Creating tranquillity for the America's Cup

Based on a paper by David Pattinson from the Wynyard Edge Alliance, which is made up of McConnell Dowell, Downer, Beca, Tonkin and Taylor, Auckland Council, and the MBIE.

Healthy Waters, Auckland Council's stormwater division, owns and maintains the Daldy Street Outfall, an asset used to discharge approximately one third of Auckland's CBD stormwater drainage into Wynyard Basin, which is also the new location for several of the 36th America's Cup (AC36) syndicate bases.

The existing outfall discharges directly into Wynyard Basin, at the junction of Wynyard Wharf and North Wharf, adjacent to the old SeaLink facility.

A condition of AC36 was that the basin required 'tranquillity' and the existing outfall compromised this. The outfall needed to be relocated and the decision was made to extend the pipeline along the full length of Brigham Street, discharging into Waitemata Harbour via a new outfall structure.

With construction of AC36's infrastructure already underway, in particular the new syndicate bases on Wynyard Point, it became apparent that relocation of the pipeline would need to be done concurrently with the AC36 work. As such, the Daldy Outfall extension was added to the scope of the AC36 project and contracted to Wynyard Edge Alliance (WEA).

The project involved a technically challenging ground stabilisation system and the installation of what is believed to be the largest diameter pipe ever laid in New Zealand. This was all within contaminated land, in tidal conditions, through the middle of construction of the syndicate bases, to an extremely tight timescale.

Innovation was key. The engineering and temporary works teams worked collaboratively with the construction team to develop, and ultimately produce, a highly technical solution that removed the need for anyone to enter the trench during pipeline installation. A safe, sustainable, robust, cost-effective solution was developed, priced and subsequently installed.

Wynyard Point: a peninsular on the north-west corner of Wynyard Quarter, Auckland.

The site

Wynyard Point is a peninsular on the north-west corner of Wynyard Quarter in Auckland's CBD. The area is bound by Brigham Street to the east and Hamer Street to the west and was reclaimed around 100 years ago from the Waitemata Harbour.

A basalt breakwater was constructed around its perimeter with a concrete seawall cast on top, then infilled with excavated arisings (from the early CBD development) and hydraulic fill/dredged arisings (from the sea).

Once capped off, the area was developed as an industrial site, with gas works, fuel storage tanks, etc, occupying the site. The ground has substantial quantities of hydrocarbons, fuel oils, asbestos, 'blue billy' (by-product from gas works), scrap steelwork and various other obstructions.

All of this classified the area as a contaminated zone, requiring air monitoring and the use of disposable overalls and gloves when any works were carried out.

The relocation design

The Daldy Street Outfall discharges into Wynyard Basin at the south-east corner of Wynyard Point and, amongst other things, the scope for the AC36 project required the need for tranquillity in Wynyard Basin and the possibility of turbulent stormwater overflows into the basin, from the outfall was undesirable.

The outfall had to be relocated, and following investigation of several possible locations, the northern tip of Wynyard Point was selected. This involved the extension of Daldy Street Outfall by some 510 metres along the entire length of Brigham Street. The new outfall would discharge directly into the Waitemata Harbour, maintaining tranquillity within Wynyard Basin.

Furthermore, with the obvious clash between works for Daldy Street and AC36's syndicate bases, the only viable solution was for WEA to execute the works as a variation to the AC36 contract, thus managing the interface with AC36 works.

The outline design was developed, target cost provided and ultimately agreed, and a variation issued for the additional works.

Site investigation

The first step of the design process was to initiate a detailed programme of geotechnical investigation. The focus of this was to determine the location and extent of the basalt breakwater along the eastern edge of Brigham Street; location and extent of an old haul road believed to be formed along the back of the basalt breakwater; physical properties of the backfill material used to construct Wynyard Point; contamination levels; information on water levels; integrity of the existing seawall; and anticipated construction loadings.

