the material must not only be resistant to chemical and microbial loads but also have a good temperature resistance and a high resistance to abrasion.

Figure 1 shows the typical loads exerted on a sewer piping system which have to be considered when selecting the material.

The condition of our sewer network is well-known meanwhile because of requirements imposed on the operator to regularly inspect sewers, to classify the damages and – resulting from this as cost-intensive consequence – to carry out repairs. The results of an inspection of pipes of 1,700km in the nominal pipe widths of < DN800 were summarised, e.g., by Prof. Dr.-Ing. Stein & Partner, S&P Bochum [2]. The fault coding corresponds to EN13508-2 [3]. **Figure 2** shows the damage ratios for Germany determined here with regard to the ratio between rigid and flexible piping systems. The clearly increased damage ratios of the criteria “broken pipe” as typical failure type of rigid brittle materials as well as “joining technology” are striking.

Sewer piping systems must be leak-tight such that any exfiltration of sewage water into the soil and groundwater as well as infiltration of pressing groundwater into the network are prevented. Infiltration of water may result in an overload of the system capacities, above all of the sewage treatment plants. Related to this are the risks of flooding as well as high additional costs for transport and sewage water purification because of the larger volume of sewage water. Back-washes of the bedding area are caused by infiltra-

tion and thus negatively influence the bedding, i.e. pipe statics. As a consequence, the piping system is increasingly subjected to damages. Cracks, fractures, and splintering typically occur in sewer pipings made of brittle pipe materials when subjected to overload. This may result in the collapse of the sewer.

Brittle fractures caused by point or line load do not occur in flexible pipes, e.g. made of polyethylene. The deformation of the flexible pipe cross-section results in a deflection or diversion of the resulting forces in the ground and thus to a self-stabilisation of the ground, the so-called “tunnel effect”. Thanks to the flexibility of the material, even larger deformations are withstood. International or national regulations, e.g. DIN EN 1295 [4], ATV-DVWK-A127 [5], serve the structural analysis and limit the permissible deformation of the sewage pipe. As experience shows, settlements are completed at least after six months. The deformations caused by settlement occurring in proper installation have verifiably no long-term effects on the static bearing capacity, the function or life of the piping system.

Plastics pipes for sewer construction

Pipes made of PVC (polyvinyl chloride), PP (polypropylene) and PE (polyethylene) are used for sewage pipes. The joining technology for PVC and PP pipes is based on elastomer-sealed slip-on couplers. The material polyethylene is mainly fused which results in a material-homogeneous joint which requires no additional sealing elements. Fused polyethylene pipes facilitate the construction and operation of a very robust and durable, permanently sealed and long-lasting sewer piping system.

The material polyethylene

PE pipes have been in use for more than 50 years in domestic water supply. With the introduction of polyethylene of the third generation – PE 100 –, the acceptance of

the material in water distribution also increased for larger dimensions thanks to the higher mechanical load-bearing capability and strength. In gas distribution, PE piping systems have already been used since mid-70s and today are the standard pipe material. PE 80 and PE 100 pipes have been used area-wide for years with excellent experience above all in the area of pressure drainage and increasingly in sewer systems.

Further optimisations of the material resulted in an improved toughness and resistance to notches. Pipes with RC labelling are specifically recommended for sand bed-free installation or use in trenchless installations. The easy installation, the high life expectancy and the related economy of PE pipings open up a broad range of use in utility line construction. Apart from the conventional installation method using open trenches, polyethylene pipes are excellently suited for modern, trenchless installation methods, such as e.g. burst lining, ploughing or horizontal directional drilling. **Figure 3** shows the typical situation of the underground sewer infrastructure with inspection chamber connection and domestic sewer system as well as gas and water distribution systems.

WHAT DOES THE USE OF A FUSED PE SEWER PIPING SYSTEM MEAN FOR THE OPERATOR?

