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UPGRADING AND REHABILITATION OF SEWERAGE SYSTEM

BY

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ABSTRACT:

The paper reviews the sewer rehabilitation methods currently being used in the country and those practised overseas in the western developed countries. For upgrading the performance of existing sewerage systems both the hydraulic and structural problems need to be considered. The most cost effective rehabilitation solutions will retain as much as practicable of the existing pipework. Various methods for improving performance of drainage systems are discussed. Flow attenuation methods for upgradation of deficient sewer system are favoured as they allow the bulk of the downstream system to be retained. Detention tanks widely used everseas for hydraulic upgradation of sewer system are discussed. Finally, the paper reviews the modern renovation techniques for structural upgrading and renovation of faulty sewers.

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1. INTRODUCTION

For upgrading the performance of the existing sewer systems the hydraulic and structural problems need to be addressed. The structural condition is closely linked with hydraulic performance as frequent surcharging of hydraulically deficient sewer systems exacerbates existing structural weaknesses and promotes collapse. It is necessary to identify the most cost effective engineering solutions to solve both structural and hydraulic problems.

Hydraulic rehabilitation covers replacement, reinforcement, flow reduction or attenuation. Structural rehabilitation includes repair, renovation and renewal. The most cost-effective rehabilitation solutions will retain as much as practicable of the existing pipework, optimising its hydraulic performance and maximising the opportunities for renovation. Such solutions also have the least detrimental impact on the community at large.

Before actual rehabilitation or renovation a complete survey of the physical conditions of the system should be carried out. The methods available for sewer inspection are visual inspection and closed-circuit television (CCTV). With the development of CCTV system it has been made possible to inspect the physical conditions of non man entry size sewers. This has helped in identifying the problems and appropriate solutions based on actual conditions.

The flow attenuation methods are favoured with rehabilitating deficient sewer systems as they allow the bulk downstream system to be retained. Detention tanks are considered as a practical and cost-effective means of upgrading sewer systems with hydraulic problems. Both on-line and off-line tanks, either as tank chambers or tank sewers, are used depending on the location and topography of site.

A number of renovation techniques have been developed. Until recently confidence has been lacking in cheaper and comparatively new renovation options, particularly regarding long term cost effectiveness. The established techniques, which have been used in the UK long enough, include: stabilization, linings and insitu coatings. The most common method for dealing with faulty sewers is the slip-lining technique whereby a new plastic pipe is inserted into the sewer. All work can be carried out with little disruption to the travelled portion of the road and minimum inconvenience to residents or businesses abutting the road way.

2. REHABILITATION

Improvements to the existing systems are generally referred to as 'rehabilitation'. The main type of problems which need to be addressed by rehabilitation fall into the following categories:

i) Public health/folding: Sewers surcharge and storm sewage rises to the surface and causes flooding in basements, streets and properties. The seriousness of the event depends on depth, the class of property and type of effluent.

ii) Structural: the sewer fails as a structure and has to be repaired, renovated, renewed or replaced. There is a close link here with hydraulic performance since frequent surcharging exacerbates existing structural weaknesses, washes out fines, enlarges voids and promotes collapse.

The upgradation of the sewerage system will require that both structural condition and hydraulic performance should be investigated. Regarding the hydraulic aspect it is crucial to be able to:

a) Understand the hydraulic behaviour of the system;
b) assess its existing performance;
c) identify causes of problems.
d) study the effectiveness of various alternative solutions;
e) estimate the costs of the main alternatives, and
f) identify the cost-effective solution(s) and evaluate the overall level of service which it provides.

3. STATUS OF SEWERAGE UPGRADING IN PAKISTAN

Sewerage Systems in recent years have advanced from a condition of "out of sight, out of mind" neglect to objects of concern and investigations. Rehabilitation of old sewerage systems are being undertaken, after studies by Consultants. The studies carried out at various places (2,3) in the country disclosed that the existing sewers over-flowed due to either being overloaded or of small size pipes, which were blocked frequently causing flooding in the streets and environmental contamination. The rehabilitation strategy followed has been replacement of the under size sewers and repair/renovation of the appurtenances such as manholes (4).

