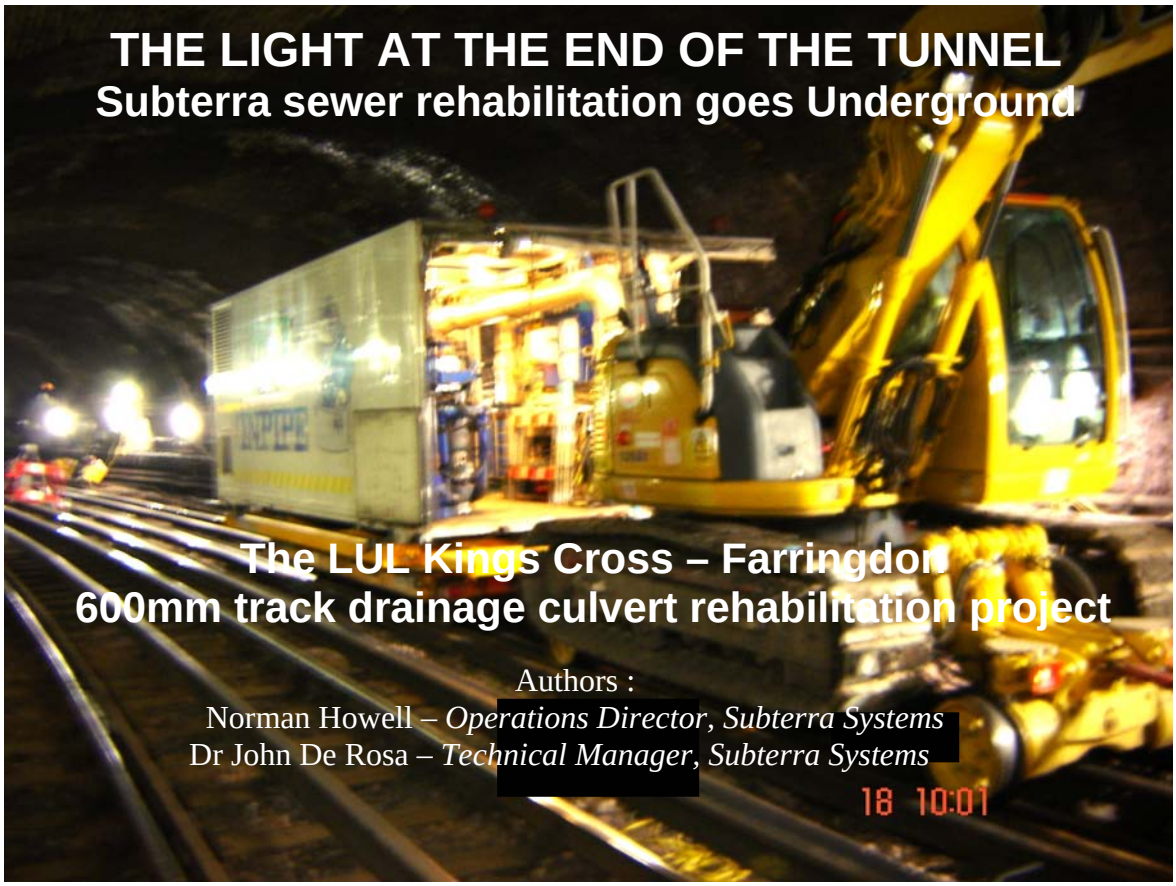

THE LIGHT AT THE END OF THE TUNNEL
Subterra sewer rehabilitation goes Underground

The LUL Kings Cross – Farringdon 600mm track drainage culvert rehabilitation project

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Award Category :	Utility Pipeline Technology

Client :	METRONET
Main Contractor:	Enterprise maintaining the infrastructure of the UK
Specialist Lining Contractor:	Subterra

Synopsis

The London Underground is presently engaged in a major track upgrade programme in order to enable the world-famous mass transport system to meet the demands of the travelling public well into first half of the 21st Century.

Poor track drainage on a section of track between Kings Cross and Farringdon on the Metropolitan Line, and the unsatisfactory structural condition of some 450 metres of 600mm nominal diameter brick culvert laid beneath it, threatened to impair the performance of new track to be laid there, potentially reducing its service life to as little as five years. The present paper describes the successful and innovative use of the Inpipe ultra-violet cured CIPP lining system to restore the structural integrity and functional capability of this culvert within the extremely demanding time constraints imposed by the operational traffic demands of the Underground. Using the Inpipe system and Subterra's expertise is estimated to have saved the client in the region of £30M when compared with conventional open cut replacement methods

Introduction

London Underground (LUL) is presently engaged in a major programme of track upgrades to make the capital's mass transport system fit to operate smoothly for the next 40 years of the new millennium. The track drainage system is an integral part of the track bed. Without drainage, rail track will suffer from wet beds, which in turn can shorten track life from 40 years to as little 5 years before full replacement is needed.

