HASTINGS BRICK ARCH SEWER REHABILITATION

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ABSTRACT

A brick arch sewer (circa 1890) which also conveyed ground water was programmed for renewal by Hastings District Council (HDC) in 2012 with a 600mmØ RC pipe. During the investigation and planning phase MWH identified that renewal with the 600mmØ RC pipe was a high risk- high cost option. Following this MWH proceeded to investigate alternative options that would still meet HDC's requirements.

This paper describes the investigation and planning phase, optioneering, risk analysis and early involvement with specialist pipe rehabilitation contractors which resulted in an alternative approach. This approach resulted in the trunk main itself being rehabilitated using Cured in Place Pipe (CIPP) liner.

The four well beings, economic, social, cultural and environmental were all taken specifically into consideration and were incorporated in to the contract document as key performance indicators. The total cost to complete the project was well below budget. All risks identified in the planning phase were either mitigated or minimised throughout the project. Disruption to the public and a number of large industries in the area was minimal and well managed. Ultimately this alternative approach was a success in every respect and met all of HDCs expectations and requirements.

KEYWORDS

Brick Arch, CIPP, Trenchless, Sewer Rehabilitation

1 INTRODUCTION

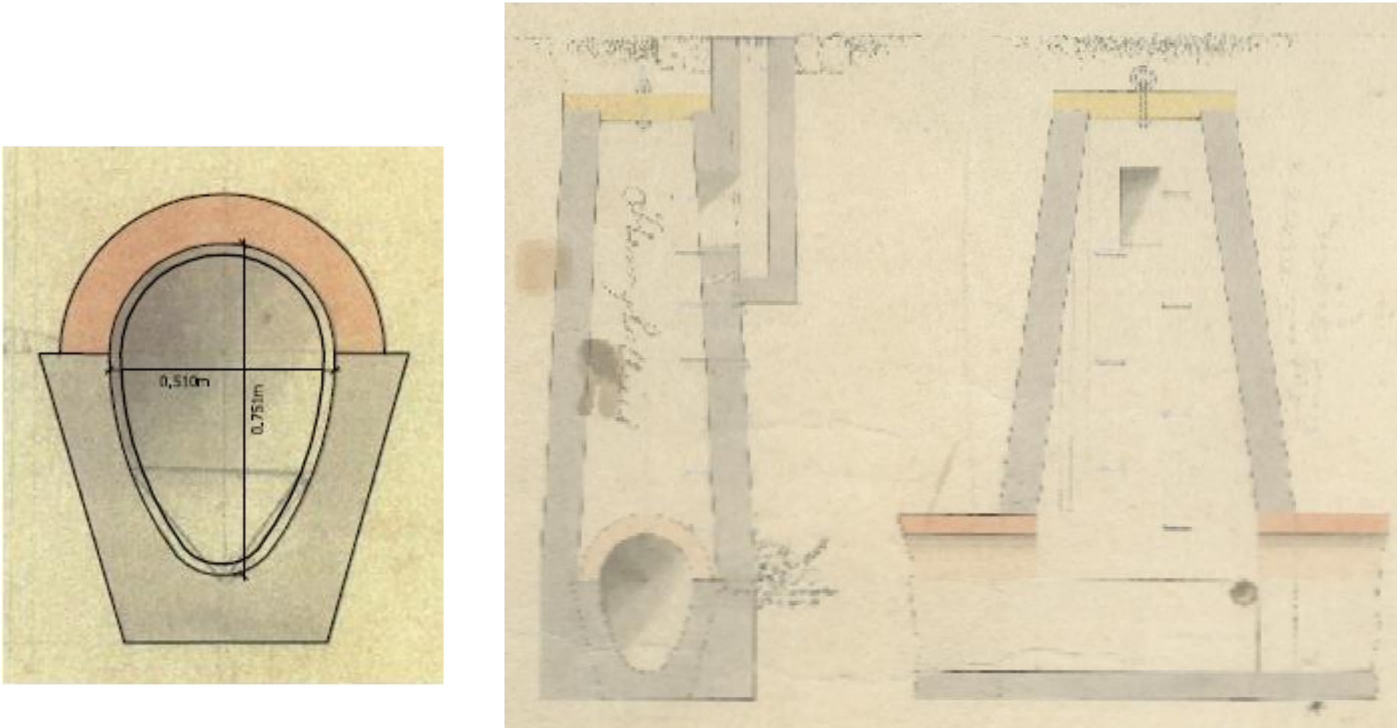
Hastings District Council engaged MWH to undertake the design, contract and construction monitoring for the rehabilitation of 1,500 metres of brick arch sewer in Hastings. This paper describes the risk analysis approach adopted which resulted in a change in thinking and rehabilitation methodology. The wider planning and investigation undertaken ensured the four well beings, economic, social, cultural and environmental impacts were all taken specifically into consideration and managed throughout the duration of the project. Technical details of the design, construction and installation of CIPP are discussed. Through good planning, careful consideration of relatively new pipe rehabilitation technology and an experienced contracting team, HDC now have a successful solution using a high quality product, within a timeframe shorter than anticipated and at a cost significantly less than initially budgeted.