In Faisalabad, the old sewerage system was in a poor condition and many sections of the sewer were overloaded causing sewage to overflow the streets at Low Points (5). Stormwater

connections and ingress of stormwater through numerous broken manholes aggravated the situation. The system operations also suffered from blockage, siltation and structural damage etc. After investigations and identification of problems the rehabilitation of the existing sewerage system was carried out to eliminate the nuisance from stagnant ponds and flooded manholes arising from surcharging and overflow. Rehabilitation works included repair of manholes arising from surcharging and overflow. Rehabilitation works inluded repair of manholes and replacement of sewers etc.

Sewerage system in Lahore was introduced in 1937 in some of the most populous parts of the city. These "egg shape" brick sewers with the passage of time have badly choked, whereas the sewage flow from the service areas has incrased manifold. The existing sewers have become inadequate to meet the current demand and need rehabilitation. Necessary steps are being taken by the concerned authorities for investigations/identification of problems and formulation of rehabilitation proposals.

Rehabilitation methods currently being used in the Country are only limited to repairs and replacement. Rehabilitation techniques and materials are needed to be improved. As reported in the literature, various methods are available for improving the hydraulic performance of drainage systems and evolving cost-effective rehabilitation solutions (6). The methods used in overseas for hydraulic upgradation of deficient sewerage systems are discussed below.

4. HYDRAULIC UPGRADING OPTIONS.

The main methods by which the performance of drainage systems can be improved fall into three broad categories:

i) Methods to reduce hydraulic input to the system where feasible;

ii) Methods to attenuate flows by providing storage for the peak flows, either on surface or within the sewerage system (7);

iii) Methods to increase the sewer system flow carrying capacity.

Reduction of the hydraulic inputs is an attempt to tackle the problem at source i.e. prevention rather than cure. Options include separation, diversions and alternative drainage of large impermeable areas. In general the flow reduction methods which control the peak flow to the system by permanent reduction or diversion have no disbenefits to the rest of the sewerage system and enable existing sewers to be retained.

The flow attenuation methods also limit the discharge hydrograph by the temporary storage of part of the flood hydrograph so that the modified peak flow does not exceed the capacity of the downstream system. On-system and off-system, storage tanks are the examples of this technique

and are discussed later. Attenuation is favoured for the reason that it allows the bulk of the downstream system to b retained and generally it is considered to offer the best opportunity for development of a cost-effective integrated solution. (8).

Methods to increase the sewer systems capacity enable it to pass excessive peaks of discharge. The methods usually involve replacement or renewal of the part of the existing sewer system and are consequently expensive.

4.1 Detention Tanks:

They fall into the flow attenuation category of rehabilitation options. In West Germany, there has been considerable upsurge in tank construction and tank philosophy is now widely accepted (9). The function of the on-system detention tanks is to provide storage within the sewerage system, and thereby limit the peak carry-on flow to the capacity of the system downstream.

The benefits are threefold:

i) The alleviation of flooding downstream.

ii) The reduction of polluting load passed to receiving waters (Where tanks are combined with storm overflows)

iii) The improvement of the hydraulic regime for rehabilitated sewers and the lengthening of their structural lives.

This type of solution offers a range of possibilities from large tanks which would store all the flood flow and enable the pipe system to take only the dry weather flow, to no storage at all, but with large pipes able to pass the storm flow peaks without surcharging. Either possibility would be grossly uneconomical and the preferred solution lies in between, the optimum balance between storage and transmission capacity depending on the physical constraints of the catchment, the level of service required and the layout of the system (10).

4.1.1 Hydraulics:

It is important to consider flow attenuation solutions as part of an overall strategy to upgrade a sewer system. When a detention tank is considered, the hydraulic effects both upstream and downstream of the site must be investigated. This necessitates the use of a hydraulic model of the sewer system. The model must be one that can accurately predict flow hydrographs at the given point in the system underboth free flow and surcharged conditions.

4.1.2 Tank Configuration:

The layout of a tank is very site specific. Steeply graded or flat sites, urban or rural environments and existing system layout all have considerable bearing on the configuration of the tank and on the flow control devices considered.

