‘Stitching up’ the past – The strengthening of three heritage marine structures in Jersey with needling technology

The three structures are the North Pier and South Pier of St. Aubin’s Harbour and the St. Aubin’s Fort Breakwater. Both structures are exposed to waves from the south west and act as breakwaters. Both structures have suffered ongoing failures or unacceptable movements during the past decades, on the inner sheltered side of the breakwaters.

In 2001 the North Pier was assessed as being in a state of instability due to movement of its internal wall and apparent settlement of the interior of the pier. The deck level of the North Pier is surfaced in asphalt which waterproofs the deck but also masks (to a certain extent) masonry movements. Large cracks however had developed and could be seen in the asphalt indicating a threat of impending wedge failure of a section of the inner wall.

St Aubin’s Fort Breakwater has in turn suffered a re-occurrence of masonry movements and loss of pointing at its inner, lower deck wall. In 2008 a bulge was also identified in part of this inner wall which prompted concerns about this part of the breakwater’s structural integrity.

North Pier - cracks at deck level

Strategy for Repairs

Many options were considered in 2005 to protect and strengthen the North Pier. The basic engineering solution of constructing a foundation on the outside of the existing alignment and then rebuilding the inner wall on this new foundation was the initial solution favoured. However, the rebuild proposals were not endorsed by the States of Jersey Planning and Heritage Departments, who asked for a ‘tying in place’ solution to be investigated for stabilising the inner wall. Environmental concerns regarding the endangered mollusc species further reinforced this argument.

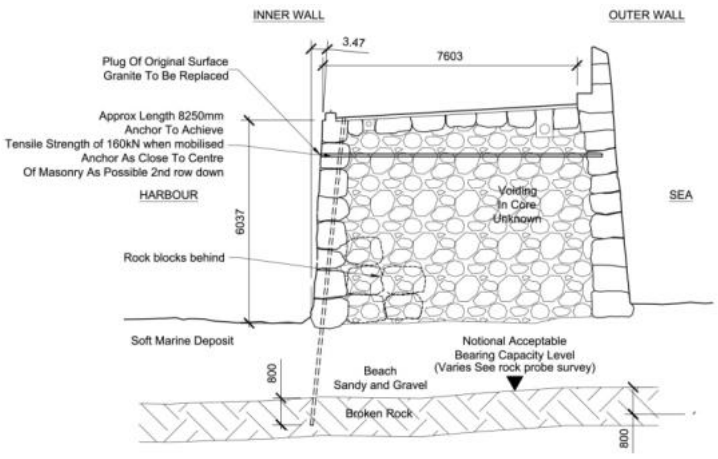


Figure 12 - Cross section of North Pier with stitching anchors

The chosen ‘stitching’ solution used Cintec anchors consisting of a number of solid stainless bars contained within a fabric sleeve injected with cementitous grout after positioning. The bond of the grout that seeps through the fabric sock used in the anchor between the masonry and the reinforced anchor is very high tying areas of loose masonry blocks together. This ‘stitching’ methodology was also able to provide a foundation solution; the numerous small diameter vertical anchors become mini piles when drilled down through the granite wall stones, through the beach deposits and into the Jersey rock shale beneath. The natural arching of the masonry blocks between mini piles at beach level then provides significant underpinning support to the existing mass granite masonry wall over and above the sea bed level materials.

To resist the inner wall overturning, after pinning the base of the wall with vertical mini piles, requires a form of top restraint in the outward direction (Figure 12). The final design consisted of horizontal ‘passive’ ties from the inner wall to the outer face although inclined raking anchors through the core of the Pier tied into the Jersey rock shale were also considered.