Information relating to utility services was also collected and this revealed a major issue with a fire-fighting water main. This would need to be diverted/relocated several times during the construction phase in order to maintain a fire-fighting provision for the Stolthaven tank farm and Wynyard Wharf, both adjacent to our work site.

Pipe design

Hydraulic analysis identified that a pipe diameter of at least 3000mm would be required for the project.

The existing pipeline in Daldy Street was 2700mm diameter with little or no fall due to the topography of the reclaimed land within which it was laid.

Furthermore, there existed very little driving head to flush the pipe, and with it being so close to the harbour, the pipe was subject to tidal flows.

The maximum diameter concrete pipe available in New Zealand was 3050mm (concrete) with an effective length of 2700mm; this would have complicated the connection detail and slowed down the laying process considerably. In addition, nearly 200 pipes would be required, significantly adding to the carbon footprint associated with manufacture and subsequent delivery into the CBD.

The final design landed on a 3000mm pipe for the upstream half of the extension and a 3500mm pipe for the downstream half.

With concrete not being a viable option, an HDPE solution was pursued. The main advantage of HDPE pipe is that it is made from an extruded rectangular section (wound onto a mandrel) with the rectangular section effectively producing a void within the pipe wall; this makes it extremely light, while remaining very strong.

Additionally, it is extremely flexible, with manhole sections, lateral connections and an expansion piece all capable of being factory produced. The pipe could be supplied in 15 metre lengths, which would greatly assist in the installation process, speed up production, and provide a better Health and Safety solution.

Following much discussion, an order was placed with Uponor, with fabrication to be done in its Thailand factory. After a 10-week fabrication programme, the pipes were transported to New Zealand by ship and delivery was made directly onto Wynyard Wharf, adjacent to Brigham Street. Two hundred truck journeys to Auckland's CBD had been avoided, providing a more desirable environmental solution.

A key feature of the pipeline design was the connection detail between adjacent pipes. A mechanical connection between pipes of this size was not possible, so a concrete cradle/saddle arrangement was designed with macalloy bars used to effectively clamp the sections together.

A strip of EVA compressible foam was detailed across the joint to maintain as good a seal as possible – this was not essential but seen as good practice.

Project stabilisation

Initial stages of design concentrated on the ground support required for the five metre deep excavation. With the basalt breakwater running along the eastern edge of the proposed trench, traditional double-row sheet piling was not an option. A second option of providing a single-row sheet pile (to the landward side) and then tying back proved unworkable as the strength of the reclaimed land would not support any type of tieback or anchor.

The preferred option soon became in-situ mass stabilisation, formed by mixing grout with the existing ground, effectively forming a low strength 'concrete' mix. The idea was to stabilise the full 12-metre width of Brigham Street, then to dig through the treated ground to lay the pipe.

However, a trial of the method failed as the equipment was not powerful enough to penetrate some of the fill. The design had to be re-thought.

At this stage, we sought advice from an international ground-engineering expert who introduced the team to the 'Cutter Soil Mixing' (CSM) method.

This method uses a powerful drill-rig with cutter heads mounted onto a kelly bar that are driven into the ground. Grout is injected behind the cutter heads as they descend, mixing the grout with the in-situ ground, similar to the initial mass stabilisation method, just more powerful.

The treated panels produced are 2.4 metres long and one metre wide (plan area of cutter head) and can be installed as deep as the kelly bar.

This ground stabilisation methodology was adopted and developed. The completed design used four abutting rows of CSM panels running the entire length of Brigham Street.

The CSM block would support the ground to the west of the excavation during pipe excavation / install. Furthermore, the mixing of existing ground with grout reduced the volume of excavation, and consequently the volume of contaminated material to dispose off-site – a more sustainable solution.

Project structures

Having completed the design of the pipe and ground stabilisation for its installation, the structures team undertook the design of the outfall structure; upstream connection into existing pipe; and manholes/lateral connections.

