DIRECTIONAL DRILLING WITH FUSIBLE PVC™ - THE BIRKDALE B PROJECT

O'Callaghan, F.W. Iplex Pipelines (NZ) Ltd
McNaught, I.B. Iplex Pipelines (NZ) Ltd
Southen, P. Pipeworks Ltd

ABSTRACT

Building new pipeline infrastructure in highly congested urban environments is causing some interesting challenges for engineers and construction companies, demanding innovative new pipeline solutions.

The Birkdale Area on Auckland's North Shore presented such a challenge requiring the installation of a complex new gravity wastewater sewer pipeline using horizontal directional drilling methods. This heavily populated area has high traffic loading, minimal construction space and many existing buried pipe services with variable knowledge of their location.

The new pipeline extended over 1,030 metres distance at up to 28 metres depth and was drilled through challenging ground conditions including sandstone and soft organic material.

Although PE100 polyethylene was originally considered, Fusible PVC™ pipe, already widely used in North and Central America, was chosen for its high tensile strength, structural performance and construction benefits for the contractor.

Fusible PVC™ brings a valuable new solution to the New Zealand Asset Manager's "toolbox", either as a drillable pipeline material for water or wastewater mains, or a rehabilitation solution, either by pipe bursting or by slip-lining inside an existing host pipe to maximise the resultant internal diameter.