The present project was concerned with the refurbishment of a stretch of drainage culvert between Kings Cross and Farringdon on the Metropolitan Line. This comprised a brick culvert varying in size from 450mm diameter to a 650mm x 600mm oval at depths to invert ranging from 1.8 metres to 2.60 metres.

The running tracks in this area had for some years suffered from wet beds and, as a consequence, had required frequent replacement of the ballast and running rails.

The culvert had been CCTV surveyed and had been found to be in either LUL condition category 'D' or 'E', which relates to grade 4 or 5 in the WRc scheme, thus requiring prompt remedial action in order to restore its structural integrity.

Under the LUL Public-Private Partnership (PPP), Metronet Rail is responsible for maintaining, replacing and upgrading all infrastructure on a number of Underground lines, including the Circle and Metropolitan lines. Four of the Metronet shareholders - Atkins, Balfour Beatty, EDF Energy and Thames Water - have combined to create a dedicated contract management business called Metronet Alliance, which is responsible for the delivery of, amongst other things, LUL's programme of track replacement.

The site

The section of culvert ran from a point just beyond the eastern end of the platform of the King's Cross station for some 450 metres eastwards (clockwise) towards Farringdon (see Figure 1). Catch pits (manholes) were located in the space between the inner and outer roads of the track, which were themselves only separated by some 800mm between adjacent sleeper ends. The catch pits were spaced at intervals of between 9 metres and 35 metres along the culvert giving a total of 16 separate lengths on this section. In places, the culvert itself ran beneath the running tracks, further complicating the problem.

Figure 1 - Location of the project

At a depth of 2.60 metres, and with a maximum available working trench width 800mm, it would not have been possible to excavate and replace the culvert by conventional open cut trenching without completely removing the running track and the ballast bed. To deal with this 450 metre length of culvert conventionally would have required closing this section of railway for some four weeks. It is estimated that LUL would have charged Metronet in the order of £15M - £20M as a compensation for this duration of track closure. In addition the capital cost of the culvert and track bed replacement works have been estimated at some £15M for this length, giving an indicative overall cost of some £100,000 per linear metre.

Figure 2 – View eastwards from platform of disused Kings Cross station (note catch pit between roads in lower left foreground)

Figure 3 – Road overbridge selected for shipping Inpipe container onto track (over parapet on left)

The challenge

The challenges facing the Alliance were therefore

1. to restore the track bed drainage on this section, in order to eliminate wet beds and thereby stabilise the track ballast, and hence the running rails;

2. to ensure the structural stability of the existing brick culvert, so that, once the new track planned for construction on this section had been laid, it would be able to realise its full maximum design life (40 years);

3. to maintain the ability to deal with the input flows from the numerous existing live drainage connections disposed at various points along the length of the existing culvert, and,

4. to carry out these remedial works with the minimum impact on services and the travelling public, and at minimum cost.

In common with other major engineering works on the LUL track, pipeline works are subject to a number of unique constraints. These are principally associated with the need to keep any disruption to LUL traffic services to an absolute minimum, and in particular the hazards associated with track electrification.

Minor works are undertaken during the so-called Engineering Hours when the traction current is switched off (normally between 0100 and 0400 each night). Any works carried out during this extremely short time window have to be fully completed, or at the very least returned to an

acceptable, secure condition that permits the safe running of the trains. An additional requirement is that all equipment must be broken down into 25kg man-portable units, as there is no powered access to track level (lifts, escalators) during this period.

For major engineering works that cannot practically be carried out in one or more of the Engineering Hours periods potentially available each night, the only alternative is to stop the trains running on the section of line concerned. Such stoppages are referred to as Possessions, which are typically scheduled over the weekend. The longer duration of Possessions introduces the potential for using heavy engineering plant that cannot be mobilised in the short nightly Engineering Hours interval. However, once granted by LUL, Possessions cannot be rescheduled, which places great emphasis on the need for meticulous planning and thorough preparation of project work.

