Sewer network renovation using glass-fiber reinforced (GRP) pipe liners

The BONEX method

1./ Antecedents

Several hundred or thousand kilometers is the total length of the communal and industrial sewer network built and operated below the ground of every civilized city of long history (in Budapest, the network is approx. 4,500 km long). Even industrial facilities can feature networks whose length adds up to several tens of kilometers. In most cases, these networks are badly worn, obsolete and their condition is about to deteriorate beyond repair in the foreseeable future.

Normally new pipes are laid to substitute for the worn sewers. However, this approach gives reason to concern because it is extremely expensive, hinders traffic within the given district of town or the factory premises and can greatly impede or paralyze the manufacturing processes.

Usually, no sufficiently large area is available to build a new sewer running parallel with the old one. Therefore, the so-called “No-Dig” renovation technologies have gained ground and importance all over the world during the last ten to twenty years.

A renovation process introduced in 1983 and named the “BONEX method” has offered proper solution to each of the three major problems inherent in the worn or wrecked sewers: corrosion resistance, water-tightness and loadability.

2./ Description of the BONEX method

Sewers are renovated by introducing pipe liners. According to the BONEX approach, the maximum length of each liner section is 6 meters. The pipe liners’ wall thickness is calculated using static dimensioning methods. In fact, the liner section is a high-strength, sand-filled and glass-fiber reinforced pipe made of polyester and provided with pipe socket and spigot of special design. To guarantee proper sealing at the pipe socket, a rubber ring of triangular or semi-circular cross-section is glued to the spigot in the pipe factory. When installed and pressed against the pipe socket at the site, this rubber ring flattens to ensure proper water-tightness. Upon request from the customer, artificial resin putty or a combination of rubber ring and resin putty can be used to guarantee proper sealing. The pipe’s wall thickness is determined to meet the expected load (the greater from the injection pressure and the payload in operation) and in function of the expected life specified by the customer (e.g. 100 years). To insert the pipe liners, only a single starting trench must be digged in the

middle of the normally 500 meters long sewer section in need of renovation. The pipe liners are placed in the cunette opened above the sewer shoulder and, then, are introduced (by applying an alternating “pull-and-push” motion) into the existing pipe, using a winch installed above the last shaft along the pipe-section to be re-lined. In case of passable (man-sized) pipe sections, the technology can be modified by carrying each pipe liner handed down in the starting trench separately to the intended place where the end of the liners can be matched and fixed.

In these cases, an anti-friction drop-shaped rubber ring or a ring of circular cross-section is normally used to seal the pipe sockets. Having put the pipe liners in place, the gap between the liner and the old sewer pipe is filled by injecting cement grout. Until completion of the process, the branching pipes and house sewers are temporarily plugged, to prevent the cement grout from penetrating in these pipe sections. In case of passable or climbable pipe sections, the plugs are installed from inside the pipe and, later, removed when the cement grout has consolidated. In case of non-climbable pipe sections, plugging and subsequent re-opening of the house sewers is done from a properly selected point, i.e. from outside the sewer to be re-lined (e.g. from the cleaning shaft of the house or the building’s basement, etc). Auxiliary devices of proper design are available for the insertion and removal of the temporary plugs and for cutting through the cement grout and the pipe liner. During the re-lining process, the sewage normally running in the main sewer and the presently plugged branch sections is delivered by pumping into a section of the main sewer yet in operation.

The renovated sewer section can be put again in operation the day following the day of injection.

3./ Manufacture of pipe liners

Pipe liners are manufactured using program-controlled filament winding machines and mechanic or hydraulic tools. Firstly, a stripping layer is applied to the mould, followed by a gel-coat free from glass-fibers, and a layer of plastic saturated with resin or a layer of glass-fiber fleece. The useful wall thickness consists of glass-roving layers previously pulled through a resin-bath, then, a layer of sand is applied between each layer of glass-roving. The weight of glass and sand can vary between 25 and 40 per cent, respectively, but their aggregate mass percent shall not exceed 65% (the rest is the weight of resin).

The thermal expansion co-efficient of a pipe wall of this structure is a good match to that of concrete. Accordingly, the composite material consisting of the pipe liner, the injected cement grout and the old concrete pipe shall not be subjected to considerable longitudinal stresses caused by temperature changes. The useful pipe wall surface is coated with a resin-free layer and the outer surface is sprayed with sand. The sand granules get embedded in the resin and, thus, are bound to the pipe wall.

The part of the sand granules that protrudes from the resin padding gets embedded in the injected cement grout. This intermediate layer allows, on the one hand, for proper composite action between the old pipe and the newly integrated pipe liner and, on the other hand, for the even distribution of minuscule tensions that may arise from minor thermal expansion, if any.