2 HISTORY OF THE BRICK ARCH

The Hastings Brick Arch sewer was one of the first pipelines constructed in the Hastings District. The 760mm x 508mm (30 inch X 20 inch) brick arch was constructed by hand between 1889 and 1892. The Brick Arch was constructed using cast in-situ concrete laid by hand to form the u-shaped base and a double layer of red bricks and mortar to form the double layered arch. Originally the Brick Arch was positioned in the centre of the dirt lane that passed through the centre of Hastings, the arch had inlets positioned at each manhole to provide drainage of the road and various access points for residents to empty their household waste and chamber pots.

Over the following years the dirt road was progressively raised and resurfaced. This resulted in the adjustment of manhole lid levels and the loss of direct access to the Brick Arch for the collection of stormwater and access points for residents to discharge waste. To address this, lateral connections from properties were laid and connected directly to the Brick Arch.

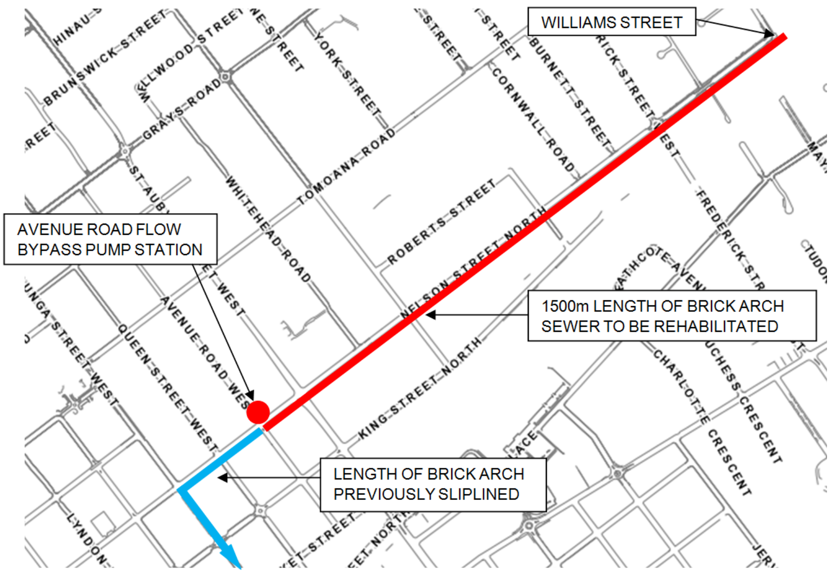
Figure 1: Original Brick Arch Pipeline and Manhole Drawings



As Hastings grew and developed the Brick Arch was divided into two defined sections. A 550 metre length on Heretaunga Street, from Karamu Road to Nelson Street which then turns ninety degrees into Nelson Street and extends another 1,750 metres to Williams Street, on the urban Hastings boundary.

In 1992 a section of the Hastings central business district was reconstructed. As part of this reconstruction the 800 metre upstream section of the Brick Arch was identified for rehabilitation. As this was the top of the Brick Arch sewer the existing cross sectional area was not required. Five PE pipes were inserted into the Brick Arch, a 450mm diameter pipe to convey sewage, two 200mm diameter pipes to convey ground water from the CBD area and two 100mm diameter pipes to provide ducts for various purposes. Both the sewerage and ground water slipline pipes discharge into the existing Brick Arch downstream at the Avenue Road West intersection.

Figure 2: Locality Map



3 THE PROBLEM

In 2010 the remaining 1,500 metre downstream section of the brick arch sewer on Nelson Street from Avenue Road West to Williams Street was identified by Hastings District Council for renewal. The need for renewal was based on the following factors:

- Asset age
- Ground water infiltration
- Loss of mortar between bricks
- Increase in maintenance intervention including repair of areas of collapsed Brick Arch
- Significant buildup of debris in the invert

Hastings District Council engaged MWH to provide construction drawings and a contract document for the renewal of the brick arch using a traditional open cut method. This method of reconstruction would have included the removal of the Brick Arch and the installation of 600mm diameter reinforced concrete pipes.