Tanks can be subdivided into on-line and off-line tank chambers or tank sewers.

The two general arrangements of detention tanks are illustrated in Figure 1.

On-line tanks form an integral part of the sewer system consisting of an enlarged flow section that fills when the inflow exceeds the carry-on flow. Discharge from the tank is controlled by a throttle at the downstream end. An emergency weir passes excess flow, either to a water course, surface storage area, on the downstream part of the sewerage system (or possibly an alternative under-loaded sewer).

Off-line tanks are physically separate from the basic system. The flow passes to the tank from an overflow which operates when the capacity of the downstream sewer is exceeded. The flow stored in the tank can be returned to the sewer either by gravity where the site allows or by pumping. An emergency overflow is required to pass the excess flows.

4.1.3 Tank structures:

These can be either tank chambers or tank sewers.

Tank Chambers can be retangular or circular. They are generally constructed as rectangular chambers similar in plan to service reservoirs (Fig:2) with floor slopes between 1:40 and 1:100.

Circular tanks are similar to those used for sedimentation at sewage treatment works and are able to include scum-removal facilities.

The size of tank chambers is virtually unlimited with the main constraints relating to surface conditions and construction restrictions. Tank chambers can be set either on-line or off-line, and their principal advantage is that large volumes may be contained in a relatively small area. The greatest proportion of existing tank chambers in UK and other overseas countries are rectangular.

4.1.4 Tank Sewers:

Tank sewers are essentially oversize sewers designed to retain the excess flows and may be on-line and off-line. They may be constructed in either circular, egg shaped or retangular cross-section with invert channels designed to carry dry weather flows and promote self-cleaning. From structural considerations circular cross-sections are preferred. Typical layout and cross-sections are shown in Fig:3. The nature of tank sewers limits their storage volume, although in highly urbanised areas they can be more easily constructed by tunnelling techniques, and result in least disruption.

The gradients must be adequate to promote self-cleaning, although it may be constrained on long tanks by head restrictions at the throttle. On-line tanks carry flow at all times and therefore, there is a need to ensure self-cleaning velocities at dry weather flows. This can be achieved by providing invert channel designed to carry dry weather flow. The principle of operation of a tank sewer limits the position of the inlet and outlet to the upstream and downstream extremities of the tank respectively.

As a general rule tanks are most effective in the upper reaches of a catchment, as the attenuation effects diminish further down the catchment. It is often more economical and effective to build one or two large tanks than several small ones. The best compromise is to site tanks at the points where large sub-catchments connect into the main sewer. Ideally tanks will be located immediately upstream of inadequate sewer lengths, and the carry-on flow controlled to below the pipe-full capacity of those lengths.

5. SEWER INSPECTION:

The objectives of critical sewer inspection are to collect information on the sewer's appearance from which its structural condition can be assessed. The choice of inspection method is between manual methods and remote methods, generally closed-circuit television (CCTV). Generally in sewers larger than 900 mm manual inspection offers technical advantage over remote methods.

5.1 Television Inspection of Sewers:

The best method for inspecting the inside of small diameter pipes is by closed-circuit television. The technique is usually applied to sewers with size varying from 225 mm to 900 mm. After a sewer line has been cleaned the skid-mounted video camera is pulled through the pipe and a continuous picture is transmitted to a television monitor in the service truck. This technique allows visual inspection and location of structural defects. The video tape can be replayed for further examination and retained for a permanent record. If tapes are reused, photographs can be taken of the video picture as a record of defective conditions in a sewer line.