- » Flexible piping absorb both static and dynamic loads from the installation situation. The PE sewer remains functional where brittle materials sensitive to fractures are failing because of point or line loads.
- » A homogeneous material bond between pipe and fitting is obtained thanks to the electrofusion technology. As compared to conventional slip-on coupler piping systems, the fused piping system does no longer consist of individual components but of one single homogeneous pipe section.
- » The joining area is level, has a hydraulically optimal smooth surface, without coupler gap, without bead and misalignment. Draining is not obstructed, deposits, obstructions and malfunctions in the sewer are avoided from the beginning (**Figures 4 and 5**).
- » Domestic sewer lines are fused on using sewage saddle fittings and are thus homogeneously jointed with the sewage main.
- » The surface of PE pipes is extremely abrasion-resistant to bedload movements from the substances in the sewage water. This property has been impressively proven by the "Darmstadt method". PE pipes are thus, for example, also used in gravel plants to transport sharp-edged, hard solids, with considerably longer lifetime compared to other pipe materials. The smooth surface at the same time prevents the formation of deposits and incrustations.



FIG. 1: Load types of a sewer piping system

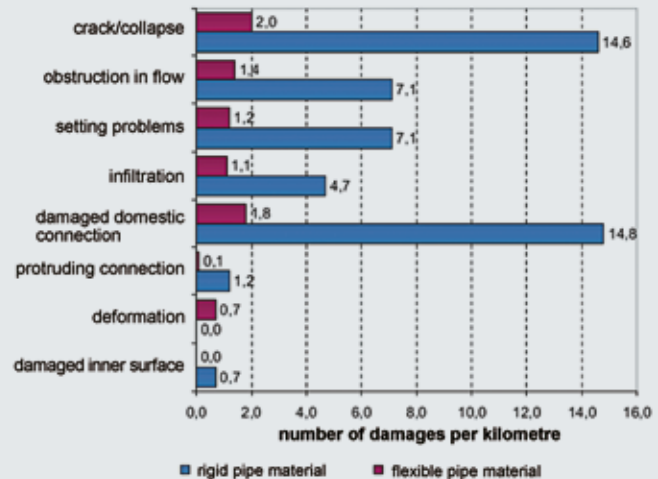


FIG. 2: Damage ratios (number of damages per sewer kilometre) of rigid and flexible pipe materials in public sewer systems (2006)



FIG. 3: Sewer infrastructure with PE pipes

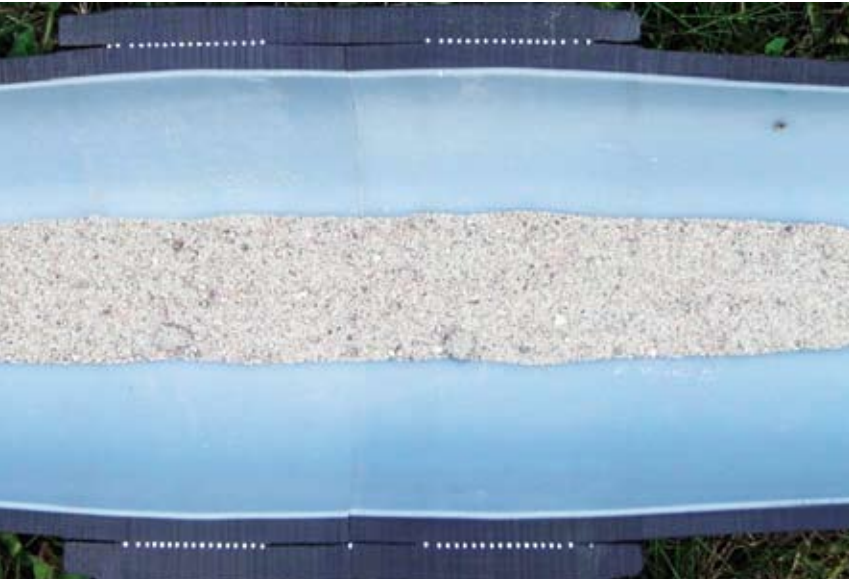


FIG. 4: Theory: Section through an electrofused pipe joint: No obstruction of the draining, hydraulically smooth channel in the joint area