KEYWORDS

Fusible PVC, FPVC, Horizontal directional drilling, fusion

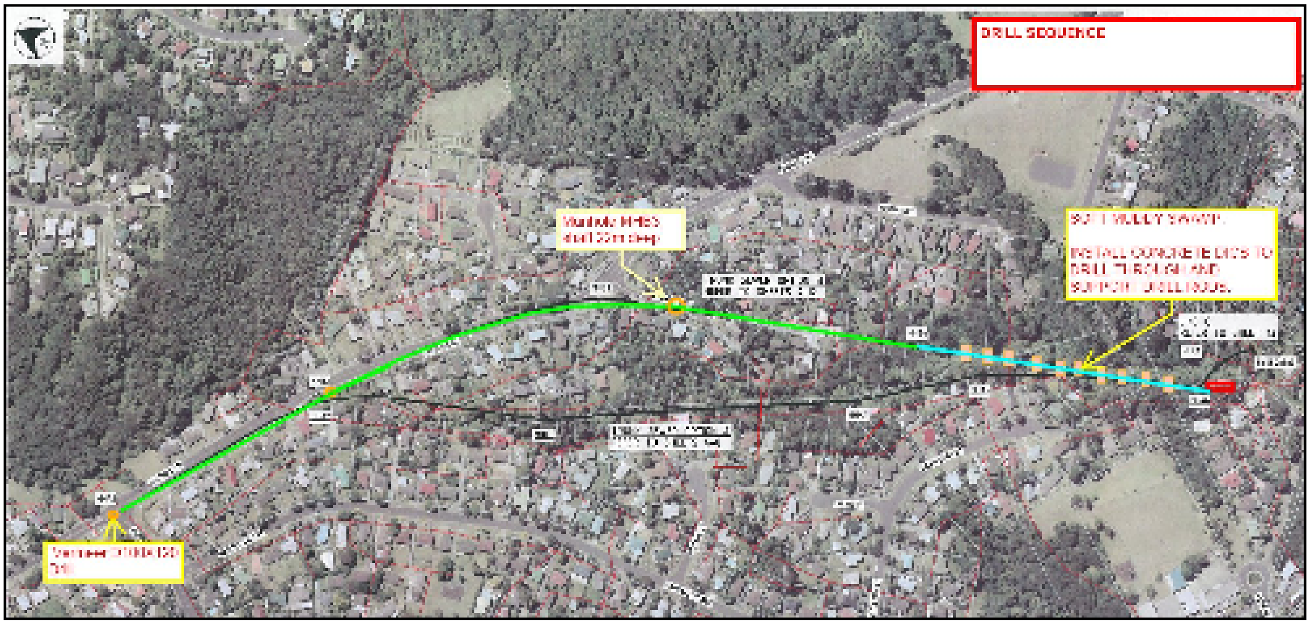
1 INTRODUCTION

In 1998 North Shore City Council launched Project Care with the primary aim of resolving the beach pollution problem caused by an overburdened sewer and stormwater system. For many years, residents living in the North Shore City Council area endured storm water induced overflows of local sewer manholes that during rain events (small and large) discharge directly into the Eskdale Stream, one of the North Shore's most environmentally significant streams. As one of the measures to eliminate the overflows, a new pipeline for extra system capacity was needed to carry these intermittent influxes of storm water, as well as the increasing loads of everyday sewage from the area. The combined geological and environmental conditions of the area dictated that trenchless installation was the only viable installation method.

The Birkdale Pipeline was divided into 3 separate contracts, Area A completed in 2009, Birkdale C scheduled for completion in September 2010 and the centre connecting section, Birkdale B being undertaken by Pipeworks Ltd.

The Birkdale B pipeline extends 1030 metres under arterial roads and established residential housing. It is being installed by state-of-the-art horizontal directional drilling methods, the pipeline has a 28m depth to invert point as it passes through a steep hillside and finally weaves through a wetland area before terminating at a newly installed manhole. The ground conditions across the site range from Waitemata series sandstone, MPA2-MPA20+, coupled with short sections of high plasticity clays, silts, sands and organics.

Photograph 1: Birkdale B site overview showing pipeline route.



2 PIPE MATERIALS

Birkdale B was originally designed and tendered in polyethylene, DN630 SDR11 PE100, complimentary to the DN560 PE pipe previously used in Birkdale C. However, following contract award Pipeworks Ltd gained approval from North Shore City Council to change the pipe material from PE to Fusible PVC™ (FPVC™) as this material offered a number of significant advantages and benefits to the project.

The Fusible PVC™ pipe chosen has an outside diameter of 550mm as compared to the 630mm of the PE pipe option, however the internal diameter of the FPVC™ pipe was only marginally smaller so the hydraulic profile of the pipeline remained suitable for the project. The most immediate advantage of this 13% reduction in pipe OD size was a significantly smaller HDD borehole with associated reduction in removed bore hole material. This provides several direct benefits including reduced drilling and installation time on site, a lower friction coefficient during installation providing easier pullbacks and improved site management due to reduced drilling lubricant volumes.

The FPVC™ material also has a higher tensile strength than the PE100 polyethylene material, typically 48 MPa for FPVC™ versus about 25 MPa for PE100 polyethylene. Safe pulling stresses are based upon a 2.5 times factor of safety applied to the tensile yield stress; typically 19 MPa for FPVC™. Added to this, polyethylene pipe is more visco-elastic and tensile loads are more time dependent when calculating maximum cross sectional stresses. Time dependence is not such a concern with FPVC™ when allowing for these peak loads when pulling pipe into a borehole. As FPVC™ has higher tensile strength this also means that pipes can be pulled over longer distances with greater certainty.

3 WHY PVC FOR DIRECTIONAL DRILLING

Table 1 outlines some important differences that exist between polyethylene and PVC-U that contribute to the successful installation of Fusible PVC™ pipelines by horizontal directional drilling. (Refer AS/NZS2566.1 1998, table 2.1)

Table 1: Comparison of material property values.

Material	Minimum Required Strength (MRS) MPa	Hydrostatic Design Stress (HDS) MPa	Young's Modulus (E) Short Term MPa	Young's Modulus (E) Short Term MPa
PE100 Polyethylene (AS/NZS4130)	10	8	950	260
PVC-U (AS/NZS 1477)	26	12.3	3200	1400

For horizontal directional drilling these physical differences mean;

- A smaller diameter drill shot
- Longer drill shots
- Smaller work site foot print
- The expectation of reduced social impacts, construction time and cost

3.1 FUSIBLE PVC PIPE

Originally invented in Canada in the mid 1990's and developed thereafter in the United States of America, FPVC™ is now widely used throughout the USA, Canada and Mexico with over two thousand installations now completed. Applications include pressure and non-pressure pipelines in the water, sewer, electrical, industrial and telecommunications industries.