Normally, the pipes are manufactured to meet requirements of five quality grades in four categories of resistance to chemicals, as shown below:

Category	Type	Description
I.	"N"	Normal
II.	"É"	Food industry quality
III.	"V"	Resistant to chemicals
IV.	"D/A"	Increased resistance to chemicals, up to + 30 ^{O}C
V.	"D/B"	Increased resistance to chemicals, up to + 80 ^{O}C

4./ Implementation

a./ Preparations

On-site preparation of implementation of the technology begins with the installation of a "portable" or temporary duct needed to deliver sewage by pumping furthermore with the installation and commissioning of the sewage pumps and the necessary automatic control system. Then, the sewer section in need of renovation is removed from service and is flushed. Removal of any foreign object is the final task of preparation.

b./ Application of the pipe liners

After having prepared the starting trench, a "pilot pipe" is pulled through the sewer section, to make sure of smooth passage of the "train of pipe liners". The pipe liners are then introduced and applied according to the above described process. When the cement grout (the filling material) has set, the individual houses' sewer connections can be re-established. In case of passable (man-sized) pipe sections, the lining can be drilled and cut through from inside while, in case of non-passable sections, this job can be done from the garden shaft or the basement of the house, depending on the design of the local system. Special drilling equipment is used to complete this job. After having commissioned the re-lined sewer section, the temporary duct and delivery pump system is dismantled and re-deployed at the next section to be renovated.

The key phases of implementation are mechanized or automated, in order to improve the productivity and to decrease the costs of the process, compared to those of the traditional approach. Depending on the local circumstances, 10 to 15 pipe liners can

be installed in each shift, i.e. 60 to 90 meter long sections can be completed using 6 m long pipes. Of course, also the time required for the preparation and dismantling phases should be taken into consideration.

c./ Quality control of the renovated/improved section

In general, quality control of the renovated sewer sections comprises verification of adherence to the design dimensions and, primarily, the impermeability properties. Standards and other technical specifications stipulate the permissible rate of exfiltration and infiltration of the concrete sewer. As the glass-fiber reinforced polyester pipe ("GRP" grade) is perfectly water-impermeable and the number of pipe connections is by 50 to 66 percent less (due to the longer pipe sections) than in the case of traditional concrete pipes, the aggregate water-tightness of the GRP-sewer surpasses by far all the respective requirements.

Since this method has been used for a relatively short time (i.e. several decades), no statistically meaningful life expectancy data are available regarding the re-lined sewer sections. However, the known substantial difference between the chemical resistance of pipes made of concrete versus glass-fiber reinforced polyester and in possession of the domestic and foreign experiences (20 and 30 to 40 years, respectively), we have reason to assume that the expected life of the GRP pipe liners shall significantly exceed that of any newly laid concrete pipeline.

5./ Advantages vs. disadvantages

a./ Advantages

- The pipe material resists to any corrosion potentially caused by the delivered fluids or the groundwater of any concentration,
- The pipe liner shall take over all stresses and load from the old and obsolete concrete pipe (which latter can, from now on, be considered an empty underground tunnel). The life of the pipe liner can be adjusted according to the customer's discretion,
- Due to the pipe liner's extremely favorable friction coefficient, the transport throughput of the renovated sewer shall increase, accompanied by the decrease to almost nil of the degree of deposit accumulation. This latter feature is of outstanding importance in cutting the subsequent maintenance costs to a minimum.
- The applicability of this method is independent from:
  - the size/dimensions of the sewer in need of renovation (non-passable, man-sized, climbable)
  - the shape or cross-section of the sewer (circular, ovoid, frog-mouth, dragon, etc.)
  - the material of the original/old pipes (concrete, reinforced concrete, earthenware, brick, cement asbestos, steel, cast iron, plastic)
  - the weather or climatic conditions (cold, hot, wet or arid)

- the type of surface preparation technology (no surface roughening is needed; to the contrary, the surface must be smoothed, dried, de-dusted, degreased, etc.).

- The branch sewers and the houses can be reconnected to the renovated and re-lined sewer without any digging or causing any disturbance to surface traffic, in case of both the passable and the non-passable sewers.
- The renovation process does not disturb or impede the operation of any other public utility network, running parallel with or perpendicular to the route of the sewer (water, gas, distance heating, electric power supply, telephone, etc.).
- The rate of progress of renovation with the Bonex technology substantially exceeds that of any competing approach and the cost of implementation is significantly lower than that of another project of identical capacity and implemented under similar conditions but involving the digging of long trenches.
- If necessary, also the access shafts can be provided with the same corrosion protection or can be lined with glass-fiber reinforced polyester coat.
- BONEX is capable of completing the entire renovation process, from the current status assessment of the old pipeline, through the preparation of the detailed implementation plans, up to the installation and commissioning phase.

b./ Disadvantages

The single disadvantage is the price of the technology compared to that of the competing approaches. Notwithstanding, the higher cost is undoubtedly offset by the disproportionately higher value added (due to the load bearing capacity) and the well-founded expectations concerning the considerably longer life of the utility.