FIG. 5: Reality: Camera inspection of the sewer: hydraulically smooth pipe joint

- » The material PE is characterised by its insensitivity to corrosion and by a high resistance to chemically aggressive transported media.
- » Pipe lengths up to 20m for PE pipes require fewer joints and thus increase the position reliability of the piping. Because of the low weight, large pipe lengths can be handled easily. In contrast, the standard length of stoneware or concrete pipes is often only 2.5m because of the high weight but also because of the production technology.
- » In case of electrofusion technology, the pipe joint in a sense conspicuous as "disturbance" exceeds the strength of the pipe. In reality this means:
 - › The fusion joint is resistant to root penetration. Recent findings have shown that the mechanisms of root penetration are not based on the presence of water in the piping, also not in case of leak-tight pipe joints, but on the preferred growth direction of the root in the area of the pipe bedding. The sand bedding offers less resistance to root growth than the natural ground [6, 7]. Following the pipe, the shoot sooner or later encounters a coupler. In case of electrofused joints, roots have no further opportunity to grow, even not in the area of the joint, and the shoot dies for lack of nutrients.
 - › The joint is tension-proof, normally even unbreakable. The mechanical load capacity of the electrofusion joint is often higher than that of the pipe. PE piping systems are specifically recommended in mining subsidence areas or in regions subject to earthquake hazards.

- › The joining area of the fusion coupler has a significantly higher ring stiffness than the pipe because the pipe wall thickness in the critical joining area is almost doubled. Nevertheless, the joint is uniformly deformed given corresponding force application.
- › Connections of sewage pipes are homogeneously connected to the sewage collector: no elastomeric sealing required, verifiably tight against internal and external pressures, expected lifetime same as pipe

The electrofusion procedure

For pressurised pipes in supply with a maximum operating pressure of 16 (25)bar, axial pipe joints are made by electrofusion technology from d 20mm up to presently d 900mm. **Figure 6** shows a typical installation situation. For disposal, there is a system of fittings in the dimension range of d 100mm to d 630mm matched to the specific requirements. These component parts are suitable for unpressurised operated gravity sewers made of HD-PE as well as for pressurised sewage systems up to a maximum system pressure of 10bar. In addition to the line installation, electrofusion technology is a very well-suited process for repairs in the pipeline and for work in places where space is at a premium, e.g. in small trenches or pipeline junctions.

How it works

The joining areas – the external pipe surface and the inner surface of the coupler – are heated to fusion temperature with heating coils integrated in the fitting by applying electric current. During this process, melt is applied



FIG. 6: PE pipe, joining method: electrofusion technology, coupler and electrofusion unit

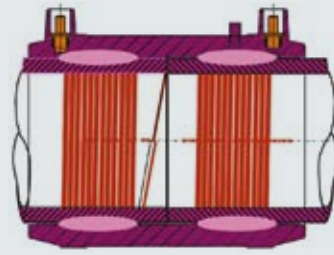


FIG. 7: Principle of electrofusion



FIG. 8: The FRIAFIT® sewage system for pipes made of HD-PE

by both component parts (Figure 7). Having cooled, an unbreakable, homogeneous joint exists. The decisive parameters for the fusion are melt temperature and fusion time as well as melt pressure. The parameters "temperature" and "time" are read via a bar code affixed at the fitting and automatically set by the fusion unit. The required fusion pressure results from the volume increase of the polyethylene melt. An optimal heat transfer is obtained by the exposed heating coils [8]. The energy is thus directly transferred to the pipe surface by convection and heat radiation.

THE PE SEWER PIPING SYSTEM

PE sewer pipes are often equipped with a bright inner layer (Figures 4 and 5) to improve sewer inspection by camera. The dimensioning is typically made in SDR17.6 with a view to the pipe statics. Within the system, the pipe and suitable connectors and connecting fittings are required (Figure 8). Thanks to the homogeneous, friction-locked and permanently tight joint, the sewage system can also be used as single PE pipe system in water catchment areas (protection area II). The high resilience of the material, together with the friction-locked electrofusion joint, also enables it to be used in land subsidence areas.

