RENOVATION OF LARGE DIAMETER PIPES & CHAMBERS

OVERVIEW

Techniques for renovating large diameter pipes and chambers are probably the oldest forms of trenchless technology. Whereas small diameter pipes could not even be inspected before the advent of CCTV equipment, it has always been possible to walk or crawl through larger ones, and in many cases to apply manually the same techniques as are used to repair brickwork or concrete above ground.

The definition of `man-entry' varies from country to country, but it is usually permissible for men to work inside pipes of 900 mm diameter and above, or non-circular pipes larger than 900 x 600 mm. Work in smaller spaces may be allowed subject to compliance with stringent safety procedures. The provision of fully trained specialised search and rescue teams on site is often mandatory. It should be remembered that the conventional emergency services are equipped primarily for rescuing people from buildings, rather than from underground confined spaces, and that their equipment may be too bulky for entry into sewers and chambers below a certain size.

Many renovation systems aimed principally at non-man-entry pipes can also be used in larger sizes, although the economics may be unfavourable because of the quantity and cost of the materials.

Rehabilitation processes should be applied not only to pipes but also to the chambers through which they run. There is little sense in sealing pipelines against groundwater infiltration and sewage exfiltration if the manholes continue to leak. Moreover, sealing a pipeline against groundwater ingress can raise the external water table and exacerbate infiltration into manholes, so manhole renovation should be regarded as an integral part of the rehabilitation process.

As with their smaller counterparts, renovation systems for large diameter pipes and chambers can be divided into pre-formed and in-situ techniques.

PRE-FORMED LINERS

Pre-formed liners, which can be made in one piece or segmental, are usually made from glass reinforced plastic (GRP), glass reinforced concrete (GRC), or ferro-cement. They are fixed within the existing pipeline using spacers for correct alignment, and then grouted in position by the injection of a cementitious (or sometimes polyurethane) material through the liner wall.

Although pre-formed liners are not as adaptable as in-situ lining for irregular pipes, and give a greater reduction in cross-sectional area, they can offer high strength and hydraulic efficiency. It may be argued that pre-formed liners are a relatively safe option from the quality assurance viewpoint, since the performance of the installed liner depends more on factory-produced elements and less on the standard of workmanship carried out within the pipe.

Although aimed mainly at gravity pipelines, certain types of pre-formed liners are designed for use in pressure pipes.

GRP Liners

GRP liner elements are made in a similar way to other fibreglass products, and comprise chopped or continuous strand glass-fibre within a resin matrix. Polyester resin is commonly used, although other types including epoxy may be adopted for specific applications. Some proprietary liners incorporate sand or other fillers within the matrix, to increase wall thickness and hence stiffness. Any size or shape can be created, although a separate mould is generally required for each configuration, which increases the cost of one-off sizes in small quantities.

The wall thickness is typically between 10 and 30 mm, as appropriate to the size of the liner and its structural requirements, and the length of each element is generally between 0.5 and 1.5 metres depending on the size of the access chambers. Short lengths may also be used to negotiate gradual bends. The ends of each element are normally formed into a spigot and socket joint within the wall thickness, which may have an integral sealing ring or rely on the application of a sealing compound during installation.

GRP liner elements are relatively light, and can often be handled without power-driven cranes or winches. Larger sizes can be made in two or more segments, typically with separate invert and soffit elements, which assists handling especially in pipelines with localised constrictions. Packing pieces are wedged between the liner and the host pipe as installation progresses, to ensure correct alignment and prevent movement during grouting.

GRP liner elements ready for installation in an egg-shaped sewer

Once the liner elements have been installed, grout is injected into the space between the liner and the host pipe. The function of the grout depends on the principles under which the liner has been designed. GRP liners can be designed according to one of the following criteria:-

(A) to form a composite structure with the host pipe;

(B) to behave as an independent element with restraint from the host pipe;

(C) to act as no more than permanent formwork for the grout.

In Types A and C, the performance of the completed liner depends partly or wholly on the grout itself, so the grout must have high strength and, in (A), must bond to the existing pipe. In B, the grout acts simply as a filler, providing restraint to the liner, and does not constitute a structural element in its own right.

With very short liners it may be possible to inject the grout into the annulus at each end of the liner, but in most cases injection is carried out through holes drilled at regular intervals around the circumference and along the length of the liner. The grout is injected in several stages to avoid excessive pressure or flotation forces on the liner, allowing time for it to cure between each stage. It is also common to brace the liner internally during the grouting operation, especially in non-circular sections where parts of the pipe wall may be fairly flat and susceptible to distortion from external pressure.

