LOCALISED REPAIRS & SEALING

OVERVIEW

Various localised repair systems have been developed, most aimed at sewer renovation but including some that are designed to seal joints in pressure pipelines. Many techniques are adaptations of full-length lining systems, especially those based on cured-in-place resin/felt tubes.

The economics of such techniques need to be assessed for each case, but clearly there are situations where damage is restricted to only part of a sewer length, and where repair of individual defects may be more cost-effective than renovating the entire length of sewer. As a general rule, it has been suggested that localised repairs can be economically viable if less than 25% of the sewer length contains structural defects, although the equation will vary according to individual circumstances.

Pre-inspection and cleaning are essential to localised repair systems just as to full-length techniques. For those localised repair methods which require a bond with the existing pipe fabric, all traces of grease and debris must be removed.

There are five broad categories of localised repair system - sleeve or `patch' repairs; resin injection systems; robotic repairs; pipe re-rounding; and pipe joint sealing. Comparison of these leads to the question of what does and does not constitute a `structural' repair.

STRUCTURAL CONSIDERATIONS

All forms of renovation provide structural enhancement to some degree. Lining systems, including sleeve repairs, do so by means of a new pipe inserted or cured within the old one, and the structural properties of the new element can be measured in isolation from the host pipe, even though in practice the restraint offered by the host pipe will enhance the 'stand-alone' performance significantly. For example, the ring stiffness of a close-fit or grouted liner may be increased by a factor of up to 7 by restraint from the host pipe if there is good support, although for design purposes a much lower factor is used.

Because liners and short-length sleeves comprise a definable structural element, they are generally regarded as `structural' renovation techniques. However, the picture is less clear with other methods such as resin or grout injection which behave in a composite manner with the existing pipe fabric and often the surrounding ground. Because there is no separate element, and the strength of the repair is more difficult to calculate, these systems are often termed `non-structural'. This is misleading, and it would be fairer to say that the structural properties of the completed repair are difficult to determine accurately. Even polyurethane (PU) or acrylate injection techniques, where the material itself has little strength, can increase structural performance appreciably by stabilising and sealing the surrounding ground. The elimination of erosion resulting from the infiltration/exfiltration cycle is also important to extending the useful life of the pipeline.

Because of these considerations, it is important to exercise engineering judgement when assessing the suitability of a particular localised repair technique, rather than relying wholly on mathematics.

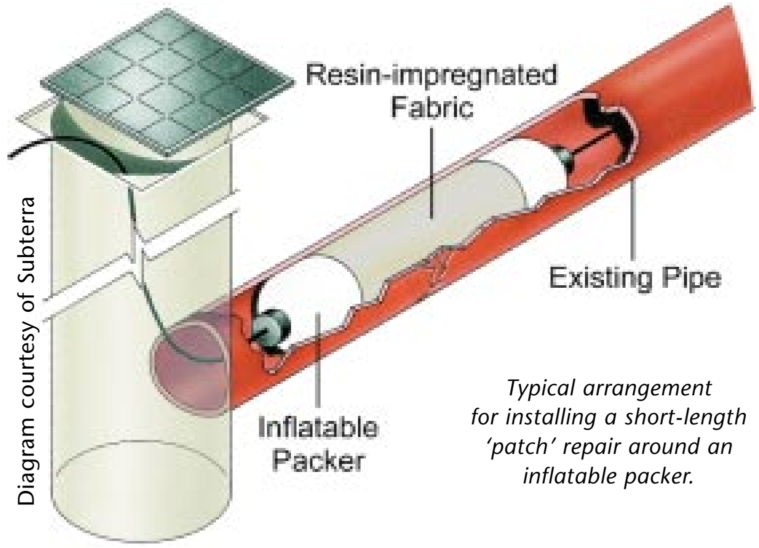
SLEEVE OR 'PATCH' REPAIRS

Most patch repair techniques entail impregnating a fabric with a suitable resin, pulling this into place within the sewer around an inflatable packer or mandrel, and then filling the packer with water, steam or air under pressure to press the patch against the existing sewer wall while the resin cures. Both thermal-cure and ambient-cure systems are available.

In many respects, patch repairs are short versions of cured-in-place liners, although often the fabrics and resins are stronger since material economy is less significant in the overall installation cost. The fabric is commonly polyester needle-felt (non-woven), either on its own or in combination with glass-fibre. Some systems use a multi-layer sandwich, the glass-fibre providing strength whilst the felt acts as a resin carrier.