4 RISK ANALYSIS

An initial desk top study and site investigation was undertaken to understand the construction of the existing Brick Arch, ground conditions, and site constraints.

Following this initial assessment of the project, concerns were raised around a number of risks that would be associated with undertaking a traditional open cut renewal. A simple but effective risk analysis was completed. The relative risk of various components of the project was calculated using the standard MWH project risk assessment method including the following formula:

Relative Risk = Likelihood x Consequence x Mitigation

The likelihood, consequence and mitigation measures available are each assigned a rating on a sliding scale from 0.1 to 1.

i.e. Under the likelihood category. Highly Unlikely = 0.1 and Will Happen = 1, with an additional three categories in between.

The key risks identified are tabulated below:

Table 1: Summary of Open Cut Renewal Risks

Disruption to a Major Arterial Intersection	Insufficient Capacity of Bypass System	Trench Collapse
Disruption and Cost Implications on Major Industry	Disruption and Damage to other Major Services	Ground Water
Major Disruption to Large Number of Residents	Unsuitable Backfill Material	Poor Ground Conditions
Disruption to High Amenity Character Area	Mass Concrete surrounding the arch and manholes	Trench Dewatering
Major Traffic Detours and Road Closures	Working at Depth	Contaminated Ground Water
Construction Time Frame	Pipe Gradient	Cost

5 OPTIONS ASSESSMENT

Following the risk analysis Hastings District Council agreed the risks associated with the traditional open cut renewal method were unacceptably high. This resulted in the assessment of alternative rehabilitation methods. A number of alternative options were assessed as discussed in Sections 5.1 to 5.6.

5.1 SLIPLINE PIPE

Unlike the upstream section a slipline pipe was not deemed an appropriate method of rehabilitation. The minimum cross sectional area required to convey design flow for the next 50 years, is no more than a 15% reduction on the existing cross-section. In addition to this there were concerns around the ability to suitably grout the annulus of the slipline pipe. This lack of grouting is an existing risk with the upstream section, as it was not grouted and should the existing brick arch catastrophically fail, the slipline will have no surrounding support. This would result in a partially defermed pipe if not a total collapse of the slipline.

5.2 SPIRAL WOUND LINER

Although the spiral wound liner met the cross sectional area criteria, and was able to be installed during low flows without the requirement for full bypass, it is only suitable for the rehabilitation of circular pipelines.

5.3 DIRECTIONAL DRILLING

Directional drilling was deemed unsuitable for this application. This was due to the limitations around the size of the pipeline required and the very flat grades available. Significant concerns were also raised regarding variances in ground conditions and the proximity of an old gravel stream bed.

5.4 MICRO-TUNNELING

Micro-tunneling was considered a viable renewal method parallel to the existing brick arch. This construction methodology also had the advantage of maintaining flows through the brick arch during construction. General enquires were made into the micro-tunneling equipment available within New Zealand and the associated cost. Due to the significant cost implications micro-tunneling was considered a second choice and would only be further investigated if bypass of live flows proved to be impractical, high risk and unacceptably expensive.

5.5 PIPE BURSTING

Pipe bursting was assessed but was discounted as the bursting head will take the path of least resistance. In this instance the bursting head would likely burst the brick arch and leave the insitu concrete base in place. This would create issues with the existing concrete channel point loading the proposed pipeline and leave a void below the invert.

5.6 CURED IN PLACE PIPE (CIPP)

When initially assessed the CIPP rehabilitation method appeared to meet all of the project requirements. These requirements included:

- A relatively thin walled liner that would not reduce the cross sectional area of the existing brick arch by more than 15%, therefore meeting the future capacity requirements.
- A liner that was able to be custom made and flexible enough to fit snugly against the existing brick arch with its varying profile.
- A fully structural liner that was both self-supporting and of external loads, therefore not reliant on the full integrity of the surrounding brick arch.

As the CIPP rehabilitation method appeared to be the preferred option going forward a risk analysis was completed as per the open cut option previously undertaken. The risks associated with open cut still remained however were identified as best managed or mitigated using the CIPP liner rehabilitation method.

