ABSTRACT
The Gisborne Wastewater Treatment Plant and Industrial Separation Project is a $21m project to treat the domestic and industrial wastewater entering Poverty Bay. This CH2M Beca designed plant processes up to 450 litres/second of industrial and municipal waste. Stormwater flows in excess of this quantity still receive coarse screening.

This paper discusses the challenges faced by the main contractor, HEB Construction (HEB), in their installation of specialised products such as High Density Polyethylene (PE) liners and Bentonite to the plant’s concrete structures. It also discusses how HEB managed these challenges to ensure the very tight construction programme was met without jeopardising the installation quality of these specialised products. The paper concludes by considering whether a more suitable solution could be provided through the use of a concrete mix capable of providing the same waterproofing and chemical resistance properties.
INTRODUCTION

Prior to 2011, Gisborne’s wastewater treatment was very minimal at best. Both industrial and domestic wastewater would discharge into Poverty Bay with solid screening to 1mm as the only form of treatment. In 2007 the Gisborne District Council engaged CH2M Beca to design a wastewater treatment plant that would treat this wastewater and separate industrial and domestic waste.

In November 2009, HEB Construction was awarded the $21m contract for the construction of the Gisborne Wastewater Treatment Plant and the Industrial Separation Project. The construction period was sixty weeks with a completion date of 21 January 2011.

The Resource Consent for the original sewage ocean-outfall discharge expired on the 31 December 2010. In order to comply with the Resource Consent, on the 1 January 2011 the new facility had to be processing Gisborne waste. As a result our contract programme became even tighter, by a period of three weeks.

The project involved a variety of different construction disciplines including structural, mechanical, electrical, civil and building works. The programming and planning of concurrent works was critical to the successful completion of this project on time.

HEB Construction relocated a team from our Tauranga based Structures operational division including management and labour to Gisborne for the contract period. Additional labour and subcontractors were sourced locally, thus providing a boost to the local economy. CH2M Beca also had a representative on site to deal with any technical issues.

During the sixty week period we constructed the following elements all within a 200m x 200m site footprint:

- A post tensioned 32.5m diameter precast concrete bio-trickling filter complete with 5000m$^3$ of structured plastic media and covered with an aluminium geodetic dome roof
- Large diameter (900 and 1000mm) rising and gravity mains, installed up to 5m deep in running sands
- Three below ground pump stations PE lined in-situ reinforced concrete pump stations up to 10m deep
- Ground improvement in the form of 1300 stone columns required to stabilise the building and Biofilter foundations against potential liquefaction
- A fully furnished Control Building embracing all the building trades including HVAC and MCC room
- A Pre-treatment Building from precast concrete panels including a high level gantry crane, milliscreens, grit classifier and screening dewatering units
- Biofilter and odour control
- Mechanical and electrical instrumentation and controls
- Commissioning of all processing systems.

The majority of the insitu concrete works specified specialised concrete protective products such as PE Liner and SikaProof Bentonite. The PE liner was specified to protect the concrete against sulphide attack and was detailed in the following locations:

- All of the below ground pump stations
- Sewage conveyance channels within the Pre-treatment Building, vortex grit chamber and flume
- All wet wells that are in contact with raw or partially treated sewage

SikaProof Bentonite was used to prevent water penetration through the deeply founded concrete footings and ground floor slabs in the Pre-treatment and Control Buildings. The bentonite also provided protection from any chemicals in the surrounding soil.

Before the construction stages and throughout the project HEB worked closely with the PE liner supplier and welder, Agru New Zealand Ltd and the SikaProof Bentonite supplier and applicator, Conspec Construction Ltd. Together we solved issues such as:

- Connection details between these products, the Fibre Reinforced Plastic (FRP) pipes and other penetrations
- The Logistics of installation and access
- Health and safety issues such as working within confined spaces
- Ensuring the working conditions were suitable for these products to achieve optimum performance.

Our challenge as the Contractor was to ensure that all of these solutions were carried out successfully and that the application of the product complied with the specifications.
The work was planned in meticulous detail in order to maintain progress in line with the contract programme and to prevent delays to other follow on trades and subcontractors.

Figure 2: Gisborne Wastewater Treatment Plant during Construction, 200x200m site footprint

PE LINER

PE liners were specified for the project due to the corrosive nature of the gases produced by the sewage. Septic conditions would be produced, particularly as the upstream reticulation system has a relatively long detention time. The liner was designed to improve the durability of the large underground pump stations and concrete channels within the works.