From CCTV survey the conditions usually observed include:

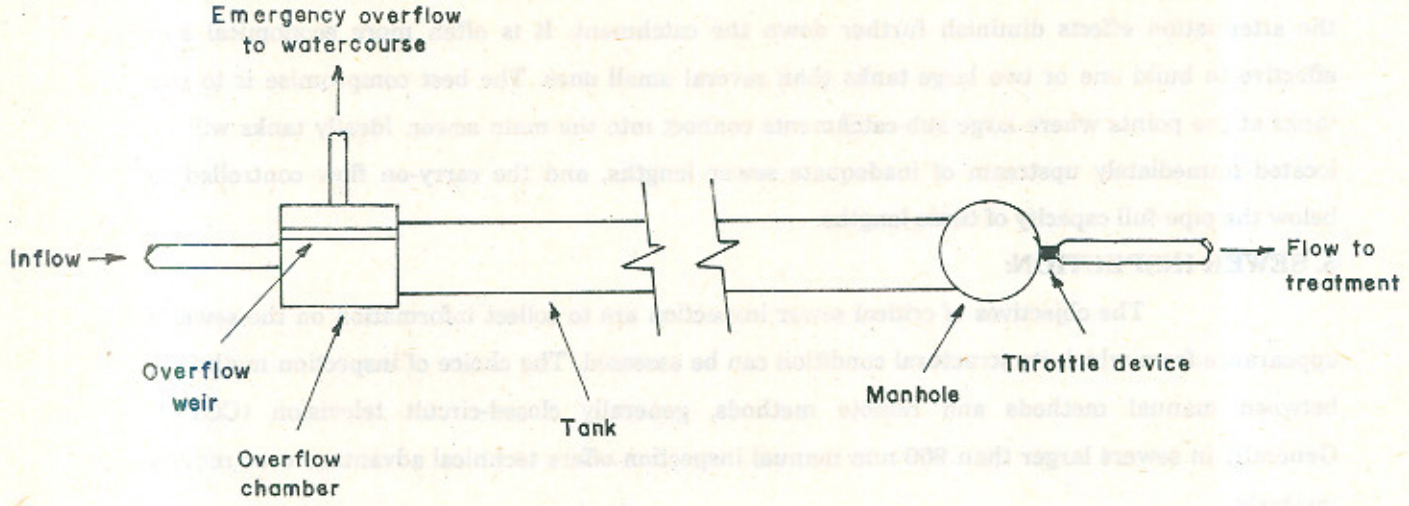
Infiltration/inflow sources, service connections, structural defects such as broken or cracked pipes, deterioration, abnormal joint conditions and any unusual conditions such as root intrusion, protruding pipes, obstructions etc.

6. RENOVATION:

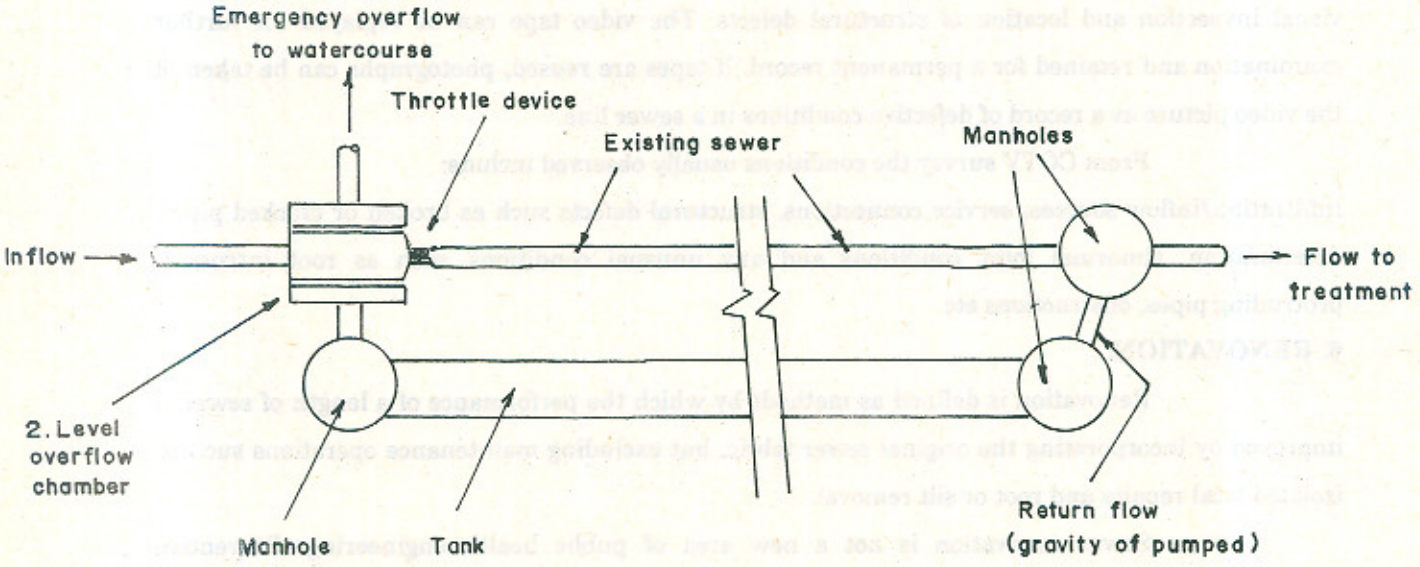
Renovation is defined as methods by which the performance of a length of sewer is improved by incorporating the original sewer fabric, but excluding maintenance operations such as isolated local repairs and root or silt removal.