6 PLANNING AND INVESTIGATION

Following the options assessment HDC agreed that CIPP rehabilitation of the brick arch was the preferred rehabilitation method. To ensure we could mitigate and manage the risks associated with the CIPP rehabilitation method a number of investigations were undertaken. Following these investigations information gathered was included in the tender document or physical works were carried out prior to lining as discussed in sections 6.1 to 6.7 below.

6.1 GROUND CONDITIONS AND GROUND WATER

To understand the risk associated with the ground water table and ground conditions, site investigations were undertaken. Bore holes were drilled and piezometers installed at three locations along the brick arch to give an indication of the ground conditions and ground water level. The bore logs indicated different profiles at the three locations. The ground conditions varied between sand and silts with areas of silty clays and gravels. Ground water levels ranged from 1.7 metres at Avenue Road West to 3.7 metres at the Frederick Street intersection (measured from the surface) during the summer months.

This information confirmed any excavations undertaken would be easy digging however there would be risk of running silts and sands and dewatering requirements in some areas.

The piezometers provided on-going monitoring of the ground water levels in the area. This on-going monitoring indicated a difference in the ground water table between the winter and summer months of up to one metre. This information was taken into consideration when determining the timing of the physical works.

6.2 LIAISON WITH KEY INDUSTRIES

A number of key industries in Hawkes Bay use or are located on or adjacent to Nelson Street and include Heinz-Watties and ENZA foods. These industries contribute significantly to the Hawkes Bay economy; due to this, the directive from HDC was that we were not to disrupt these businesses in any way that would have a detrimental financial impact.

Meetings were held with each of the key companies in the area to explain what is required to rehabilitate the brick arch and to better understand how this could detrimentally impact on business. The key issue identified was the large number of heavy vehicles entering and exiting these industries via Nelson Street and intersecting roads particularly during the peak processing season. The option of detour for these vehicles was not acceptable due to the financial and time implications. This meant that the construction methodology and traffic management would need to account for the large number of heavy vehicles on this road and proactively manage the construction works to ensure business was not disrupted. Throughout the duration of the contract the lines of communication with these businesses stayed open ensuring a no surprises environment.

6.3 TRAFFIC CONSIDERATIONS

The brick arch extends the length of Nelson Street and passes through 10 (ten) intersections, including major intersections at St Aubyn Street and Frederick Street. Traffic volumes for Nelson Street and major associated intersections range from 6,500 to 16,500 vehicles per day many of which are heavy vehicles servicing the surrounding industries. Detailed diagrams of the major intersections, bus routes and road use were produced to assist the contractor in providing appropriate traffic management.

6.4 MANHOLE RENEWAL

As builts were consulted to provide details of the existing manholes that would require renewal. The as builts indicated the manholes constructed along the brick arch were cast insitu or precast concrete of varying size and shape. Many of the original manholes had small openings at the surface that then widened out to larger square or rectangular chambers at the base.

Prior to the contract commencing a manhole was deconstructed as a trial. The trial was to ensure the manholes could be safely and practically removed. The trial was successful and the contract proceeding with the inclusion of all 22 manholes for removal.

Photograph 1: Deconstruction of original brick arch manholes

6.5 CONSTRUCTION OF SEWER RIDERMAINS

Sewer laterals were identified as a major risk associated with this project. Rather than further complicate the CIPP rehabilitation contract a decision was made during the planning phase to construct sewer rider mains ahead of the brick arch rehabilitation. The construction of sewer rider mains was consistent with HDC's policy to remove all direct connections to trunk sewer mains. In doing so it simplified the operation of the brick arch and reduced the risk associated with lateral failure within the road, at significant depth.

The construction of the rider mains also removed the risk associated with identifying laterals and cutting open the liner to accommodate the lateral. This process would have extented the duration of the contract and required the continuous liner to be cut open at multiple locations. Although there are 'top hat' liner products available that form a sealed joint at the trunk sewer, there was limited confidence amongst the project team as to the integrity and water tightness of the existing lateral connections many of which were earthenware.

Each of the sewer rider mains were constructed to intercept lateral connections entered at manholes. This design ensured the only connections into the brick arch were within manholes, providing a high level of confidence in the contractors ability to achieve complete water tightness of the liner. Detailed visual inspections were undertaken at each manhole and any sealing requirements were able to be undertaken by hand.