Trenchless installation methods for FPVC™ include conventional horizontal direction drilling, slip-lining, static pipe bursting and open cut installations in unstable or seismically active ground. Continuous pull-in lengths exceeding 1500 metres have been successfully achieved.

FPVC™ conforms to the usual PVC-U pipe Standards of the country of manufacture and utilises conventional, off the shelf ductile iron socketed fittings and couplings.

3.2 FPVC™ PIPE FUSION PROCESS

Licensed and trained fusion technicians perform the patented fusion process. The fusion welding equipment is specifically calibrated and designed for use with fusible PVC pipe. The fusion process consists of the following steps;

1. Pipe ends are precisely and securely aligned

2. The fusion machine dual rotary cutting head faces and accurately squares both pipe ends simultaneously

3. An electronically controlled heating element in the heater plate, heats the pipe ends in preparation for fusion bonding, forming a melted bead of fusible material

4. Following heating (heat soak) of the pipe ends and developing the proper bead, the heater plate is removed and the pipe ends are brought together and securely held under controlled pressure until the newly formed joint cools.

5. When the joint has cooled to the required conditions it can be moved or installed immediately.

Fusion times are comparable with other thermoplastic materials. The PVC formulation and fusion conditions, including temperature and pressure, are unique to Fusible PVC™. Testing in accordance with appropriate Standard methods demonstrates that the tensile strength of the fused joint is equivalent to the tensile strength of the parent pipe.

Photograph 2: Fusion welding of FPVC™ pipe.

Photograph 3: Applying an intermediate weld between two FPVC™ welded strings for slip-lining of an existing concrete pressure sewer, USA.

4 HORIZONTAL DIRECTIONAL DRILLING AT BIRKDALE B

The pilot hole was drilled with a Bottom Hole Assembly (BHA), configured for drilling through rock, utilising a down-hole mud motor and non-magnetic steering. Six weeks was required for the pilot drill, as the requirements for both grade and invert level tolerance were most stringent. Various hole enlargement sizes will follow; up to a final size of 28" (712mm) before the product installation takes place.

4.1 Site drilling challenges

There were a significant number of challenges facing the drill crew during this phase of construction;

- Site conditions prohibited the use of a Maxi HDD Rig. Instead, a Vermeer D100X120 drill rig was used. This versatile rig was most suitable for the restrictive setup area available, however a job this size, being 28" diameter hole drilled in 1030m of sandstone and clay, is most certainly on the outer limits of the rigs capability. Special care, solid know how and use of extensive experience would need to be maximised to ensure no problems occurred which could be associated with operating closely within the limitations of the rig, drill pipe or tooling.

- The Rig was set approximately 30m off line and at a distance some 20 metres back from pipeline start point due to site space requirements around existing roads and houses. The pilot was drilled to intersect the pipeline alignment at Chainage 76m and a needed to complete a 130m horizontal curve coupled with a 200m vertical curve to achieve this and continue on the designed grade of 0.5%.

- A drilled grade of 0.5% through the first 300m, with the drilled grade from 300m to approx 800m being reduced from 1.1% to 0.8%. This reduced designed grade enabled the upstream pipe alignment grade to be increased and introduced a "safety" aspect for the final 200m in the swamp. The contractor was able to change the grade between 1% and 2.5% to reduce likelihood of under verticals being created.

- The purpose of the 0.5% grade in the first 300-metre section was required pass underneath a concrete lined stream channel at chainage 207m. Achieving the 0.5% grade ensured that borehole missed the base of this channel by 0.8m.