Sewer renovation is not a new area of public health engineering. Preventive maintenance and renovation in one form or another have been practised from the earliest days of sewer construction. Repointing of sewers certainly used to find more favour than in recent times.

Rapid advances have been made in the state of the art and many new materials and methods developed for sewer renovation. The established renovation techniques, which have been used in UK long enough to highlight problems and have developed to overcome them, are briefly discussed below:



(a) On-line tank



(b) Off-line tank

FIG-1 DETENTION TANKS

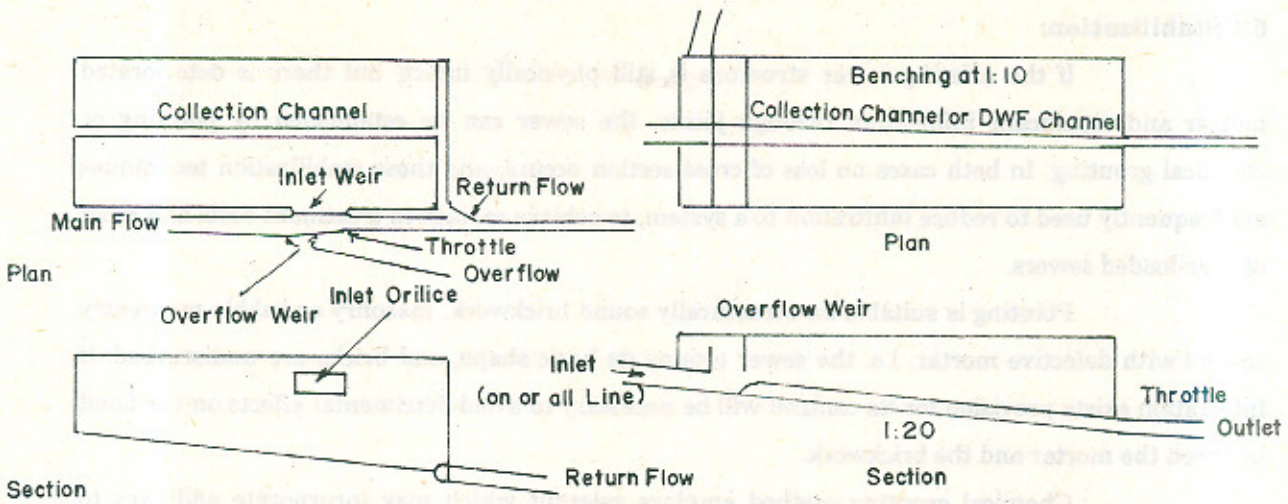


FIG-2 RECTANGULAR TANK CHAMBERS

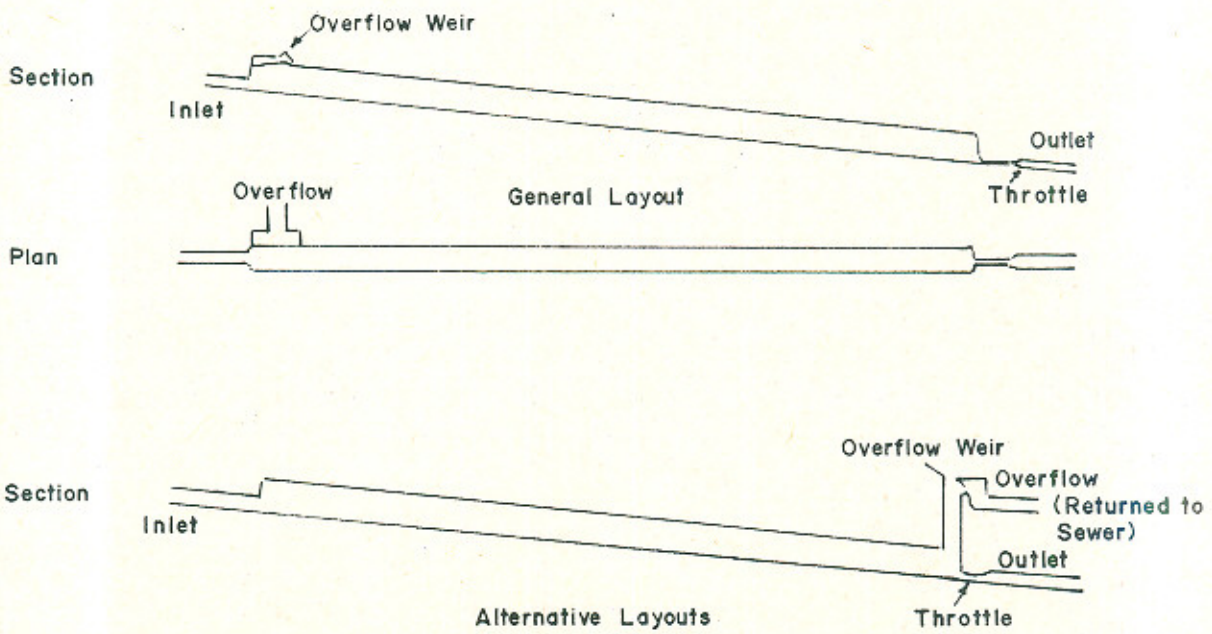


FIG-3 TANK SEWERS (TYPICAL DETAILS)

6.1 Stabilization:

If the existing sewer structure is still physically intact, but there is deteriorated mortar and significant infiltration through joints, the sewer can be established by pointing or chemical grouting. In both cases no loss of cross section occurs, and these stabilization techniques are frequently used to reduce infiltration to a system, to achieve savings in treatment costs and relief of over-loaded sewers.

Pointing is suitable for structurally sound brickwork, masonry or rubble man entry sewers with defective mortar, i.e. the sewer retains its basic shape, and bricks are undisturbed. If infiltration exists provision for its controll will be necessary to avoid detrimental effects on the bond between the mortar and the brickwork.