At high temperatures the sulphur compounds in the sewage are reduced by anaerobic bacteria to form hydrogen sulphide ($H_2S$). This gas once in contact with the concrete surface undergoes an oxidation process due to the anaerobic bacteria producing a weak but destructive sulphuric acid.

PE Liner is a thermoplastic lining cast onto concrete surfaces during construction to provide a barrier against this sulphuric acid attack. The liner has a high resistance to chemical, biological and gaseous attacks.

The PE liner is cast onto the concrete surface during construction. Mechanically anchored studs applied to the liner during manufacture provide a bond between the liner and concrete to prevent pull out.

The PE liner specified and used was PE Agrusafe 3mm black liner with 13mm studs. CH2M Beca selected this product in preference to an alternative protective coating system, as a result of previous bad experiences with post applied coatings. Specifications of coatings such as coal tar epoxy were based on an over optimistic service life estimate from the manufacturers and the final application often contained pinholes resulting of failure of the system.

Access for remedial work, maintenance or reapplication of the coatings would have been almost impossible once the Gisborne plant was operational. Coatings normally require a dry, well ventilated space for application and for the concrete to be prepared with laitance or damage concrete removed back to sound concrete. Due to the tight discharge consent conditions and plant design, it is difficult to bypass some sections unless in a storm or other emergency situation. Even then some areas such as the inlet channel and storm overflow screen cannot be bypassed at all. Beca also had previous experience with the PE Liner system from past projects on milliscreening plants and wastewater treatment plants in Napier and New Plymouth but to a lesser extent than required at Gisborne.

The PE liners were cast onto the internal concrete faces of the walls to the three below ground pump stations and to the underside of the precast lid panels. The liner was also used on the internal walls to the Pre-treatment Building, grit separation and flume channels.

The largest of the three pump stations was the Outfall Pump Station. This measured 10m x 10m x 10m deep with 800mm thick external walls. We constructed the pump station in three vertical wall lifts as we progressed to the top. The outer 800mm thick walls were poured first followed by the internal walls.

Wall shutters were fitted with PE Liner prior to being installed. Attention to detail was needed when fixing the standard sheet size of 4m x 2m. The more we could utilise a full sheet the less insitu welding was required. The fixing of liner also involved placing end profiles and

Figure 3: Pre-treatment Building Screened Effluent Channel, PE liner
joining strips (Tear off Profile) again to minimise the amount of insitu welding.

![Figure 4: Agrusafe End Profile](image)

To connect the liner to the 3.6m x 3.6m timber shutters we used panel pins on the outer 20mm border of the sheet. This would ensure that the small holes left after stripping the shutters could be sealed by an overlaying strip. This was installed over the joints between sheets and welded to each sheet.

![Figure 5: Agrusafe Tear Off Profile](image)

Once the shutters were installed and concrete poured, the shutters were be stripped. The PE liner was then have to be cleaned and water blasted so that welding could take place.

Experienced and trained PE welders carried out the welding of each joint in the liner. A hand held extrusion welding machine was used to weld the joints. During welding, the operating temperatures were measured using an infrared thermometer to verify no temperature drop occurred that would have indicate a weaker weld.

Welding of a joint was undertaken in continuous weld lengths. This was only limited by the height of the access scaffold installed. The PE Liner was joined by using a hot gas extrusion welding machine that applied single V or fillet welds. The extruder would be filled with welding filler material, which was an identical material to that of the sheet being welded. The welder heated this filler material until plasticised. This was then be applied to a welding groove by welding shoe via a nozzle on the end of the gun. The joint on the sheet would be heated by hot air from the gun and again plasticised. Once this reached welding temperatures the filler material was applied to form a seal between the two sheets.

Following the DVS 2225 Technical code the temperature was measured to ensure optimal conditions were met. The hot air temperature used to heat the sheet joint needed to be in a range of 250-300ºC and the extruder temperature needed to be in a range of 200-230 ºC. During the welding on each joint the welders measured temperatures to ensure they were in the above range.

After a run was completed a High Frequency Spark Tester PPM MK 3 tested the weld. A failure would be marked and repaired immediately. For overlapping welding, this was tested using a vacuum box with gauge and vacuum pump. Again these failures were marked and repaired immediately.

**CONSTRUCTION CHALLENGES – PE LINER**

**Thermal Shrinkage and Stretching**

After the PE liner had been secured to the shutters with panel pins, large thermal movements were noticed as a result of changes in ambient temperature, particularly between early morning and afternoon. This situation coupled with the additional heating from the sun, was made worse by utilising black material. A sheet of the PE liner would expand and contract by a maximum of 50mm. This movement would be enough to remove the panel pins and detach the liner from its joining and end profiles.