6.6 FLOW BYPASS

Flow bypass was identified as one of the largest risk associated with CIPP rehabilitation of the brick arch. The most significant inflow came from the brick arch upstream of Avenue Road West, which includes additional inflow from ground water. The ground water flow within the brick arch was identified as needing to be removed from the wastewater stream. This was required to ensure the rehabilitated brick arch has suitable capacity for at least the next 50 years, and to reduce the volume of flow entering the wastewater treatment plant. Based on these needs the decision was made to install a ground water pump station, which diverted the ground water to the storm water system. This pump station was designed to initially divert and pump both the ground water and waste water streams at a rate of approximately 70l/s into the nearby Western Interceptor trunk sewer. This provided assistance in the bypass of flows required as part of the CIPP installation, and was designed with the ability to then be isolated and retrofitted for just ground water diversion.

The pump station was operational prior to the flow diversion being required as part of the rehabilitation. During this time the pump station did experience a mechanical failure. Due to the criticality of the bypass pump station continuously operating, additional emergency pumping capacity at the Avenue Road pump station was installed for the duration of the CIPP rehabilitation in case of another failure. This pump was a diesel powered pump capable of pumping approximately 68l/s.

The remaining flow diversion required for the CIPP rehabilitation was managed using two simple methodologies.

- Over-pumping by suction truck was utilised for collection of localised flows where no alternative network was available. This included the various rider mains installed along Nelson Street. Flows within these sections were minimal and generally did not have more than ten (10) residential connections.

- Due to the grid like sewer network throughout much of Hastings bifurcation manholes were utilised by plugging the usual outlets. The small number of connections between the brick arch and bifurcation manholes were picked up using suction trucks.

Although the flows required to be removed by suction truck were relatively small careful planning was required. There were a large number of locations that required continuous monitoring and the continuous rotation of two suction trunks to ensure no overflows occurred and the sewer network was operational at all times.

6.7 ASSESSMENT OF CCTV

CCTV was undertaken to gain an understanding of the condition of the brick arch and identify any major defects in the form of protrusions or holes within the brick arch.

Two types of defects were identified that may have resulted in small inherent defects. No action was required to remedy these defects and the potential for minor inherent defects within the liner had to be accepted.

- Circumferential cracking may result in a small inherent defect within the liner.
- Small holes were identified at a number of locations along the brick arch. These holes were smooth edged and relatively small and the liner easily bridged the holes.

Four other types of defects were identified that would require remedial work:

- One location on the brick arch had a significantly damaged invert. To minimise the extent of the likely defect inherent to the liner passing over the break, a rapid setting grout was used to fill the break to form a temporary base sufficient for the liner to cure against.
- Displaced bricks were removed remotely prior to lining.
- Protruding laterals were removed remotely prior to lining.
- Protruding rebar was removed remotely prior to lining.

7 EARLY CONTRACTOR INVOLVEMENT

Following the planning and investigation phase where the known risks and constraints were identified, investigated and plans put in place to minimize or mitigate, it was identified early contractor involvement was necessary to understand the more specific constraints and risks associated with CIPP rehabilitation before proceeding to full design and tender

Three specialist lining contractors within New Zealand were identified as capable of undertaking the construction works. These contractors were invited to participate in a workshop to discuss the project. There were four key purposes for the workshop:

a. Carry out a site visit and explain the scope of works and desired outcome
b. Explain the risks and constraints previously identified as part of the investigation phase
c. Discuss and understand any limitations or constraints the contractors may have
d. Understand the risks specifically associated with CIPP and how they could be proactively managed and minimised

The key outcomes of the early contractor involvement included:

a. The shape and size of the existing manholes where not suitable for inversion.
b. The specialist lining contractors would use local civil contractors to undertake reconstruction on the manholes and any other general civil works required.
c. The contractors had a high level of confidence in their ability to fully clean the arch with minimal risk to the brick structure by using jetting units with directional control.
d. A pre-liner was not required to protect the liner against ground water infiltration. Pre-liners are only required when ground water infiltration is so significant it creates a continuous curtain of water. Or to prevent the migration of resin into the surrounding ground causing contamination in particularly sensitive ecological areas.
e. The defects including circumferential cracking, holes and protrusions identified by CCTV could be remediated without man entry or were small enough the liner would not be detrimentally affected.
f. The contractors explained and showed examples of potential imperfections that may be present in the finished product to ensure we did not have unreasonable expectations. These imperfections were predominately the formation of wrinkles or worst case scenario fins.