- A "hard daylight measurement" was required for 4 different points along the route, with specified reduced levels requiring the strictest adherence. High-end professional steering services were combined with suitably experienced and conscientious drilling supervision personnel and this yielded the results necessary. At an open manhole of 23m deep and 1.8m diameter, the bottom of the manhole was intersected well within a tolerance of 89mm from target. This was in rock conditions at 550m away from the drilling rig.

- From Ch840 through to Ch1024 the pipeline design required the alignment to be created under long sections of the streambed in the Protected reserve. With the contractors proven ability with drill location and steering, they were able to introduce another curve of R300m that ensured that the pipe alignment only crossed the stream once and remained in "better" ground. This would ensure that the potential for surface fractures within the streambed was minimised.

- At the final mark at the "top" of the bore the drill was approximately 120mm high from design RL. However, this was needed as the ground conditions in this area are very soft (organics and silts) and the reaming process required to upsize the bore is expected to drop the drill section to the required levels.

- No less than three compound curves were required to complete the steering of the pilot bore and this presented its own challenges. In addition to other drilling regimes and parameters, a solid mud engineering process, coupled with "smooth" and accurate steering needed to be employed to lower the required torque to rotate the small 3 ½" drill pipe over such a long distance.

- There was groundwater influx into the borehole of up to 50m3 per day. Various methods of sediment settling, flocculation and dewatering were employed to enable a disposal of completely solids free water into the NSCC sewer system.

- Construction of a 22m deep, 1980mm (ID) shaft was required at Chainage 560m in the centre of a small cul-de-sac. This involved a detailed methodology to ensure this shaft was installed without disruption to residents and property in close proximity.

- Construction of an 8m deep access shaft at CH76 for Mud return and tooling changes. This shaft was positioned adjacent to the berm and parking lane of the very busy Eskdale Road and was achieved using H piles and timber lagging in hard sandstone.

- At the intersection point at CH1024m a large "coffer dam" type excavation 4m wide x 10m long x 6.5m deep was installed to capture both the finished pipeline and also to connect the 560 diameter PE line that was installed by the previous contract. Excavators installed sheet piles and UC wailers with Vibro hammers in swamp like conditions. Swamp mats, geotextiles, geo-grids and significant amounts of graded aggregates were required for the installation. Significant construction works were required to excavate the "slops" from within the cofferdam. This excavation is within 6m of Eskdale Stream and approx 4.5m below the stream.

- Extensive onsite mud testing including rheological properties, filtration properties, viscosity, gel strengths, mud weights, sand contents and PH/Hardness. To ensure that the maximum volume of cuttings were sufficiently suspended to be carried over the long length of the bore, alternative bentonite mixes were used. Polymers and detergents were also employed at times dependent on soil conditions.

- Mud recycling is employed on the project instead of the pump and dispose regime that is so often used in drilling projects. The recycling system consisted of a DFE 2000 de-sander and 40ft container suspension tanks and was able to process 100% of the returning mud.

- Overcoming delivery of the drilling mud returns of various viscosities/mud weights through a 1024m bore length on relatively "flat" grades.

Photograph 4: Vermeer D100X120 drill rig, Birkdale site

CONCLUSIONS

Although PE100 polyethylene was originally considered, Fusible PVC™ pipe, already widely used in North and Central America, was chosen for its high tensile strength, structural performance and construction benefits for the contractor.

Fusible PVC™ brings a valuable new solution to the New Zealand Asset Manager's "toolbox", either as a drillable pipeline material for water or wastewater mains, or, a rehabilitation solution by slip-lining inside an existing host pipe to maximise the resultant internal diameter.

ACKNOWLEDGEMENTS

Anthony, B. Ancon Drilling Ltd

Jonkers, I. Pipeworks Ltd

Meyers, G. Pipeworks Ltd

REFERENCES

AS/NZS 2566.1 Buried flexible pipelines

Underground solutions Inc. USA