This resulted in us spending an excessive amount of valuable time to remedy the movement and ensure good connections with joining strips. This exercise was relatively easy to undertake when the shutters were not in place. However the size of the structures that we were casting meant that the shutters were in place for a number of days.
Figure 7: Thermal Shrinkage of PE Liner installed on timber shutters

We found that the change in overnight temperatures would result in the liner moving from its fixed position. Once shutters were in place there was little we could do to remedy this situation apart from lifting the shutters out and re-fixing, adding more pressure to our contract programme. Thermal movement would also be caused by the concrete temperature rise during hydration of the cement in the concrete setting process.

We also discovered that at joints where the liner stretched and abutted with another sheet, there would be buckling in the sheets and the liner would be bulging inwards, reducing concrete cover to reinforcing steel. We attempted to address this bulging by our placing method of pouring the concrete around this location. We forced the ‘bulge’ back to the side of the sheet while maintaining good concrete placing practices.

This degree of thermal movement dissuaded us away from using the propriety 5 to10mm joining strips.

Figure 8: Outfall Pump Station - PE Liner gaps at joints

We therefore modified how we fixed the PE sheet to the shutters in consultation with the supplier. Two sheets would be butted up to each other, meaning an overlay of liner would be required to join sheets. This process required two fillet welds and twice the amount of work per join. We believed this was a necessary step to take as the time required to remedy the movement was too great and impossible once the shutters were installed. The consequence of this was that the PE welder would spend longer welding each connection, consuming valuable additional time which we could not really afford within our construction program.

Pipe Interfaces

Although PE liner was specified in the design there were few details provided for the interface with GRP pipes and steel pipe lines which entered the below ground pump stations and the Pre-treatment building channels. Representatives from the HEB team, CH2M Beca and the PE liner supplier, Agru, worked together to come up with effective solutions.

The selected solution was to use a fabric backed liner that could be glued internally or externally to steel or GRP pipes. Depending on the size of the channel and the diameter of the pipe, the external or internal option would be installed. The preferred option was for the external band which reduced any negative effects on the hydraulics of the plant and possible grit / sediment wear on the internal strips.

Initially we would glued the fabric back liner onto the fabricated steel pipes before installation. However we found it difficult to get this to line up with the PE liner on the concrete walls. This meant we often had to remove and reinstall the fabric backing strips, causing lost time on installation.

Where possible we accordingly glued this fabric backed PE liner to the pipe once it was installed. This would ensure it was positioned in the correct location and decreased the amount of rework for each pipe penetration.

Welding Joints and Sealing

The PE welders were based in Auckland and due to our construction methodology it was not feasible to get them to mobilise to site after each concrete pour. This would have required the welders to physically work below the form workers who were preparing to pour another lift of the walls. This introduced an unacceptable safety hazard within these confined spaces. With such a tight construction programme we had no alternative but to proceed with the construction of the pump stations and leave the PE liner welding until after construction was complete.

All the pump stations and Pre-treatment building channels were classified as a confined
space. All operatives including welders were required to be Confined Spaced and Gas Detector trained in order to enter. After construction had been completed within these areas, access platforms would be re-installed for the HDPE welders. Daily confined space permits were issued with gas detectors and a trained watch person. A HEB operative would be the confined space watch person and often there were three or four confined spaces operational at one time. This would add more pressure on the available labour resources.

The amount of time that was required to weld and seal each pump station and channel was considerably more than was initially programmed. This was further exacerbated as for the pump stations in particular as the concrete works had to be completed before welding could start. The previously described movement in the PE liner meant that most joints required an overlapping strip which needed two welds. We also experienced delays due to wet weather as welding could not take place if the surface of liner was wet.

All of these factors added pressure on the already tight construction programme. We improvised by using large tarpaulin drop sheets over the pump stations and worked seven days a week in order to complete areas faster. We also requested the welders to mobilise additional crews and HEB opened up access to other areas. Obviously this meant scaffold and access had to be provided and shifted on a regular basis which proved an expensive exercise. It also required constant supervision and communication with scaffolders.

There was no way of seeing whether there were any imperfections in the concrete placement which was concealed behind the liner.

There is a potential for the PE studs to pull out from the concrete substrate due to the high hydrostatic pressure caused by the depth of the pump stations. At the construction joints in between each wall lift, the cold joint is reliant on good preparation of previously poured concrete and setup of the hydrophilic waterproofing profile and sealant. At these locations with a high external ground water table there is a risk that water can make its way through the construction joints creating pressure behind the PE liner increasing the potential of “pull out” from the concrete.