Photograph 2: Example of a minor wrinkle, major wrinkle and a major fin from other CIPP projects

g. Various types of liners and resins are available.
h. There are generally 8-12 week lead times on liner materials as they are not produced in New Zealand.
i. The liners are cured using heat as a catalyst. Various heat sources are used – hot water, steam and ultra violet lamps.
j. There are risks with the use of various chemicals within the resin used to impregnate the liner tube. Material safety data sheets are provided and the risks are minimised through stringent procedures covering the safe transportation and handling of the resin. Good ventilation of the site is required to minimize the inhalation of potentially harmful chemicals.
k. During curing the liner can leach very small quantities of styrene which in larger doses is harmful and in some cases deadly to aquatic life and many microorganisms.

8 PREFORMANCE BASED CONTRACT

The contract document was performance based which defined the performance parameters required but to not process to reach the outcome required. Due the nature of the proposed works, with multiple risks and constraints being identified and the various propriety liner materials and resins available, the contract included contractor design elements including the flow bypass and liner design

The objective of the contract was to rehabilitate the existing brick arch sewer via CIPP liner, to ensure a watertight conduit whilst maximising its current cross sectional (thus maximising capacity), whilst meeting the specification and all quality standards within the contract.

. Rather, a number of constraints and key performance indicators where outlined.

The contract works were required to be undertaken in a manner to ensure minimal disruption to the community including all residents, road users and businesses in the vicinity of the construction works. Tenderers were required to demonstrate how the wellbeing of the community is to be protected during the construction works. Community wellbeing was defined as including the following:

- Social/cultural, impact on the community, public risk, community networks and level of service.
- Environmental, dust, noise, vibrations and contamination.
- Economic, cost to road users, detours, Watties/ENZA processing seasons and demand and damage to roads not generally used by these industries.

Key performance indicators were included in the document, those that relate to the key objective community well-being are listed below:

- The brick arch sewer is a non-man entry pipe. Therefore, all internal pipe repairs/alterations will require robotic/remote entry and repair.
- The tenderer must demonstrate that the styrene content of the curing water will not have a detrimental effect on the Hastings District Council waste water treatment plant at East Clive, which consists of 2 (two) biological trickling filters. If this is unachievable, the tenderer must arrange alternative means of disposing the curing water, i.e. tanker out.
- Open cut construction and/or launch and receive locations within the St Aubyn Street and Frederick Street intersections will not be permitted, except for manhole reconstruction.
- Due to the depth of the brick arch, existing ground conditions, high water table and presence of adjacent services, suitable shoring is required. It was noted that there are numerous services crossing the brick arch which may require support during any excavation works.
- Two-way traffic (two live traffic lanes) in Nelson Street North, Frederick Street and St Aubyn Street must be maintained throughout the construction period. Construction may not be undertaken along the Heinz Watties transport routes between February 2011 and April 2011
- Pedestrian and vehicle access outside of the Rudolf Steiner School must be maintained; alternatively, construction work should be undertaken during school holidays.
- Dewatering will be required in areas of open cut excavation. Due to possible contamination of the ground water, any ground water must be discharged to an approved location within the sewage network or removed from site and disposed of at the waste water treatment plant. If the contractor can prove that the ground water is not contaminated, filtered clean water may be discharged to the storm water system as approved by Hastings District Council.
- Bypass/over pumping of affected live sewers to be effectively managed as per the specification.
- Noise during the construction works must not exceed the Hastings District Council limit of 40 dBA at property boundaries. All equipment used on site must incorporate best practice regarding noise attenuation. Typical noise readings for the equipment to be used on site shall be included in the contractors tender submission. These measurements must be in terms of dBA L10 and Dba Lmax.

9 PHYSICAL WORKS

Following tender, the contract was awarded to PipeWorks in December 2011 for the tender price of $1,935,274.

The Contract Works include the following activities:

- Flow diversion
- Removal of all debris from existing brick arch
- Repair of defects within the existing
- Removal and reconstruction of
- CCTV inspection & assessment
- Rehabilitation of brick arch sewer main
- Liner design
- Supply As Built Information

manholes

- Testing
- Reinstatement

10 THE LINER

10.1 DESIGN

The Contractor was responsible for the design of the liner. As part of the liner design the following minimum requirements were required to be satisfied:

- The rehabilitated brick arch must be designed for an asset life of 50 (fifty) years or greater.
- The cross sectional area of the rehabilitated brick arch must not be decreased by more than 15%.
- The liner shall have a design factor of safety of at least 2.
- The liner shall be designed to fully support hydraulic, soil and live loads. Any structural contribution from the original pipe shall be ignored in the liner design, i.e. fully deteriorated gravity pipe condition.
- It is to be assumed that there is no bond between the liner and the existing pipe.
- Vertical earth pressures shall comprise the full height of soil and construction materials above the pipe without reductions for trench effects.
- Groundwater level shall be taken as being at ground level.
- Soil density shall be taken as at least 20 kN/m^3.
- The modulus of soil reaction shall be no more than 2.0 MPa.
- A traffic loading at least equivalent to HLP 400 loading as distributed in accordance with Clause 4.7.2 and Figure 4.2 of AS/NZS 2566.1:1998.
- The flexural bending and modulus of elasticity used in the design shall be supported by test results from samples taken from previous contracts.

As the liner tube and resin are proprietary products that can vary depending upon liner requirements and individual contractor preference, the flexural bending and modulus of elasticity can vary between products which have an impact on the design of the liner. Due to this variance a generic or standard design is not appropriate. The liner inversion tube and resin must be confirmed and appropriate testing undertaken prior to confirmation of final design.

The design for an egg-shaped pipe involves a two-step process;

1. Evaluating the circular crown of the pipe
2. Analysing the relatively straight section at the side of pipe as a beam alongside the concrete section

The maximum resulting thickness from these two equations will determine the liner thickness required. In the case of the Hastings brick arch rehabilitation the required liner thickness was calculated as 23mm.

The contractor used a 26mm liner to ensure the design thickness was achieved.

In addition to the structural considerations, the physical properties of the liner must ensure the CIPP system is chemically and biologically resistant to internal exposure to sewage, sewage related gases and mild concentrations of industrial effluent for the service life of the lining. Chemical resistance includes satisfactory performance in the presence of carbon monoxide, carbon dioxide, methane, hydrogen sulphide, sewer gas saturated with moisture, traces of mercaptans, gasoline, vegetable oil, kerosene, tap water (pH 5.5-9.0), detergent, soap, and dilute concentrations of sulphuric, nitric and phosphoric acid.

The lining must also be resistant to external exposure to soil bacteria and any chemical attack which may be due to residues remaining on the pipe wall or materials in the surrounding ground.

The liner must be resistant to abrasion from the migration of silt, sand and debris along the pipe.

10.2 LINER CONSTRUCTION

The liner used to rehabilitate the brick arch was a polyester felt lining tube which is a flexible, multiple layer tube with an exterior thermoplastic coating. It is manufactured to be continuous and seamless fitting snugly against the host pipe.

The liner consists of three key components.

1. The **polyester felt lining** is manufactured from one or more needled polyester felt layers constructed together to form a tube. Each tube is tailor made to be the appropriate diameter, thickness, and length to meet the required specification based on the liner design and accurate measurement of the host pipe.

   The diameter of each tube is achieved by slitting felt for individual layers to a calculated width before closure into tubular form. Seams in the butted or overlapped edges are formed through a technique known as heat bonding, where a controlled heat source is applied to the felt and the heated felt surfaces are pressed together to form a strong, consistent bond which allows resin passage between the two surfaces. Appropriate sizing for each tube is determined in the tube design phase. Tubes are typically slightly undersized to prevent wrinkling of the liner along the length of the pipe. This provides a smooth interior surface for the finished liner.

2. The very outermost layer of the felt lining is coated with an **impermeable thermoplastic film** to allow for vacuum-assisted resin impregnation of the tube, resin containment, and containment of the fluid used to invert the tube and cure the thermosetting resin.

3. Seams in this coated layer are then sealed with an **impermeable thermoplastic sealing strip** which is bonded to the exterior of the coated layer.

10.3 LINER PREPARATION AND INSTALLATION

The preparation of the liner is a two-step process. First the resin must be mixed in a well-ventilated and secure location as it is classified as a hazardous substance. Following the mixing the resin is now ready to be impregnated into the felt liner.

Impregnation of the liner with the resin can be undertaken either on or off-site. It is often completed off-site in a large temperature controlled warehouse and transported to site within a refrigeration container. This process ensures temperature control and provides greater time between impregnation and actual installation. For the Hastings brick arch however this was not the methodology followed. The 1500 metre length of brick arch was rehabilitated using three continuous very long shots of CIPP, 484m, 492m and 524m of 610mm diameter 26mm thick felt liner. Because of the length of liner required and the volume of resin, impregnation off site was impractical and too cumbersome.