The solution

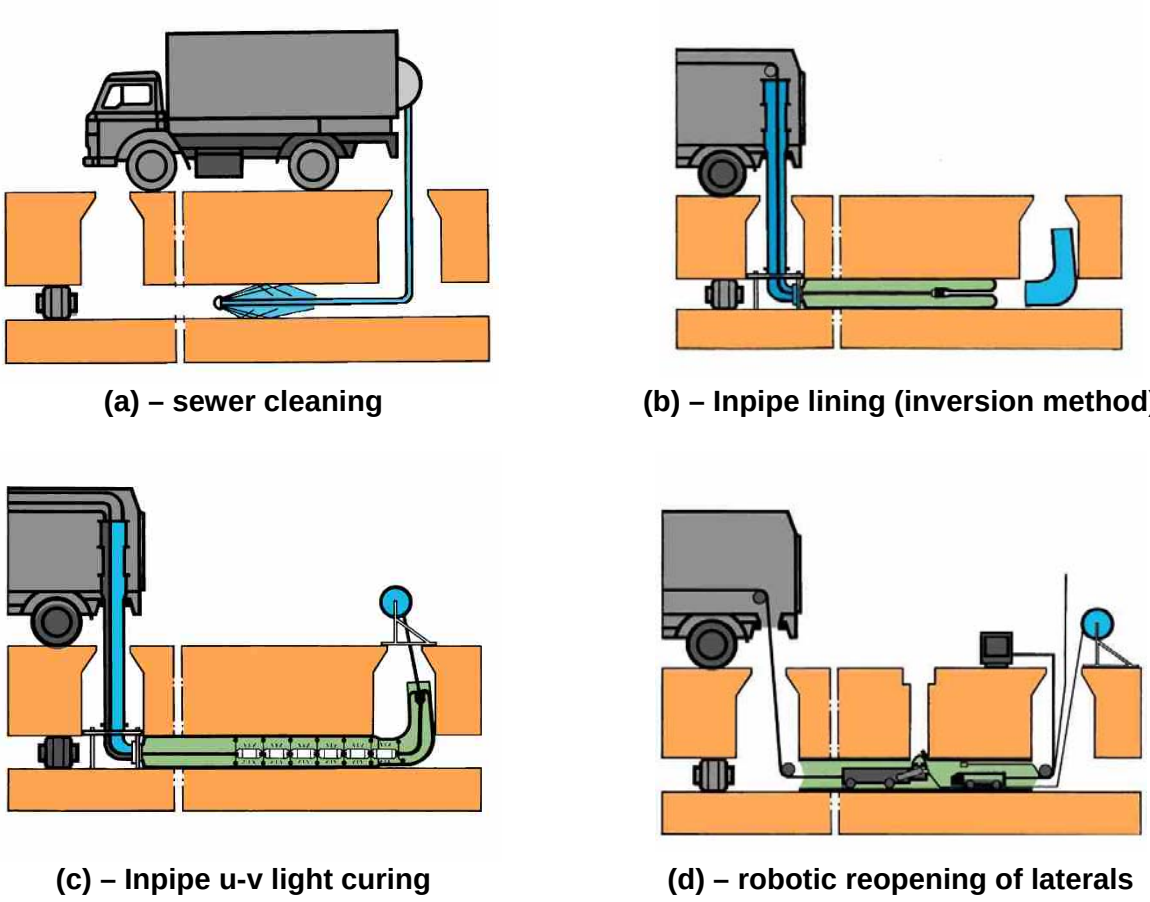
The section of track requiring remediation had originally been constructed in cutting, with retaining walls built on either side. The section closest to Kings Cross station had been covered over with a brick arch to form a tunnel. It quickly became obvious to the Metronet Alliance Engineering Team that complete removal of the track ballast and relaying of the culvert would have involved digging down to below the level of the retaining wall foundations. In order to do this safely would have required substantial additional civils works to underpin and stabilise the walls and dependent structures, and therefore had to be considered only as a solution of last resort.

Owing to the size of the culvert (650mm maximum dimension), solutions involving man-entry techniques were automatically disqualified. Conventional sliplining and modified close-fit lining processes using polyethylene (PE) pipe were ruled on the basis of the long insertion trenches required, for the same reasons that had disqualified the open cut trenching option. Conventional cured-in-place pipe (CIPP) lining systems were also discounted, ambient curing systems on the grounds of the large sewer sizes involved, and heat-cured felt-and-resin inversion systems on the grounds of the limited out-of-service intervals available for installation; the restricted space available for scaffold towers for liner inversion; and the problems associated with the disposal of contaminated heating water generated in the curing of such liners.

As part of these investigations, Metronet Alliance approached Subterra, who are an operating division of their affiliate contractor, Enterprise plc, to help identify potential solutions for this problem.

Subterra proposed the use of Inpipe, which is an innovative u-v light cured CIPP lining system. Subterra is the UK licensee for the Inpipe technology. The Inpipe liner comprises a glass fibre mat reinforcement, which is impregnated with a resin containing a special u-v initiator, sandwiched between two styrene-resistant containment foils. At the installation site, the soft sock is either inverted or towed into the existing pipeline, inflated to a tight fit using low pressure (0.5 bar) compressed air, and is then cured by drawing a train of u-v lights along its whole length at a specified, controlled speed to ensure that full curing of the liner occurs. The result is a new, tight-fitting, glass fibre reinforced pipe inside the existing pipeline that is designed to resist the combined external hydrostatic pressure head and surcharge/trafficking loads. The liner ends are then trimmed and any laterals reopened using a robotic cutter.