At the beginning of the project our experience with PE liners was limited. We did however identify that the installation of this product was likely to cause added pressure to the contract programme. In the initial stages of the project we suggested an alternative solution of adding concrete admixtures like Microsilica and higher cement contents to the mix design to slow the rate of hydrogen sulphide degradation of concrete. Unfortunately due to the tight programme the design management team had very minimal time to adequately investigate this approach.

**SIKAPROOF BENTONITE**

The footings and ground supported floors of the Pre-treatment Building and Control Building specified a product called SikaProof Bentonite. This is a waterproofing system for reinforced concrete structures. Bentonite is a Geosynthetic Clay Liner with high strength fibres that are thermally locked to provide good self-confining properties.

SikaProof Bentonite prevents water penetration through the concrete and protects the concrete against chemical attack from the surrounding soil. This product carries a warranty for 20 years when installed by Sika NZ Ltd approved and trained applicators. The product has a self healing membrane which swells when wetted and seals cracks that form in concrete. According to a BRANZ Appraisal it meets the New Zealand Building Code Clause E2 External Moisture by having a vapour flow resistance not less than 90MN s/g (mega-newton seconds per gram).

The bentonite in this application is typically installed on a 50mm site concrete layer that is free from any standing water. The concrete formwork is required to be in place as the bentonite is applied up the walls/sides of the footings. The yellow non-woven side is
installed so as to be in contact with the concrete. Before installation, the site concrete and shutter surfaces were checked to ensure they were clean and smooth with no loose materials, oil, grease or any other substance that may harm the waterproofing capacity of the product.

The transition between horizontal and vertical surface requires a 40mm SikaProof Bentonite Paste fillet to be installed on all internal corners. The vertical sheet is fixed by light nails or staples to the shutters. After the shutter is stripped nails are removed with the formwork. The Bentonite will then swell when wetted and seal the penetrations left by these fixings.

To ensure water-tightness is achieved at joints a 150mm overlap is required with SikaProof Bentonite Paste applied entirely over the overlap region. Roll ends are overlapped by 300mm and staggered. Floor to wall laps require 350mm overlap with the paste required to completely close the joint, which is then also lapped in the down stream direction of flow from external ground water.

After installation of the bentonite to shutters the pre-tied reinforcing cage would be installed. The bentonite had to be protected from rain. Rain and pooling water could lead to premature hydration of the bentonite and potential damage.

After the concrete was poured and the shutters stripped, but before backfilling, a termination bar would be installed 100-150mm below the finished ground level / tanking line. The termination bar would prevent any material getting in between the concrete and bentonite. This termination bar would be fixed at 300mm centres around the perimeter of the concrete footings.

CH2M Beca specified this waterproofing product based on previous jobs and its capability to self heal. They opted for this type of waterproofing over a paint applied coating due to the accessibility issues and to reduce the amount of rework. If the paint applied to a concrete panel or footing cracks it is no longer waterproof at this point. If the Bentonite product is damaged it has the ability to self heal, thereby not jeopardising the waterproofing capacity. Beca did specify a water proofing admixture called Sika 1 for the precast panels on site, however opted for the Bentonite for the foundations.

**CONSTRUCTION CHALLENGES – SIKAPROOF BENTONITE**

**Pre-tying Reinforcing**

Formwork had to be installed on site concrete before bentonite could be installed. This required the shutters to be level and to finished concrete height before reinforcing was installed. For the deep footings of the Pre-treatment and Control Buildings reinforcing would be pre-tied in sections prior to installation.

This process required a lot of additional work. The detailing of reinforcing was done to ensure that our construction method and pre-tying would be successful. The footings would effectively be set out twice, once for shutter installation in the permanent location and once for reinforcing tying. Dimensions were checked as each length of footing was being tied, to ensure correct lengths, widths and reinforcing cover were achieved. The Control Building footings were stepped which resulted in depth changes up to 1200mm in places. This meant this had to be mirrored when tying was taking place.