Although polyester resin may be used as in full-length liners, epoxy resin is a common alternative for localised repairs. Epoxies can be formulated to be water-immiscible, whereas polyester resins are adversely affected by water prior to cure. This may be particularly relevant in techniques which are designed for installation without diverting the flows in the pipeline. The drawback of epoxy resins, apart from their higher cost, is that the cure regime is more critical. Most epoxy-based systems require thermal cure, and ambient cure is generally restricted to polyester resins.

The patch may be pre-formed into a tube of the correct circumference, or it may simply be a rectangle of material which is wrapped around the packer and scrolls out to the wall of the pipe when the packer is inflated. In the latter case an overlap will be visible in the finished tube, but this is of little consequence to the performance of the repair.



Typical arrangement for installing a short-length 'patch' repair around an inflatable packer.

Impregnation of the fabric is usually, but not always, carried out on site. With some systems the patch is pre-impregnated and refrigerated for delivery to site. Whilst on-site impregnation is generally acceptable, care is needed to avoid health risks and the spillage of chemicals, some of which are toxic in their unreacted state. The styrene solvent found in most polyester resins dictates the need for adequate ventilation, and this matter is discussed more fully in the Cured-in Place Lining Section.

During mixing and impregnation, it is important to exclude air from the resin as far as possible. Entrained air weakens the material and, in severe cases, can result in porosity. It may be impossible to avoid air entrainment, especially with viscous resins, and some systems overcome this with vacuum impregnation.

With both ambient and thermal cured systems, it is essential to limit the rise in temperature of the materials until the patch is inflated within the pipe. One of the most common causes of failure is premature cure, where the patch has started to harden before it is in position. Exothermic cure starts as soon as the components of the resin are mixed, and the rate of temperature rise increases with the volume of resin. Mixed resin should therefore be applied to the fabric immediately, and not left in the mixing vessel. Due regard should also be paid to the temperature of the surface on which the fabric is placed during impregnation, and, once impregnated, the patch should be positioned and inflated without delay.

Packers are generally made from an elastomer such as rubber, and internal pressure first expands the packer and then presses the patch against the pipe wall. Compressed air is used for inflation with most ambient-cure systems. Thermal cure methods may use a mixture of compressed air and steam, or hot water which is recirculated between the packer and a boiler unit on the surface. Care is needed to avoid over-pressurisation, especially with water-inflated systems where the packer is subjected to both a static head and an additional pumping head which is related to fluid friction in the return hose.

Photo courtesy of Subterra

Localised repair using a short length of resin-impregnated liner tube

The curing time depends on the resin formulation, the thickness of the patch, the temperature within the packer (in thermal-cure systems), and the temperature of the existing pipe wall. A high ground-water table will tend to act as a heat sink, cooling the outer surface of the patch, and additional curing time should be allowed.

After curing, the packer is deflated and removed. The patch should then be inspected by CCTV, and any lateral connections reopened using the same techniques available for full-length liners.

RESIN INJECTION

Resin injection systems fall into two categories: those whose principal function is to seal the pipeline against infiltration and exfiltration, and those which aim to restore the structure of a damaged pipe.

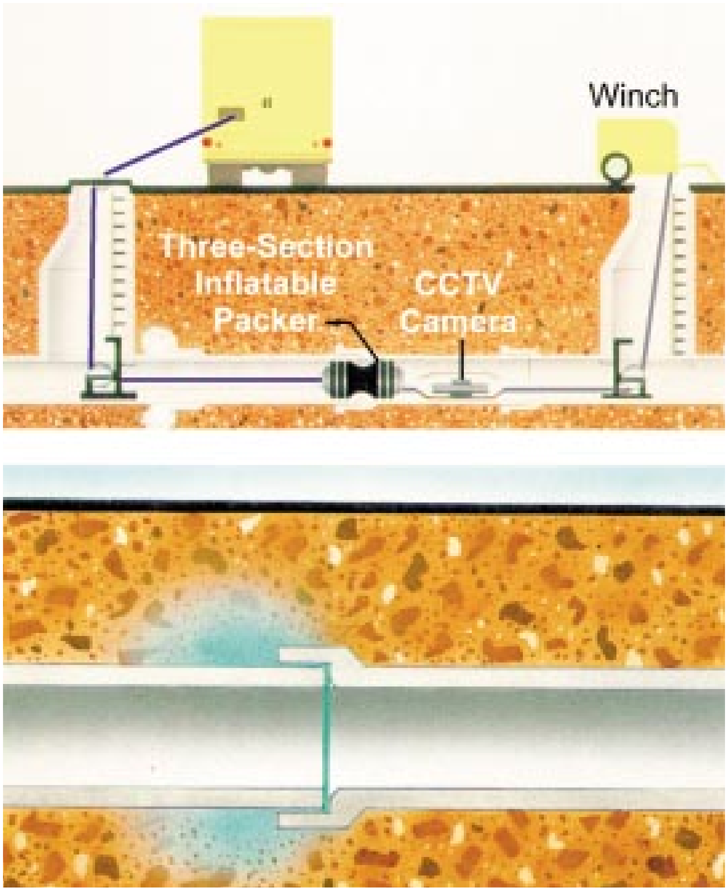
A common method of sealing leaking joints in gravity pipelines is to used a special packer which combines the functions of leakage testing and grout injection. Joint testing and sealing may or may not be `localised', depending on how many joints fail, but can be included under this heading since it aims to identify and cure a specific defect.