The outfall structure was designed to blend in with the existing basalt breakwater at the northern end of Brigham Street.

Due to the tidal nature of the installation, in-situ concrete was not a viable option so precast units were developed as the preferred solution. The headwall was split into five segments, following the sloping face of the breakwater. However, the shape of each unit precluded transportation from the precast yard (due to size constraints) so each unit was constructed from a pair of precast wall units, connected together on site with an in-situ base unit.

The client expressed a desire to blend the headwall in with the existing breakwater. To satisfy this requirement, the concrete panels were coloured with an eight percent (by binder volume) black oxide additive, and the wall units given a profiled finish to replicate a rock pattern.

Following installation of the precast 'U' sections within the breakwater, an in-situ pour was designed to tie the units together, at the top, out of the tide.

The structure was completed with the introduction of a flap valve across the pipe outfall, designed to discourage kayakers/adventurous children entering the pipe and reduce the risk of prevailing winds blowing unwanted gases back up the pipe.

North Wharf connection

The existing Daldy Street pipeline runs northwards along Daldy Street, terminating at a point where it meets the northern edge of North Wharf.

An overview of Wynard point and the route of the new pipe.

The wharf is a 100-year-old reinforced concrete structure constructed with columns, beams, cross bracing, and a 200mm thick deck slab on top.

When Wynyard Point was developed (infilled), the existing outlet had no point of discharge and the solution was to break a hole in the side of the pipe and divert the flow along a newly formed channel. This arrangement has been in place for many years.

Access to the existing outlet is possible, albeit difficult. A survey team was able to undertake a comprehensive laser survey of the existing pipe under the wharf at the intended point of connection. From this survey, a detailed model of a transition piece was made to connect into the existing pipe and move the new alignment away from other columns of the existing wharf structure.

Bend/manholes/lateral connections

Due to the existing layout, a 24-degree bend was detailed to replicate the kink in the existing road alignment in Brigham Street.

Access to the pipeline would be required for maintenance, periodic inspection and cleaning. There is access under the flap valve at the outfall and, in addition, two manholes were added – one adjacent to the bend and one at the mid-point of Brigham Street. No ladders were detailed to discourage unauthorised entry.

As the Daldy pipeline design developed, drainage works for the AC36 syndicate bases were completed, and lateral connections for these outlets were catered for in the Daldy design.

We therefore added a 24-degree bend, two manhole sections and all lateral connections to Uponor's HDPE pipeline order. These were all factory made, fitted and delivered with the main pipeline onto Wynyard Wharf.

Installation

Working alongside the design team, our engineering team devised and developed the temporary works schemes required for the installation of the permanent works.

Collectively, the permanent and temporary works teams produced a robust, innovative, engineered solution for installation.

The key feature of the pipeline installation was that worker

The ground was littered with redundant pipes, scrap steel, chains, an old ship's boiler and propeller.

entry into the trench was precluded, due primarily to safety concerns regarding the depth and tidal conditions. All pipe installations were carried out from existing ground level, thus protecting the workforce – a critical feature of the design.

The CSM installation works were sub-contracted to Wagstaff Piling from Brisbane. The contractor mobilised equipment from Australia and set up its plant on site central to the new pipeline.

Following the extensive ground investigation work, it was clear there would be many obstructions in the ground that could hamper progress.

With this in mind, WEA set up an attendant team to initially dig a guide trench for each panel and then clear any obstructions if encountered. This proved to be very beneficial as the ground was littered with redundant pipes, scrap steel, chains, an old ship's boiler and propeller.

The phasing of the work had to dovetail in with progress on the AC36 syndicate bases and infill bridges. By careful planning and integration with the other teams, we were able to maintain progress on site without delay to any party.

Five months after commencing work, and 959 CSM panels and 13,000 cubic metres of treated ground later, the CSM works were successfully completed.