GRP liners offer high resistance to most chemicals at moderate temperatures, and are often suitable for use in sewers which are subject to attack resulting from the presence of H2S. The internal surface has low hydraulic roughness, which may to some extent compensate for the reduction in bore. As with all polymeric materials, GRP suffers from creep under sustained loading, which reduces the long-term flexural modulus and hence increases the wall thickness, weight and cost of liners designed to satisfy long-term structural requirements.

Installation of GRP liner sections in a man-entry sewer

GRC Liners

A cementitious material reinforced with glass strands can be used to form a structural liner with high compressive, tensile and flexural strength. Mould-formed one-piece or segmental elements can be manufactured to any size and shape.

The application of GRC liners is similar to that of GRP, except that they are not used as non-structural liners. The cost of the constituent materials is lower than for GRP liners, although GRC liners are heavier, and the costs of handling and transportation within the host pipe may therefore be higher.

Because of their inherent rigidity, GRC liners do not require bracing during the grouting operation. In other respects, the installation procedures are similar to those for GRP liners described above. The rigidity also minimises long-term creep.

Being a cementitious material, GRC's resistance to certain chemicals such as acids resulting from H2S is not as high as that of many polymerics. Hydraulic performance depends on the quality of the internal finish, but the roughness coefficient is likely to be higher than for GRP.

Ferro-cement

Ferro-cement comprises layers of steel reinforcing mesh within cement mortar. In some respects it may appear similar to reinforced concrete, but in practice its properties are significantly different. The fine mesh acts in composite with the cement matrix and gives a degree of flexibility and resilience to the finished product, in contrast to the rigid or brittle nature of many concrete materials. The mesh also controls crack propagation, and ferro-cement has been used to produce a variety of watertight structures including boat hulls.

Although pre-formed ferro-cement pipe liners are not particularly widespread at present, the material can be viewed as a viable alternative to GRP and GRC, subject to the usual economic considerations. The installation procedures are also similar.

Ferro-cement is also used as an in-situ lining technique, described below.

IN-SITU RENOVATION

Economic considerations aside, the main advantage of most in-situ lining techniques is that they can conform to changes in size or shape within any particular section of pipeline. Whereas pre-formed liners have to be sized to suit the minimum dimensions of each section, in-situ techniques can follow the existing profile, minimising the bore reduction and the quantity of grout needed to fill the annular space.

Non-man-entry pipe renovation techniques such as spirally wound lining (Refer Sliplining Section) and cured-in-place lining (refer Cured-in Place Lining) may be used in larger pipes. Because of the liner wall thickness and hence the quantity of resin needed to produce a structural, large diameter CIPP liner, the choice is usually determined by an economic comparison with techniques aimed specifically at man-entry pipe renovation.

Some man-entry in-situ lining systems are highly dependent on the quality of workmanship underground, since there are often no factory-produced elements as the basis of the liner. In the absence of a pre-formed product which can be tested above ground in the same way as any new pipe, it may be difficult to assess precisely the structural performance of in-situ liners, especially in unusually shaped conduits.

Nevertheless, if properly installed, in-situ man-entry lining techniques have much to offer, especially where bore reduction must be minimised, or where the cost of manufacturing pre-formed liners in a wide range of shapes and sizes would be prohibitive. They may be particularly attractive for the renovation of old masonry culverts and sewers, which were often constructed to varying cross-sections and with changes of direction following old watercourses.

Many in-situ techniques rely on adhesion between the liner material and the existing pipe wall, and it is therefore essential that the pipe be cleaned thoroughly, and that all grease deposits and loose material be removed. For those methods which include steel reinforcement, the installation procedure must incorporate a method of ensuring that the minimum cover to the steel is achieved.

Sprayed Concrete

Essentially a stabilisation technique for old brickwork and masonry pipelines, the sprayed concrete forms a new inner skin which enhances strength, reduces leakage and prevents further loss of mortar. The concrete is trowelled after application to produce a smooth surface. Reinforcement may be fixed to the existing pipe wall prior to applying the concrete, adding to the structural strength and creating a new reinforced concrete pipe with the old pipeline. The design of the concrete mix is important, to ensure full penetration and encapsulation of the reinforcement.

Pre-cast concrete units are commonly used to line the invert, especially if the flow in the pipe cannot be stopped off completely.

Spray lining is also commonly used for water main rehabilitation – see Spraylining Section.

Ferro-cement

As well as being a material for pre-formed liners, ferro-cement may be installed in-situ. Layers of steel mesh are fixed to the existing pipe wall and a mortar is then applied over and through the mesh. In this case the liner relies on a bond between the old pipe and the cementitious mortar, and the mesh-reinforced lining offers high strength and crack control. As with sprayed concrete lining, most installations use a pre-cast invert unit, with an insitu applied lining for the remainder of the pipe.