A packer with inflatable end elements is positioned across a pipe joint and pressurised to isolate the joint. Air or water pressure is then applied to the centre section of the packer, and the rate of pressure loss through the joint is measured. If the loss exceeds a specified limit, a sealing gel is injected into the joint through the packer, and the joint is re-tested.

There are numerous variations in packer design and sophistication, and most systems use either a two-part acrylic grout or a water-reactive polyurethane resin. In either case the grout has little intrinsic strength, but turns the ground around the leaking joint into an impermeable mass which prevents leakage and also enhances structural stability.

It should be noted that acrylamide sealing grouts are now regarded as a health risk in several countries because of the toxicity of the unreacted components. However, acrylate grouts, despite their similar name, have very different chemical properties and are believed to be safe.

Polyurethane (PU) grouts are hydrophilic and react either with free water in the soil or with water injected through the packer at the same time as the grout. Although plain water can be used, a styrene-butadiene rubber (SBR) solution is often mixed with the water in the ratio 1:4 to add resilience to the cured grout and to reduce shrinkage. The proportion of grout to water affects the properties of the material – ratios stronger than 1:5 tend to produce a foam, whereas slightly weaker mixes create a gel. A ratio of 1 part PU grout to 8 parts water (or water/SBR) is generally recommended for pipe sealing.



Joint testing and sealing using an inflatable packer

Many PU grouts contain acetone to reduce viscosity and increase miscibility. The flammability of acetone should be considered when storing the material, and certain manufacturers now offer PU grouts which are acetone free.

A different form of resin injection system, normally using an epoxy resin or mortar, may be used to stabilise and re-bond the existing pipe structure, in addition to sealing against exfiltration and infiltration. Although aimed originally at pipes where damage was not too severe or extensive, the technique has evolved to be suitable for more serious defects. An inflatable packer isolates the defect and injects a rapid-setting epoxy resin into the crack, fracture or hole in the pipe wall. The packer is left in position until the resin has cured, and a thin internal collar of resin usually remains after packer withdrawal.

FILL-AND-DRAIN SYSTEMS

A different approach to leak sealing is taken by `fill and drain' techniques which treat the main sewer, branches and manholes in one operation. One of the most widely used systems was invented in Hungary.

The section to be sealed is first isolated and then filled from a manhole with an environmentally safe chemical solution (usually sodium silicate). After a predetermined interval to allow the chemical to permeate through leaking joints and cracks, the solution is pumped out quickly. The section is then filled with a second proprietary chemical solution, and this reacts with the residue of the first chemical to form a waterproof gel. The second chemical is then pumped out and the pipe is cleaned to remove any residue.

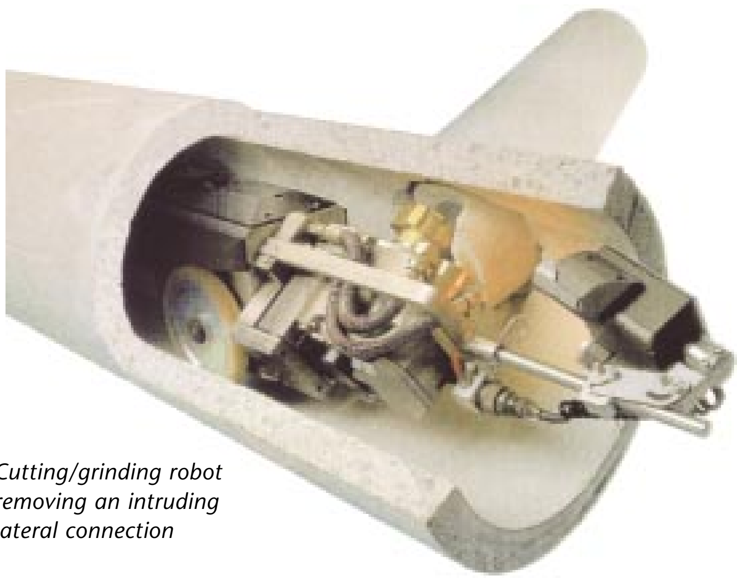
As with packer-injected sealants, the effect of the system is to turn the manhole and pipe surround into an impermeable mass around points of leakage. Because of plant requirements and the volumes of materials, fill-and-drain systems are aimed more at large-scale leakage control projects than at the treatment of isolated lengths. They have the advantage of treating leaks throughout the whole system in a single operation.