In order to monitor the behaviour of the CSM panels during excavation for the pipeline, inclinometers were installed at regular intervals along the length of the pipeline. There were concerns relating to a horizontal displacement of the panels during excavation that could lead to a vertical deformation behind the panels; this could subsequently lead to differential settlement of Stolthaven's fuel tanks in the northern section of Brigham Street.

These concerns never eventuated and the CSM walls behaved well, with horizontal displacements typically less than 10mm.

Site excavation

With ground stabilisation in place well ahead, excavation for the pipeline could begin. A 47-tonne excavator was selected for the five metre deep excavation. This was a compromise between digging power, reach, swing radius, and ground bearing pressure on the existing road/seawall.

The tidal range of the adjacent harbour runs between pipe invert and pipe crown; with the porous breakwater alongside, it was thought that water would always be present within the excavated trench, typically following the tide. This proved to be the case.

Excavation of the trench would follow the vertical face of the installed CSM panels (row 1) to the west and the seawall/basalt breakwater to the east. Control therefore centred around the depth of excavation, which would always be underwater.

To assist with this 'blind' dig, a GPS sensor was fitted to the excavator and formation of the trench bottom was controlled electronically. At each cradle position, a slight over-dig was required to allow for the thicker cradle; the GPS catered for this. Excavation was carried out to 100mm below the underside of the concrete cradles (used to support the pipe).

The excavated ground was extremely variable, with reinforced concrete sections (thought to be an old damaged wharf structure), steel pipes, steel rope, 'blue billy', pockets of hydrocarbons, basalt boulders and weak soils – all encountered on a regular basis.

At times, the water within the trench became very dirty/oily, and environmental measures such as plugging holes in the seawall, adding oil booms/silt-socks within the harbour, pumping / sucking out to the treatment plant were instigated. Although minor leakages occurred, there were no pollution incidents, which was considered a major risk during the design phase.

All excavated material was transported to a spoil handling area, where it was sorted and either disposed of off-site or mixed with cement to form mudcrete that would later be used as backfill for the pipeline. Due to the contaminants found in Brigham Street, the site was deemed a contaminated zone, hence the need for disposable paper overalls and gloves.

Pipe installation

After sufficient excavation had been completed, the first concrete cradle could be installed. With a minimum of one metre depth of water always present in the trench, inspection of the formation and setting levels from within was not possible.

To overcome this, a steel gantry was utilised, spanning between the existing seawall and the CSM wall, to suspend and position each cradle.

Concrete cradle for pipe support being lowered into place.

The precast concrete cradles were prepared for installation; macalloy bars screwed into the top were used to suspend the cradle from a spreader beam above and a grout bag strapped underneath.

The spreader beam with cradle were positioned above the steel gantry and lowered down through a central opening. Lowering continued through the opening until the spreader beam sat on the cross beams of the steel gantry.

By careful surveying, the cradle was positioned and suspended off the steel gantry at the correct chainage, offset and reduced level.

After a final survey check, a grout pump was connected to a hose on the grout bag and approximately two cubic metres of grout pumped into the bag, filling the void between the underside of the cradle and the formation below. Following an overnight initial setting period, the spreader beam and gantry were removed, leaving the cradle in its final correct position.

With water levels typically higher than the top of the installed cradle making it invisible, a survey frame was temporarily placed on top of the cradle to assist with surveying. Once set in place, the frame was removed.

Prior to installation, each pipe was positioned on a preparation frame. Preparation included the removal of temporary 'spiders' welded across the open ends to maintain the pipe shape during transportation and adding water and air vents to the top of the pipe. By rotating the pipe on the frame, the need for 'working at height' was eliminated.

Following preparation of the pipe, two lifting straps were wrapped around the pipe and connected to a bespoke spreader beam. The pipe was lifted from the preparation frame and lowered into the excavation between the next pair of cradles. However, as the pipe was lowered into the water, the buoyancy of the pipe would force the pipe to float.