The key advantages of the Inpipe system include, in particular, the high production rates that can be achieved thanks to the rapid curing process; the elimination of risks associated with contact with the uncured resin and the minimum styrene emissions, both achieved thanks to the inner and outer liner product containment foils; and the absence of large volumes of contaminated water for discharge that are generated in other CIPP lining processes.



(a) – sewer cleaning

(b) – Inpipe lining (inversion method)

(c) – Inpipe u-v light curing

(d) – robotic reopening of laterals

Figure 4 – Inpipe lining process (schematic)

Implementation

A joint Metronet Alliance/Enterprise/Subterra team was established first to assess the feasibility of using the Inpipe technology in this environment, and subsequently to plan in detail, and then execute, the culvert lining project over a series of three weekend Possessions.

In concept, the initial idea was to make use of an existing, truck-mounted Inpipe lining unit by detaching it from its road vehicle and lifting the unit onto flat bed rail wagons. The Inpipe unit could then be positioned alongside convenient catch pits to carry out the lining work conventionally.

Owing to the complex rules surrounding the operation of Possessions, it was not possible to load the Inpipe unit onto railcars at a convenient siding yard and then transport it to the work site. The only potential solution to this problem was to lift the unit from a convenient roadside location onto the tracks using a mobile crane. A suitable solution was devised, which provided the impetus to proceed.

The culvert lengths were CCTV inspected by Enterprise and, based on these results, other teams undertook the preliminary cleaning of the culvert lengths in anticipation of the lining works.

In the meantime, Subterra adapted an existing, truck-mounted Inpipe installation unit operated by one of its sister Inpipe licensees (USSR, Eire), so that it could be lifted from its normal road unit onto suitable LUL flatbed railcars.

Figure 5 – Night shipping of Inpipe equipment container from overbridge to track

Figure 6 – Inpipe equipment container loaded onto roadrailer flatcar

Prior to commencing the works, all of the specialist equipment that was to be used for the Inpipe liner installation had first to be approved for use on LUL's network in close collaboration with Metronet's own safety advisors. This included not only the Inpipe liner installation equipment itself, but also Subterra's hydraulically powered robot cutter, and the powered Tirfor winches that were to be used for pulling the liners into position. In addition, all of the team involved in carrying out the liner installation had to be fully trained and certificated to work on LUL's track. Full site procedures for each of the key lining stages were also prepared and approved by Metronet prior to commencement of the works.

During Possessions, all passenger operations on the section affected were suspended, and the track current switched off. Mobilisation onto the tracks took place typically some time after 0200 hrs on Saturday morning, with demobilisation being essentially complete by 2000 hrs on Sunday evening. During this interval, work ran around the clock, albeit with crews being strictly limited to a 12-hour shift, with no individual allowed to return for 11 hours minimum.

Figure 7 – unloading Inpipe product crate at point of use

Figure 8 – Inpipe liner insertion

The Inpipe liners themselves were of the "winch-in-place" type, and were supplied with an additional opaque black external sheathing that permitted handling in full sunlight without the risk of premature cure initiation. In order to allow for any variations in the internal circumference of the

brick barrel culvert sections, the Inpipe liners were all designed to cope with a range of nominal host pipe diameters. The liners manufactured for the 650m x 600mm brick barrel culvert were suitable for lining pipe diameters ranging from 595mmto 716mm, whilst those for the 450mm nominal diameter sections could cope with host pipe bores ranging from 447mm to 538mm. The corresponding nominal wall thicknesses of these liners were 10.2mm and 7.4 mm respectively.

Figure 9 – Tirfor winch and boom arrangement

Figure 10 – Inpipe unit positioned for liner curing

A total of 370 metres of Inpipe liner was installed in seven separate installations during the course of the three available weekend Possessions. The maximum liner length installed in a single pull was 70 metres, which had a weight of 2.7 tonnes, with three others being in excess of 60 metres.

Figure 11 – Inpipe liner inflated and curing in progress

Figure 12 – hydraulically-powered cutter unit on rail flatcar

Figure 10 – cutter robot

Conclusions

The client has expressed his delight at the results obtained, and was particularly pleased with the exceptional rate of production achieved during these three Possessions.

Disruption to the London Underground system caused by these necessary track drainage rehabilitation works was minimised by adopting the fast-curing Inpipe CIPP lining process. This permitted the required liner installations to be carried out during the course of three planned possessions of short duration, in conjunction with other essential maintenance works.

Based on an average cost of weekend Possessions of £500,000, at £1.5M, the total charge for occupying the track in order to carry out these works using the Inpipe system was a mere 10% of what Metronet would have been charged, if they had had to resort to a conventional open cut excavation and relay solution.

When the costs of the open cut works themselves, plus those that would have been incurred in stabilising the retaining walls on this section of track are also taken into account, it has been conservatively estimated that the use of this innovative approach saved LUL in the order of £30M.