ROBOTIC REPAIRS

Robotic repair systems, largely developed in Switzerland, are used mainly in gravity pipelines and comprise a grinding robot and a filler robot. The former removes encrustation and intrusions, and also mills out cracks to provide a good surface and key for the repair materials. The filler robot applies an epoxy mortar into the slot formed by the grinder, and trowels off the material to a smooth finish.

Robots are available for use in pipes from 200 to 800 mm diameter. Typically, the smaller versions will operate in diameters up to 200-400 mm, and the larger ones from 300 mm upwards. Various axle and wheel sets are used to position the robot centrally within the pipe.

Photo courtesy of KA-TE System AG



Cutting/grinding robot removing an intruding lateral connection

The grinding head is hydraulically driven, giving high torque at low speeds, and can be fitted with various shapes of diamond or carbide cutters suitable for clayware, concrete, polymeric materials and even steel. Some of the more powerful grinding robots can cut through steel reinforcement. It is common for the cutters to be cooled by a water spray issuing from the central hub.

The wheels are usually driven by electric motors, as are the head rotation and extension functions. The operation of the robot is monitored by a CCTV camera attached to the head, and a further camera can usually be added for forward view. Some grinding robots have the facility to inject a sealing compound through a hollow drill, which prevent infiltration from affecting the mortar applied by the filler robot. They may also be fitted with a high pressure water jet to remove the debris created by the grinding operation.

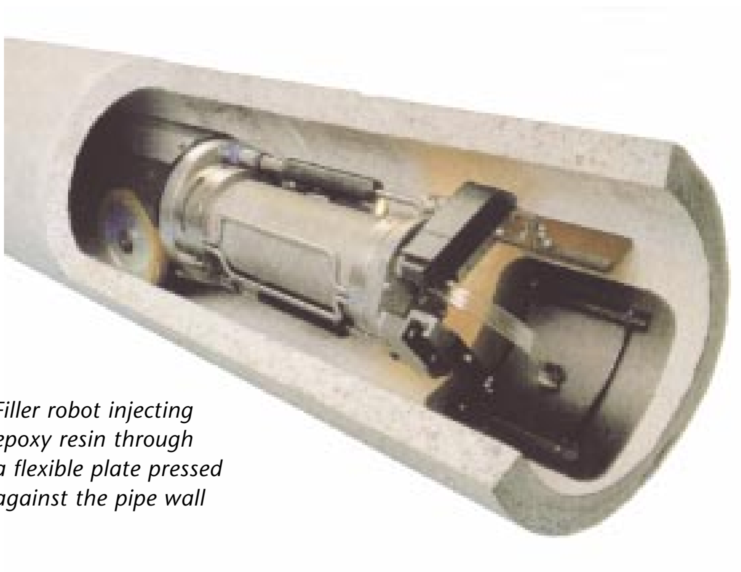
Typically, cracks are milled out to a width and depth of between 25 and 30 mm. It is essential to clean the area of the repair thoroughly after grinding, since any dust, mud or debris will prevent the mortar from adhering. Intruding laterals, grout deposits and hard encrustation can also be removed.

The properties of the epoxy mortar are important, since the material is normally applied to wet surfaces. The two-part mortar may either be mixed prior to filling the canister on board the filler robot, or in some designs the components are loaded into the robot separately and mixed at the outlet as they are used. As with the grinding robots, the filler robots are self-propelled and have on-board cameras.

The epoxy is applied by a system of remotely-controlled nozzles and spatulas, the material being forced out of the canister by a piston driven by compressed air. Alternatively, the mortar can be injected through a flexible plate or former pressed against the pipe wall.

In addition to filling slots milled by the grinding robot, the filler robot can apply the epoxy around poorly made connections, to seal the connection to the main pipe. Some systems allow the use of special formers or shields which act as a temporary shutter and allow defective lateral connections to be remoulded in epoxy mortar. They can also insert an inflatable stopper up a branch, to assist in reforming a connection and to temporarily stop the flow.