Manhole connection

Special demands are made on the manhole connection:

- » Settlement of the manhole results in bending and shear stresses which concentrate here

- » The deflection capability of the connection is required by standards
- » Tensile loads at the manhole base should be avoided
- » Leak-tightness of the connections, also with regard to pressing groundwater
- » Different material properties of concrete and PE must be considered in the design.

Figure 9 shows a test to prove the deflection capability and leak-tightness of the inspection chamber connection area of the dimension d 630mm under extreme conditions. The inspection chamber is filled with water. No leakage occurred during a deflection by 4° in the course of the test period of 24 hours.

Inspection chamber connection

The sewage inspection chamber adapter ASF is connected to the manhole base by the anchoring web with T profile (Figure 10). Typically, the inspection chamber lining is vibration filled into the concrete during production. The webs engaged behind guarantee a tight grip in the concrete and reliable leak-tightness of the joining area. In order to obtain levelness in the channel, it is of importance that the pipe wall thickness of the selected PE pipe as well as the wall thickness of the sewage insert sleeve are considered when designing the channel of the inspection chamber base.

Sewage insert sleeve

The sewage insert sleeve AEM (Figure 11) is fused onto the PE sewer pipe. The interface to the manhole is made in an articulated way using a push-fit connection. Tempe-

perature fluctuations, e.g. during the installation of the pipes, may result in high tensile forces because of the PE thermal expansion coefficient. These forces concentrate in the inspection chamber connection. The connection is not made in a friction-locked way but by push-fit connection to prevent these forces. The flexibility of the connection prevents any possible consequential damages. The articulating link is sealed by two elastomeric sealing rings inserted in separate beads. Additional reliability is offered by a third, water-swellable sealing ring: If in contact with

water, the volume of the swellable ring increases manifold and thus reliably seals off the inspection chamber connection to the surrounding ground. **Figure 12** shows such a level transition area between inspection chamber and pipe during a camera inspection.

Connection of domestic sewer systems

The sewage saddle ASA-TL (**Figure 13**) facilitates the connection of the PE domestic sewer pipe d160/DN150 to the PE sewer in the dimensions d 200mm to d 630mm.



FIG. 9: Test of an inspection chamber connection d 630mm



FIG. 10: The undercut anchoring webs of the inspection chamber lining ASF provide a strong and tight connection to the concrete



FIG. 11: Connection of PE pipes to a concrete manhole base with sewage inspection chamber adapter ASF and insert sleeve AEM

FIG. 12: Camera inspection in the area of the manhole connection and transition from clinker-clad channel to PE pipe



The joint – for saddle and domestic sewer – is made by electrofusion technology. The domestic sewer spigot is already designed as electrofusion coupler and thus facilitates the direct connection without interfering displacement or drain obstructions. A separation of the piping for subsequent connections or even for renovation work, e.g. burst lining, is no longer needed.

Figure 14 shows a cross-section through the fusion joints of the sewage saddle ASA to the pipe and the domestic sewer. The sewage saddle was assembled using a combined clamping and tapping unit. The system is designed such that after tapping no protrusion or obstacle constricts the free cross-section DN150 in the drainage area. The connection of the sewage saddle ASA is without displacement and interfering drain obstructions (**Figure 15**).

Leakage test for pressing groundwater

DIN 4060 [9] requires that joints of buried sewers, pipes and inspection chambers must be permanently leak-tight at an internal and external pressure of 0 to 0.5bar. A hands-on testing of the joints under external pressure – like in case of surrounding groundwater – is typically not performed.

At the large-scale testing facility of IKT – Institute for Underground Infrastructure in Gelsenkirchen – domestic sewers were installed at a PE sewer pipe d 355mm with FRIAFIT sewage saddles ASA-TL 355/160. The proof of the leak-tightness was carried out at four FRIAFIT sewage saddles ASA-TL (**Figure 16**). After the successful internal pressure test according to DIN EN 1610, the system was buried under hands-on condition with a depth of cover of 5.5m.