Chemical grouting method employs gelgrout which may incorporate additives to inhibit root growth. Chemical grouting is applicable to both man entry and non man entry pipe sewers that are of good shape and stable, where infiltration is a problem.

6.2 Lining techniques

The lining methods are used to improve the structural capacity of the sewer, to improve the hydraulic characteristics, to reduce infiltration or to provide an improved abrasion or chemical resistance. The broad categories are : pipe linings and segmental linings (with longitudinal joints). Linings are manufactured from various materials, and can be used for both man entry and non man entry sewers. Some loss of cross sectional area will result, the proportion lost depending on the particular system used.

6.2.1 Pipe Linings:

Pipe linings may be installed inside the sewer in either short or continuous length. Man entry or non man entry sewers may be lined and pipe shape need not necessarily be circular. The following pipelinings are used in the UK.

- Glass Reinforced Plastic (GRP)
- Poly Olefin Pipes.
- The insitu form process

i) Glass Reinforced Plastic (GRP).

GRP is a resin based material reinforced with glass fibre, sand generally being added as an aggregate and filter. An inner resin rich liner is provided to protect the internal fibre reinforcement and provide a high chemical and abrasion resistance. An external finish of coarse sand is normally required to improve the lining/grout bond. GRP pipe linings are used mainly for man entry sewers.

ii) Poly Olefin Pipes.