To overcome this, water was added through a central port on the crown of the pipe that filled the helical annulus, venting at either end. This operation effectively tripled the weight of the pipe and allowed it to settle into the cradles below.

With the pipe sunk into position, saddles were added to the pipe ends and bolted down to the cradles below. Two additional saddles were also landed onto the pipe (at third points), which would prevent uplift during the next operation.

During the design phase, it was identified that laying pipe bedding under such a large diameter pipe, and underwater, would be extremely difficult. To this end, a flowable fill was specified, which would be tremmied in underwater.

The additional temporary saddles would prevent uplift of the pipe. A wooden staff with a laser target attached to the top was used to check the height of the flowable fill poured – the finished surface being approximately one metre above pipe invert and always below tide level.

The final stage of pipe laying was backfilling the remaining pipeline with the mudcrete produced in the spoil handling area (by mixing selected excavated arisings with cement). The target strength of mudcrete was 1 MPa, which was regularly exceeded. The mudcrete was returned to the pipeline area and deposited by excavator in layers.

The process of excavation, cradle install, pipe laying, flowable fill and mudcrete backfill continued on a cyclic basis along the entire length of the pipeline.

An additional feature of the temporary works design was purpose built 'pigs' that were installed in the first full pipe laid (of each diameter) and pulled through the sections of completed pipe. This had the effect of cleaning any silt and debris from the pipeline as installation progressed, negating the need for a final clean out upon completion.

Project sequencing

Against common practice, Phase 1 of the pipeline installation commenced at the central point of the 510 metre extension and headed in a southerly direction, thus clearing syndicate bases C, D and E in a timely fashion.

The non-mechanical connection, symmetrical pipes, and a flat invert facilitated this, enabling the AC36 finishing works to be completed and milestones associated with the project met. Installation continued as far as North Wharf, stopping two pipes short of the connection point, which would be re-visited once the outlet was formed.

At this stage, pipe laying returned to the starting point and Phase 2 headed in a northerly direction towards the outfall structure. Having made the final connection into the completed headwall, the operation returned to the southern end to make the final connection into the existing point of outfall.

As mentioned earlier, the shape and size of the outfall units precluded precasting in one unit. Because of this, the (patterned, blackened) wall sections were precast in Busck's yard in Whangerei and transported down to site. Once on site, each pair of walls was set upon a casting bed situated on Wynyard Wharf, alongside the new outfall position. An in-situ base slab was cast between the walls to tie them together and form a 'U' shape section.

Prior to the pipeline installation reaching the northern end of Brigham Street, excavation commenced for the new outfall structure. Additional CSM panels had been installed to the rear of the outfall to allow a steepened back wall of excavation and to provide a stabilised area for the crane to sit on while lifting in the 'U' sections.

Again, excavation utilised GPS to allow the correct formation level to be achieved one metre below lowest tide.

Left: Precast outfall wall panel. Above: Pipe installation underway.

Excavation commenced with the excavator but was completed by a barge mounted excavator due to access difficulties.

Upon completion of excavation, a prefabricated steel frame was lowered into the excavation with diver assistance. The frame was fabricated with four adjustable legs (to set to the required level), scaffold poles with survey targets added (to assist positioning below water), and angled guides to assist landing the precast sections.

Once positioned correctly, concrete was poured within the frame to within 50mm of the top flange. A grout curtain was installed around the perimeter of the frame to contain the concrete, and a sliding screed rail was added to the frame to assist in screeding the concrete to the required level – a difficult operation for divers underwater.

With the seating frame set and precast units completed, a 400-tonne mobile crane was set up above the outfall structure, which lifted each of the five 'U' sections into the water and onto the seating frame. The first (downstream) unit was set against a steel angle section to locate the downstream toe, and subsequent units lowered in and placed against the previous unit.

With the five 'U' shaped units installed, the backwall sections were lifted in and bolted to the upstream unit, and the final cradle lifted in and bolted to the backwall, ready to receive the last pipe.