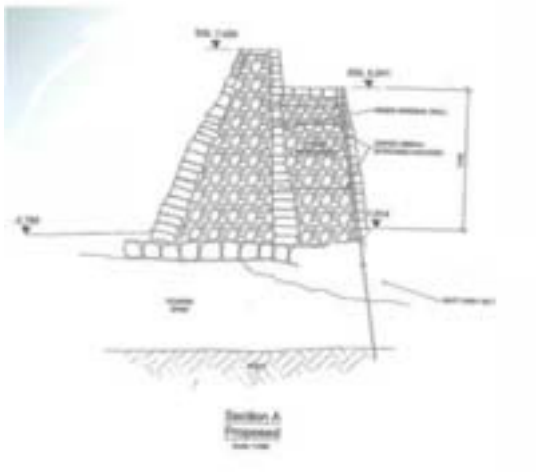


Figure 13 - St. Aubin’s Fort inner wall ties and mini piles

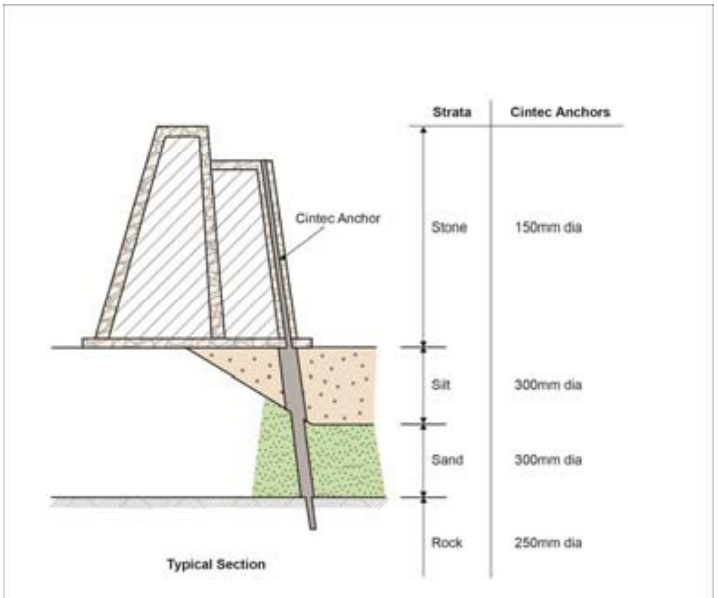
The budget was focused upon dealing with the bulging section only. The engineering options considered were:

- Partial rebuild and removal of cementitious grout;
- Take down and partial rebuild in sections;
- Mini-piling to provide an effective inner foundation;
- Reduction of wave energy forces on the outside face of the breakwater – rock armour;
- The ‘stitching’ option repairs and strengthening.

The quality of the grout that was pumped into the end of the structure in 1972 was found (in 2009) to now be of deteriorating variable quality and consistency. However, it was not thought pragmatic or cost effective to dismantle this end of the lower deck structure and rebuild it in its original form, whilst the ‘stitching’ anchor solution provided clear benefits allowing the structure to be anchored and stitched together without changing its character and with minimal impact.

In order to optimise the number of anchors, an iterative process was used, finding the optimum spacing to satisfy the onerous load criteria imposed by the sea conditions in such an exposed location. Horizontal ties were inserted through the inner wall of the main breakwater so that the inside face wall of the lower deck was not only tied to the inner bulk of the original wall but also had additional cantilevered ‘beam’ support.

Another design philosophy applied in the design of both structures repair works was that within the weaker strata such as sand, this grout injected anchor/pile system expands, reducing the potential for buckling and increasing skin friction.



Implementation

Not only did the final design solution comply with the planning authority requirements, it furthermore mitigated pollution control concerns by the 'sock' principle of the anchor system where the grout is contained within a small radius of the sock diameter. Only a small surface area of grout oozes through the sock material to bond to the adjacent substrates and when cured, forms a concrete skin over the 'sock' material (Figure 16 before grouting injection/Figure 17 after grouting injection). This way the repair works to the three structures were wrapped into one project, realising benefits in terms of cost and programme and lessons learnt from the trials.

Figure 15 - Anchors with coupler

Figure 16 - Pre-injection with masking tape

Figure 17 - Anchor expanded

At the North Pier the vertical drilling works for the anchors took place through the inner wall concrete up-stand used for vessel mooring. Plugs in the masonry were reinserted to enable invisible fix (such as that shown in Figure 20) once the anchor had been installed. The supplier utilised standard 2.5m anchor lengths for both structures, coupled together to achieve vertical and horizontal lengths as required (Fig 15). Another valuable aspect of the installation process was that each individual anchor drilling provided its own borehole information. This allowed the length of the anchors to be reduced where, for example, the rock outcrop was found to be at a shallower depth.

Figure 19 - North Pier vertical drilling

Figure 20 - Anchor with plug cap replaced, 'Secret fix'

From a large machine platform aided by localised, demountable scaffolding the horizontal anchors were drilled and fixed (Figure 19). The number of verticals and horizontals at the inner wall of the Fort Breakwater required careful setting out to avoid conflicts and also to allow for flexibility with respect to deck positioning of the rig on the structure. In-situ vertical load tests took place on the anchors to confirm design assumptions, configuration and spacing of the anchors. The storm events at St. Aubin's Fort in December 2010 coincided with high tides, so the contractor re-focused upon the St Aubin's Harbour North Pier work, another advantage of having wrapped both works into one. In February 2011 they remobilised back out at the Fort Breakwater.

Figure 19 - Fort horizontal drilling

Conclusion

The ‘stitching’ method used to stabilise and strengthen these two marine heritage structures has proved to be effective on a number of fronts. The ‘secret’ or ‘hidden’ fix of the structure means that the heritage planning aspects of the strengthening works are achieved. The predicted wave pressure paths and loadings were analysed in an empirical way to maximise the effectiveness of the solution in areas of local maximum distress.

Environmentally, the impact on the endangered mollusc species is now negligible and the risk of grout spillage is low. Economically, the costs budgeted for the original rebuilding of the inner wall of the North Pier on a new foundation, were of a similar magnitude to that for the ‘stitching’ techniques. There is a certainty with respect to the capacity of each anchor or mini pile as the drilling technique means that every element’s bearing capacity is known and recorded. The technique therefore proved itself adaptable to the engineering judgements so necessary in this type of work; effective in terms of providing strengthening and repairs to threatened parts of heritage structures; and cost effective.