Sewers may be sliplined with polyolefin pipes. The materials mainly used are polyethylene and poly propylene. Sliplining is a relatively rapid renovation method. The pipes are drawn and/or jacked inside the sewer, subsequently length being added as desired. A none cone is fixed to the leading edge to reduce the likelihood of pipe snagging, and to facilitate attachment of the winch cable. Fig. 4 shows the traditional slip lining technique.

iii) Insituform.

The insituform process was developed specifically for pipe renovation and has been in use in the UK since the early 1970s. The technique involves the insertion of a flexible lining into the sewer, utilising an inversion process (Fig.5). The lining is inserted via existing manholes under pressure of water, and cured by circulating hot water. Insituform utilizes a thermosetting polyester resin which is maintained in position in the sewer by a woven polyester needle felt bag until cured.

Insituform provides a rapid renovation method utilising existing manholes, and linings upto 300 m may be installed in a single insertion depending on the size. Hydraulic capacity is maximised as the lining is usually sized to fit tightly against the existing sewer. The lining can

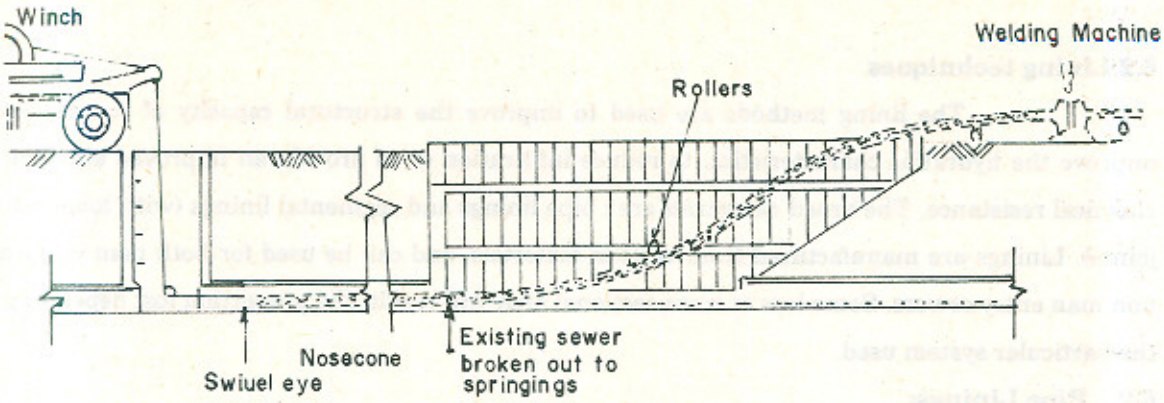


Figure 4 — Traditional sliplining

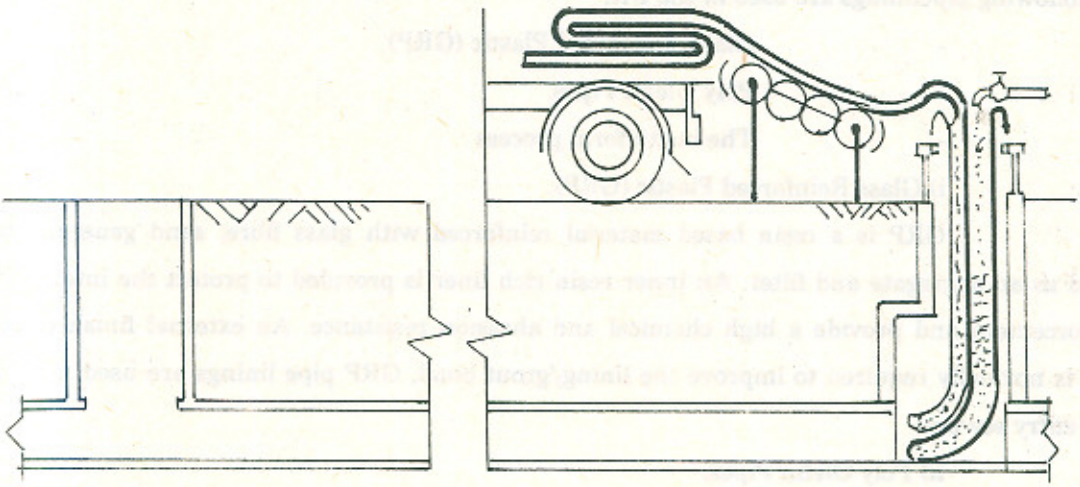
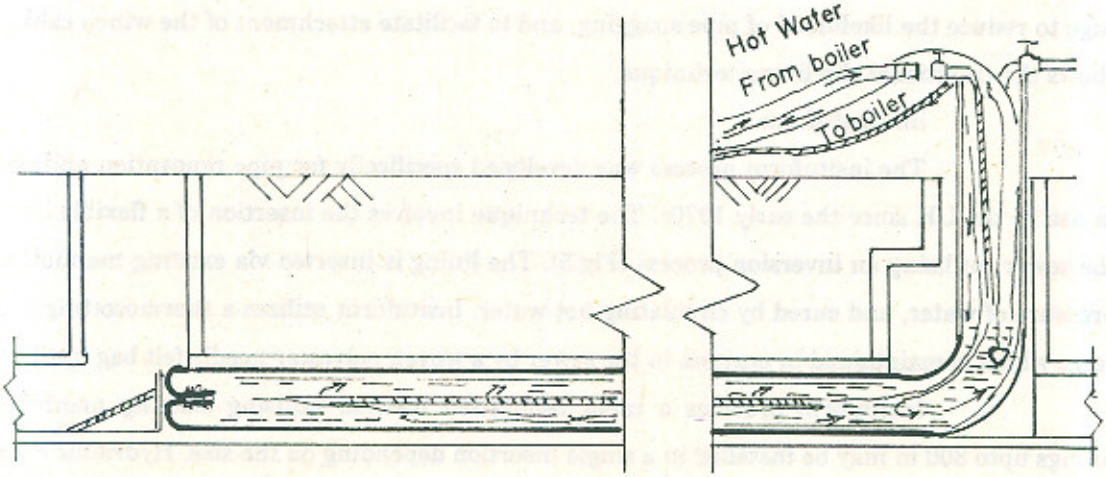


Figure 5 — (a) Commencing insertion



(b) Insertion completed—curing by hot water

Figure 5 — The Insituform system circulation

Source: WRC I

accommodate small deformations and changes in the direction of sewers.

6.2.2. Segmental Linings:

The segmental linings are suitable for man entry sewers and are available in a variety of shapes. From structural consideration the joint location is critical, and normally the joints should not be located at or near the crown. Segments may be installed through the existing manhole chambers with the cover slab removed or via specially constructed access shafts. Segmental lining types used include: Glass reinforced cement, Glass reinforced plastic, precast Gunite, and polyester Resin Concrete.