The test for external pressure was made one year later. The test facility was flooded to simulate a “groundwater level” of 5.5m. The resulting external pressure of 0.55bar at the joints was maintained throughout 120 hours. The test period of 120 hours having elapsed, no penetrating water was detected and the leak-tightness of the FRIAFIT sewage saddles ASA-TL was confirmed [10].

Fittings

- » Sewage bends ABM and ABMS: The sewage bend ABM with coupler on both ends permits a change of direction with minimum footprint. The bends d160 in 15°, 30°, and 45° are hydraulically optimised and offer a level passage when pipes SDR 17/17.6 are used. The type with bright inner layer facilitates an optimal view during camera inspection. The sewage bend ABMS with coupler/spigot end can be directly fused with the spigot end to the outlet of the sewage saddle ASA-TL (**Figure 13**).
- » Material transitions PE – PVC/PP/stoneware (Transition fittings UKG and ASA-TL/KG): The transition fitting UKG (**Figure 17**) and the transition saddle ASA-TL/KG facilitate the direct transition to domestic sewer pipes made,



FIG. 13: Domestic sewer pipes are connected using the sewage saddle ASA-TL, in this case in connection with sewage bends ABMS d 160mm

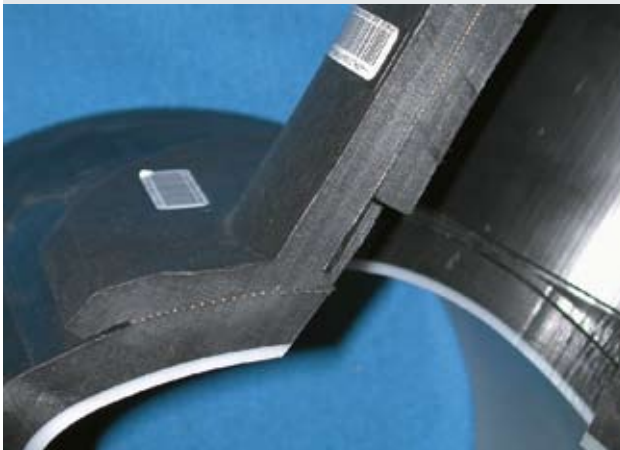


FIG. 14: Sectional model of the sewage saddle with the joints saddle-pipe and outlet-domestic sewer



FIG. 15: View into the sewage pipe: Smooth, displacement-free inlets Good inspection capability of the pipes thanks to bright inner layer

e.g., of PVC or PP. The slip-on coupler of the UKG seals off with a lip-sealing ring. The joint is made level, without interfering displacement.

- » Material transition PE – stoneware USTZ: Because of the considerable wall thickness difference between sto-

neware and PE pipe, a new fitting was specifically developed for this material transition. This facilitates direct connection without any further fittings.

CONCLUSION

The use of polyethylene in piping construction has stood the test of time already for five decades in the pressure piping systems for gas and water supply. Because of the advantages PE pipes offer in installation, operation and also from economic points of view, they are also increasingly replacing conventional pipe materials in sewage applications. PE piping systems for discharge pipes offer an intelligent response to the urgent issues regarding the required damage remedies in the sewer and above all regarding future prevention of damages.

Electrofusion joints correspond to the state-of-the-art in PE piping construction. Processes and fittings have proven themselves in practice and could establish themselves because of the reliability a homogeneous material

connection offers, the easy handling as well as the processing.

A broad fitting range offers the user problem solutions for almost any needs and all installation situations seen in practice. The sewage saddle for domestic sewers facilitates the consequent implementation of a comprehensive homogeneous and fused drainage network.

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FIG. 16: Detail of the test set-up with four FRIAFIT sewage saddles before burying



FIG. 17: Transition fitting PE/PVC-PP UKG



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