Some ferro-cement linings have been developed which are suitable for acidic conditions encountered in chemical or industrial applications.

In-situ Reinforced Concrete

A continuous in-situ reinforced concrete lining system is available for man-entry pipelines from 900 mm to over 5500 mm diameter. Reinforcing steel is attached to the sewer wall, and lightweight formwork is then installed, usually in two-metre lengths which are locked together with pins. Concrete is pumped under pressure behind the formwork to create a monolithic lining. It is a technique which forms a bond with the existing structure.

The process accommodates bends and slight deformation, and produces a smooth finish with low hydraulic roughness. Connections can be formed through the use of adapted shutters, and flows can be maintained without overpumping.

Spirally Wound Liners

Spirally wound liners are formed in-situ from a uPVC strip (or `profile') which is helically wound to produce a close-fit tube within the existing pipe. The profile is transported in coils and is fed into the pipeline through existing access points. In some systems, the profile is arranged into a helix within the host pipe, in contact with the pipe wall, and a separate locking strip is hammered into the joint between adjacent turns of the helix. Integral rubber seals produce a watertight joint. H-section plates may be used to join the end of the profile from one coil to the leading end of the next coil, allowing any length of tube to be installed in one operation.

Photo courtesy of Tubemakers Water

Spirally wound liner being installed in an egg-shaped pipeline

Other systems have interlocking profile edges rather than a separate locking strip, and one variant uses a self-powered winding machine, similar in concept to that used for spirally wound non-man-entry liners, which travels through the host pipe as it forms the liner. The system can create non-circular liners, the shape being determined by the configuration of the winding cage.

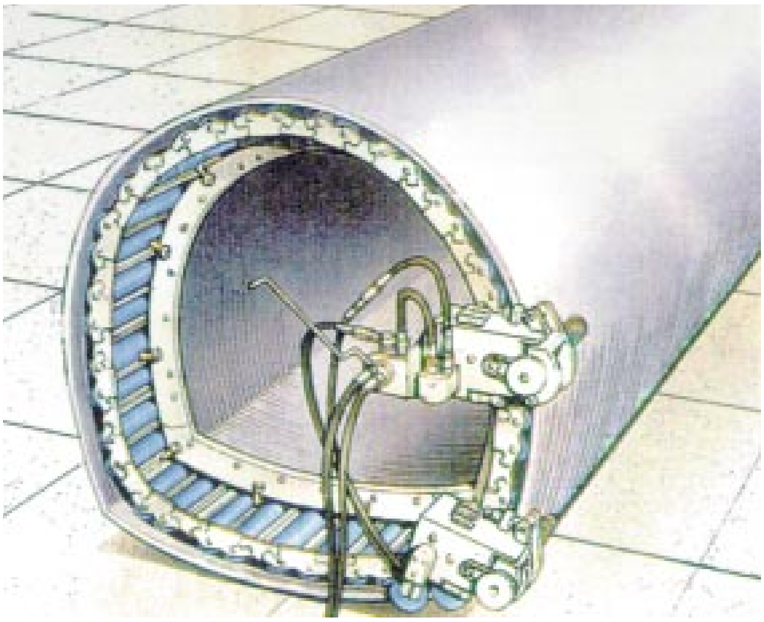

Diagram courtesy of Sekisui Chemical Co Ltd

Spirally wound liner formed by a machine travelling through the host pipeline

The profile has a ribbed outer surface in the form of `T-beams' which increase the structural strength of the tube and also provide a mechanical bond with the grout injected between the liner and the existing pipe wall. The inner surface of the tube has a low roughness coefficient, and the material resists most chemicals. In some systems, steel reinforcement can be inserted between the profile ribs prior to winding, to increase the strength of the tube.

The profile has sufficient flexibility to accommodate slight or gradual changes in the size and shape of the host pipe. Where the variations are more severe, manually installed tubes can be tailored to fit by making longitudinal V-shaped cuts, and then sealing these with H-section jointing plates bonded with a solvent adhesive.

Once the tube is installed and sealed, a standard PFA/cement grout is injected through holes drilled at intervals around the perimeter and along the length of the liner. Bracing may be fitted within the tube to prevent distortion from grouting pressure or flotation forces, and grouting is carried out in several stages depending on the dimensions of the liner. The holes are sealed with PVC plugs when grouting is complete. Lateral openings are cut out as the tube is installed, and rapid-hardening mortar is used to seal around the connection between the liner and the pipe wall.

Spirally wound liners are suitable for circular or non-circular man-entry pipes up to 3000 mm diameter, subject to safety regulations regarding the minimum size for man-entry, and can be installed in limited flows without over-pumping.