6.3 Insitu coatings.

The technique may be used to extend the life of an existing sewer by increasing its strength and to protect the existing fabric from corrosion. Hydraulic performance can also be improved by the use of coatings. Precast gunite segments for sewer renovation are basically grade 40 (40 N/mm2) Sprayed concrete using a maximum aggregate size of 10 mm (11). Steel mesh reinforcement is fixed to the existing sewer wall and gunite is applied by a hand spray. The reinforcement should be suitably spaced in the wall to allow full penetration by the gunite. To improve the structural strength the coating thickness or area of steel reinforcement may be increased.

7. SUMMARY

For upgrading the performance of the existing systems the hydraulic problems of a drainage area should be considered in parallel with an assessment of the structural condition of the network. The most cost effective rehabilitation solutions will retain as much as practicable of the existing pipework, optimising its hydraulic performance and maximising the opportunities for structural renovation.

Flow attenuation methods are favoured for hydraulic rehabilitation of sewerage systems as they allow the bulk of the downstream system to be retained. Detention tanks are a practical method of upgrading sewer systems with hydraulic problems. Both on-line and off-line tanks can be used, type of system depending on the location and topography of the site.

Stabilization, linings and insitu coatings are the established techniques for structural upgrading and renovation of faulty sewer systems.

The slip-lining is the most common method as the work can be carried out with little inconvenience to the public.

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