The reinforcing cages for the footings were pre-tied in large sections and lifted into place. Due to the size of the Control Building footings the entire reinforcing cage could not be lifted in at once. We therefore split the cage at the nearest lap and lifted it into place in sections. This required end walls of shutters to be removed slightly to allow room for cage lapping bars to be slewed and threaded into place. This was a very challenging and time consuming exercise. It would also require the bentonite to be re-fixed before the shutter was put back into final position. Care was needed when installing reinforcing cages, as the tolerance between cage and shutter was the 75mm cover to reinforcing steel. Damage to the Bentonite on the shutters would require the cage to be removed and bentonite re-fixed.
Wet Weather
The installation of the bentonite could not be undertaken in wet weather. Programming of the installation was therefore done not only on productivity of site work, but included consideration of the weather forecast. The applicators also travelled down from Tauranga so continuity of work was required in order for their visit to be productive and cost effective.

Good weather would play a huge part in ensuring the construction programme for these buildings was met. Being one of the wettest winters Gisborne has had for a long time, did not help. Once site concrete was poured, formwork installed and reinforcing pre-tied, no other progress could continue on footings until the bentonite was installed to the shutters. The weather would often cause major delays in programme and with no inclement weather days permitted within the Resource Consent requirements, this time had to be made up.

After installing large sections of reinforcement, a great deal of setup work was required before the footings could be poured. If the Bentonite got wet or water pooled within the footing shutters this would cause premature hydration of the Bentonite. This would require the bentonite to be replaced before pouring concrete. To prevent this from occurring and causing major programme delays polythene drop sheets were installed and covered the entire footing footprint. This prevented the Bentonite from getting wet. However on the numerous wet days we encountered on site this would slow progress on these footings as polythene sheets could not be lifted for long periods of time at the risk of wetting the Bentonite.

Approved and Trained Applicators
We used Bentonite approved and trained applicators from Conspec Construction based in Tauranga. To ensure the applicators were optimally utilised on site and to minimise undesirable remobilisation costs, large areas of bentonite work would be prepared so the application was as continuous as possible. This would often mean construction work of footings and floors would be on hold until the Bentonite was installed. Intricate reprogramming of other trades and subcontractors and optimisation of site labour was required to alleviate any impacts on construction programme.

Termination Strips
Before backfilling the concrete footings of both the Pre-treatment and Control Buildings a termination strip would be installed. The termination strip was 2-3mm thick zinc plated steel that was fixed at 300mm centres. The majority of the footing was backfilled directly after the pour, however the termination strip was still exposed until final site level and landscaping was done.

Construction activities around these strips would cause added pressure on the strips causing them to come loose. Before final site backfilling and levelling these strips were
repaired to ensure no material could get between the Bentonite and the concrete.

**PERSONAL PROJECT EXPERIENCE**

Being Project Engineer on a job of this size was a fantastic learning curve especially dealing with these specialised products. I had never worked with either before and spent a lot of time going over the details of these products and discussing it with suppliers.

Huge amounts of pre-planning and programming of other trades and subcontractors was undertaken to ensure installation of these products occurred on the required dates. I was often dealing with four to five different areas of work which required these products to be simultaneously applied to ensure that the construction programme was met. Arranging scaffold access, confined space permits and labour was planned day by day. The site team and I dealt with construction challenges involving these membranes daily. We used initiative to solve them immediately in order to mitigate any delays.

**CONCLUSION**

The Gisborne Wastewater Treatment plant was successfully commissioned and operational on 28 December 2010, three weeks ahead of programme and three days before the Resource Consent expired. The degree of delays and challenges we had to overcome made it a fantastic achievement by all involved. The people, communication and teamwork demonstrated by HEB, Client Gisborne District Council and the Engineer CH2M Beca ultimately provided the recipe for success.

Both the PE Liner and Bentonite products are definitely useful in their own rights. However their use needs to be weighed up with the constructability of these concrete structures especially when required to be done at a rapid pace. The specialised applicators and welders limit the availability of resources to an isolated location such as Gisborne. Additionally this weather dependent work did have a huge impact on the construction programme.

In terms of providing hydrogen sulphide protection to concrete surfaces, I believe that further investigations into the design of sulphide resistant concrete mix would be valuable. Additions of waterproofing admixtures such as Sika 1 will also help to resolve the constructability issues experienced with the installation of the Bentonite.

The construction process required for the PE liner and bentonite dictate that we can not assess the concrete quality, as it is visibly hidden by these membranes. The large labour cost and time penalties involved with installation of these membranes also well offsets the initial material savings.

I believe a suitable admixture inclusion into the concrete mix design could effectively replace these products. However we must remember whatever the outcome it needs to be both constructable and durable so that it can deal with the harsh environment of a wastewater treatment plant. As in Gisborne’s case access for rework or inspections is almost impossible once a wastewater treatment plant is fully operational and bypassing treatment for isolations to various areas is not acceptable.