Epoxy Coatings

High-bond epoxy coatings may be used to seal and protect pipelines, manholes and other underground structures, and to provide a smooth internal surface for ease of maintenance and low hydraulic roughness. The materials offer good adhesion and corrosion resistance, together with high impermeability and a very smooth finished surface. They are designed for in-situ application to steel, concrete and fibreglass, usually by means of purpose-designed spraying equipment.

Repointing

Brick sewers or chambers with missing mortar or degraded joints may require little more than repointing, using the same techniques that are applied to above-ground structures. Thorough cleaning and raking out of the old mortar is essential. The term `pressure pointing' is sometimes used to refer to the conveyance of mortar through a pressurised hose to an application nozzle. Since the mortar is at atmospheric pressure once it issues from the nozzle, the term should not be taken to imply that the material is necessarily forced into joints any more effectively than by other methods.

MANHOLE RENOVATION

There are two basic methods of manhole rehabilitation - sealing by resin or grout injection into joints, cracks and the surrounding ground, or installing an in-situ or pre-formed internal liner.

Injection

Most injection processes use materials similar to those employed in pipe joint sealing - polyurethane or acrylic grouts - which are injected through nozzles fitted into the chamber walls. Polyurethane grouts are water-reactive and can be injected without a catalyst if there is sufficient free water in the surrounding ground. The process generally involves the drilling of injection holes in a predetermined pattern, through which the grout is injected to create a flexible external membrane. Tunnels, man-entry sewers, basements and pumping stations can also be treated by this method.

The effect is to convert the manhole surround into an impermeable mass, sealing against infiltration and exfiltration whilst also providing unquantifiable structural enhancement. A similar effect is achieved by the `fill and drain' sealing systems which treat the pipework and manholes in the same operation.

Rapid setting hydraulic cements are suitable for plugging holes and cracks, even against strong infiltration, and can be used prior to grout injection to prevent the grout from being washed out. Some hydraulic cements have a setting time of just a few seconds, and expand during set.

In-situ Lining

A specially formulated mortar can be applied to the prepared inner face of a manhole, using a robotic applicator which obviates the need to enter the chamber. The technique is suitable for brickwork, blockwork or pre-cast concrete manholes, and a single application creates a dense, uniform liner of any thickness from 12 mm to 50 mm. If there is a severe risk of corrosion, the treatment can be followed by the application of epoxy resin which is sprayed over the fresh mortar before corrosion can restart.

The helically wound lining technique described previously for man-entry pipelines can also be used for chamber renovation. The uPVC material may be installed in circular or rectangular structures, and is either prefabricated or tailored on site. Preparation normally involves removing ladders, step-irons and any internal back-drops, before cleaning the surface of the structure by high pressure water jetting. Removal of the manhole cover slab is usually required for prefabricated liners, whereas in-situ liners are installed by feeding the uPVC strip through the manhole opening and spirally winding it within the chamber. Annulus grouting is carried out to bond the liner to the chamber walls. The underside of the cover slab can be lined in-situ, or a new slab may be cast integrally with uPVC used as permanent formwork. Joints between the wall liner and the cover slab are sealed either with a polyurethane sealant or by PVC welding.

A further in-situ technique is a cured-in-place system using structural glass-fibre with an impermeable inner membrane. The fabric is tailored to the exact dimensions of the manhole before being impregnated with an epoxy resin. After cleaning and any pre-treatment of the manhole, the liner is lowered into position and the integral inflation bladder is pressurised to between 0.25 and 0.5 bar. Steam is used to heat the liner to approximately 120°C until curing is complete, which normally takes one to two hours. After removal of the inflation bladder, the incoming pipes are reopened and any excess liner is trimmed at the cover slab.

Also available are cementitious products that can be sprayed, trowelled or brushed onto the internal surface of the chamber to form a waterproof coating. Thorough preparation of the surface is essential, and it may be necessary to use a bonding or stabilising agent before applying the cementitious material.

SUMMARY

- Compliance with recognised safety procedures is especially important with man-entry lining systems, and the choice of technique may be influenced by permissible working practices.
- Renovation systems aimed mainly at non-man-entry pipelines may also be suitable for larger sizes, although the volume and cost of materials may be a determining factor.
- Pre-formed liners such as GRP and GRC use factory-manufactured units with known properties, and are less dependent on the quality of work underground. However, they do not adapt easily to varying pipe dimensions, and may produce a significant reduction in bore.
- In-situ lining techniques are adaptable to changes in size and shape, and minimise the loss of cross-section, but some methods rely more heavily on the quality of materials and workmanship on site.
- Manhole and chamber renovation should be viewed as an integral part of the rehabilitation process. Systems aimed at large diameter pipelines may also be suitable for manhole lining.