An onsite methodology was developed which required the liner, already accurately cut to the required length, being laid out on site. A conveyor belt was set up to transport the liner from the storage location to the wet out location. An incision is made into the liner and the resin pumped into the felt lining. Each resin impregnation point is then sealed using an impermeable thermoplastic sealing strip which is bonded to the exterior of the coated layer.

Photograph 3: Liner tubes delivered to site

Photograph 4: Conveyor belt

Vacuum suction points are placed along the liner to ensure even distribution of the resin within the tube and ensure the liner is free from entrained air. In this instance the resin was colored a bright pink which made for easy visual inspection of the impregnated liner. The impregnated liner is then finally put through a roller set at a predetermined height ensuring suitable liner thickness with resin impregnation.

Photograph 5: Liner Impregnation with resin

Photograph 6: Roller

The liner is then lifted to the top of the inversion tower, over another roller and into the inversion tube. The liner is fed through the inversion tube until the end is visible. At this point the liner is inverted or folded inside out and secured to the end of the inversion tube using stainless steel bands. A water feed is attached to the inversion tube; the water then begins to slowly fill the lining tube forcing the tube to invert. The water head within the tower then slowly continues to invert the liner along the length of the host pipe. It is critical to ensure that the head of water is sufficient to prevent any ground water infiltration accumulating between the liner and the host pipe.

Photograph 7: Inversion tower

Photograph 8: Inverted liner ready for insertion

Once the liner has been inverted into the host pipe it is a slow continuous process to extend the liner the full length of the host pipe. Once the sealed end of the liner reaches the receiving manhole it is secured. A flexible hose has been inserted within the liner during the insertion process, then operates to continuously recirculate water throughout the liner as it is heated using a generator on site. The water temperature is monitored throughout the curing process using thermocouples to gauge the temperature of both the incoming and outgoing water supply. In addition to this thermocouples are also measuring temperature a various points along the surface of the liner to ensure the consistent curing of the liner.

Once the inversion and curing process is underway works cannot be halted under any circumstance due to the risk of the liner curing prematurely or not curing continuously i.e. resulting is soft spots within the liner. Due to the nature of the inversion and curing process unable to be interrupted well planned flow bypass with contingency equipment and plans was paramount to the success of this project. The continuous nature of the liner installation and curing also meant night time works in a residential area. Due to this the generator on site was insulated for noise reduction, and was monitored with sound equipment.

Continuous communication with residents to explain the process, likely noise disruption and provision of alternate accommodation if required was vital to the public success of the project.

The final value of the contract was $1,650,000. This was the result of a number of provisional sums including allowance for the tanker removal of curing water, remedy of additional defects within the host pipe and additional cleaning been required which did not eventuate and minimal contingency requirements.

Photograph 9: Inverted liner full of curing water inserted into the pipeline via a manhole

Photograph 10: Entire site set up within the centre of the road to ensure two-way traffic is maintained for the duration of the project.

11 CONCLUSIONS

The rehabilitation of the brick arch sewer was a successful project in every respect. This was a result of the effort put into considering alternatives and challenging the original open cut methodology. This was then followed through with good planning and investigation to confirm that the change in methodology was valid and the associated risks and unknowns could be eliminated or effectively managed.

Each of the community well beings identified during the optioneering phase and included in the contract requirements were achieved. These achievements included:

Social/Cultural – the primary social consideration during this project was the impact on the surrounding community, road users and residents.

The original concept of an open cut methodology was expected to span two summer seasons. In contrast to this the contract works were completed in fourteen (14) weeks significantly reducing the period of disruption to the community.

Traffic flow was maintained for the duration of the contract; residents were kept well informed of progress during the contract which resulted in no complaints.

Environmental – potential impacts on the environment with the use of hazardous chemicals was effectively managed through stringent environmental and health and safety procedures. These procedures included containment of resin and testing of curing water prior to and during discharge.

Economic – There was no negative cost implications to surrounding industry as business as usual for trucking routes were maintained throughout the contract.

The brick arch was rehabilitated for a cost significantly less than HDC's budget due to the change in construction methodology. Further cost savings were made during the contract as a number of provisional sums included for project unknowns were not required. These significant savings enabled HDC to redirect funds to other improvements within the community.

The quality of the finished liner met the contract specification and exceeded expectations with the contactor PipeWorks setting a record for the largest volume of liner installed within New Zealand. This single shot was the 524 metres of 610mm diameter 26mm thick felt liner.

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