The final stages of the headwall construction were to concrete around the outside of the seating frame to lock it in place, construct an in-situ tie beam to connect the tops of the wall panels together, and grout the void between the 'bedding' concrete and the underside of the units.

This final operation was undertaken with divers using an intricate system of grout tubes and bleed valves to ensure the seawater below the units was fully displaced during the grouting operation.

Upon completion of the headwall, the working space created during initial excavation was backfilled with basalt boulders, blending the new headwall into the existing breakwater. Completion of the headwall allowed for excavation and laying of the last two pipes into the back of the completed structure.

The North Wharf

To complete the Daldy Street Outfall extension, it was necessary to tie the newly laid pipeline into the existing pipe under North Wharf. This followed completion of the pipeline downstream in order to provide an outlet.

With ground stabilisation provided by the previously installed CSM panels, excavation commenced between North Wharf and the previously laid pipe – a distance of approximately 10 metres in length. Excavation continued under North Wharf (under tidal conditions), including breaking through the existing retaining wall.

As excavation progressed, blinding concrete was laid on the formation as the flow of Daldy would soon pass over this area – environmental protection was thus afforded.

The stainless steel transition piece was connected to the first HDPE pipe section, and the whole unit lowered over the edge of North Wharf, at low tide, into a rope sling hung off the side of the wharf.

With the weight of this combination pipe taken by the main hook on the crane, an auxiliary line was threaded through a hole in the wharf, directly above the connection point and onto the end of the transition piece. On the incoming tide, the weight was taken off the crane as the pipe began to float. At this point, the auxiliary line was hoisted and the pipe section pulled into place under the wharf and into position – the stainless steel transition piece fitting into the old outlet. The annulus of the pipe was then flooded, sinking the pipe into position.

The flow of Daldy pipeline immediately started to run through the new pipe, through a short 10m section of excavation, then through the remaining pipeline previously installed.

At this stage, all that remained was to measure and cut the final pipe, place it in the remaining gap and add the final pair of saddles to clamp it in place.

The final diversion of Daldy Street Outfall had been successfully completed.

Street reinstatement

Following completion of the diversion, reinstatement of Brigham Street North is required, which includes a single carriageway road, swales to receive surface run-off (connected into the Daldy pipeline), a footpath, and miscellaneous lighting, signage and road marking.

The final touch will be to replace the five Pohutukawa trees removed to facilitate the works, with nine new trees planted. Completion is due August 2020.

Project wrap up

Integration of designers, temporary works teams and construction staff, from an early stage, enabled an innovative, effective, technically sound, and safe system of design and installation to be developed.

As each design package was issued, a full understanding of design requirement and proposed installation method had been gained.

Construction Execution Procedures were developed alongside the design, with input not only from construction and design team members, but also representatives from the health, safety, environment and quality (HSEQ), contamination, stakeholder, owners, and consenting teams. This team effort was extremely valuable.

Crucially, the design and installation method developed included a number of innovative solutions. These were: CSM ground stabilisation; GPS controlled excavations; preclusion of worker entry into the pipe excavation; steel gantry to support pipe cradles; use of steel survey frame; grout bags to set cradles; a highly flexible pipe material – HDPE; possibly the largest pipe ever laid in this country; pipe laying through tidal conditions; flooding of pipe annulus to allow sinking of pipes; flowable fill placement underwater; use of mudcrete to reduce disposal; precast elements to headwall; use of headwall seating frame underwater; grouting of precast units underwater; and installation of transition piece under North Wharf.

Furthermore, coordination between the Daldy installation team with other AC36 construction teams (syndicate bases, infill bridges, etc), played a huge part in the successful execution of the project and allowed all project milestones to be met.

The flow of the Daldy Street Outfall has been successfully diverted, providing improved water quality for Healthy Waters and allowing full tranquillity of Wynyard Basin to be achieved in time for the 36th America's Cup event.