Photo courtesy of KA-TE System AG



Filler robot injecting epoxy resin through a flexible plate pressed against the pipe wall

All robot functions are controlled from a central console housed in a vehicle which also contains hose reels, a compressor, a hydraulic power-pack and other ancillary equipment. There is also a hoist for lifting the robots into and out of manholes. The main source of power is a large generator which is usually trailer-mounted.

Robotic repair systems are versatile, but they need a consistent programme of work to be economically viable. They have found favour in regions which offer a predictable workload for localised repairs, but have been less successful in commercial terms where the demand is only sporadic.

MECHANICAL JOINT SEALING

Another method of joint sealing involves installing, across the joint, a metal band or clip faced with an elastomeric material which forms a seal with the inner surface of the pipe. Systems of this type are available for both gravity and pressure pipes. Mechanical sealing systems have the advantage of not relying on in-situ chemical reactions, and can also be installed quickly. The cost of the materials is, however, higher than for cured-in-place methods.

Mechanical systems are available for sealing joints in man-entry pressure pipes rated at up to 20 bar. Only 2 to 3 bar pressure is needed to tighten the seal, so low-modulus pipe materials such as PE and uPVC are not overstressed. Repair modules are available for pipes from 600 to 3000 mm diameter, and the seal can be made of NBR rubber for gas applications or EDPM rubber for potable water. Tapered versions are manufactured for use between pipes of varying diameter, and to seal the annulus at the ends of sliplined pipes.

Photo courtesy of Toa Grout Kogyo Co

Stainless steel and rubber internal repair sleeve for gravity pipes, with additional hydrophilic rubber seals (yellow)

Mechanical repair modules are also available for non-man-entry gravity pipes from 200 to 600 mm diameter. The stainless steel inner sleeve is in the form of a scrolled clip which can expand in diameter, and an integral ratchet mechanism prevents the unit from contracting again. The outer rubber sleeve also has bands of hydrophilic rubber to give a watertight seal with the existing pipe. The repair modules are installed by means of an inflatable packer which expands the clip and presses the rubber against the pipe wall. The packer can then be deflated and withdrawn. Variations are available for sealing around connections, and for structural renovation in conjunction with a cured-in-place sleeve.

PIPE RE-ROUNDING

Re-rounding is not a stand-alone technique, but is intended to re-shape a deformed pipe prior to patch repair or relining. An expander unit is used to re-round the pipe and install a metal or plastic clip which holds the pipe fragments in position until a patch or liner is installed.

The expander can be made from an elastomeric material inflated with hydraulic pressure, or it may be a variant of a hydraulic mole with steel `petals' that are forced outwards by hydraulic rams. The plastic or metal clip is scrolled around the expander prior to insertion, and held in place with bands or tape. The clip usually has some form of ratchet or locking arrangement to keep it at its expanded size. After positioning under CCTV control, the clip is expanded with sufficient pressure to re-round the pipe.

Although a useful technique in the trenchless technology armoury, pipe re-rounding is not always successful. During expansion, the unit will take the path of least resistance. For example, if there is a void beneath the pipe invert, the clip may be forced down when expanded, rather than re-shaping the soffit of the pipe. It is also important to follow with relining or patch repair as soon as possible after the re-rounding operation, since the clip has limited structural strength and may soon become misshapen if left without support.

SUMMARY

- Sleeve or 'patch' repairs usually follow similar principles to full-length cured-in-place liners, and provide a short section of structural liner within the host pipe. They are most commonly used for the renovation of gravity sewers and drains, and can be of any diameter from 100 mm upwards.
- Depending on the materials used, resin injection systems stabilise the pipe surround and/or the fabric of the pipe. They also seal against infiltration and exfiltration, and prevent soil erosion.
- 'Fill and drain' systems have a similar function to resin injection techniques, but treat the entire system (including chambers and laterals) in one operation. They are aimed mainly at larger-scale projects.
- Robotic repair systems can undertake a wide range of tasks including the repair of defective junctions. Because the equipment is relatively expensive, continuity of work is generally necessary for commercial viability.
- Mechanical joint sealing is an alternative to cured-in-place systems for gravity pipelines, and may also be used in pressure pipes. Installation is usually very quick.
- Pipe re-rounding is not a stand-alone technique, but may be used as a precursor to many localised repair or full-length renovation methods where the deformation of the host pipe exceeds permissible limits.