INNOVATIVE COASTAL CLIFF STABILISATION - THE SCARBOROUGH CLIFFS STABILISATION PROJECT

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ABSTRACT
Coastal cliff erosion and retreat is a common problem worldwide. Long-term erosion due to natural coastal processes have caused the iconic vibrant red cliffs of the Redcliffe peninsular (Scarborough, Queensland, Australia), to retreat landwards, which posed a potential risk to public safety and infrastructure (Figure 1).

Figure 1 - Image of the iconic Scarborough Cliffs (pre-works)

Investigations into coastal processes and geotechnical conditions at the site found that the retreat of the 320m long section of cliffs was largely driven by the slow notch erosion of the cliff base resulting in translational block failure of the overlying laterized cliff face and rotational collapse of the weaker cliff crest soils (Figure 2).

Figure 2 - Typical example of notch erosion along the base of the cliffs

The Scarborough Cliffs Stabilisation Project, initiated by Moreton Bay Regional Council (MBRC), sought to provide erosion protection for the cliffs to prevent further retreat, but also retain the natural, iconic aesthetic and public amenity of the cliffs as much as possible.

A conventional rock armour revetment solution was considered but was found to have significant negative impact on the aesthetics of the cliffs and constrained foreshore accessibility. In order to design an effective solution that was suitable for the unique site conditions and better met project objectives, innovative and alternate site-specific options were developed by ICM with MBRC engineers.

To prevent continued notch erosion of the cliff base and subsequently improve the overall stability of the cliffs, a 'lower cliff hardening' solution was developed. This solution comprised of a coloured and textured, soil-nailed, glass-fibre reinforced polymer reinforced shotcrete wall, which aimed to replicate the natural form and aesthetic of the existing lower cliff (Figure 3).

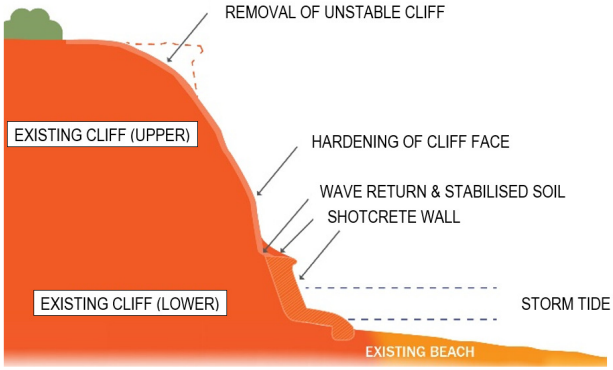

Figure 3 - Diagram of the overall adopted solution including the shotcrete erosion protection wall

The wall included a 'bullnose' wave return with a similar shape to the natural notch erosion at the base to reduce overtopping and reflect wave energy in a similar nature to the existing conditions. The drainage system was comprised of conventional vertical strip-drains and PVC weep holes to release water from the cliff. However, given the walls exposure to wave impact and inter-tidal location, a geotextile wrapped 'bladder' of drainage aggregate was included to dissipate potential wave driven water flowing up through the weep holes and prevent loss of cliff sediments and subsequent notch erosion behind the wall.

Small and large-scale in-situ trials were undertaken by ICM to develop suitable colour profiles for the shotcrete

solution and confirm an appropriate texture could be produced.

The design also included the option to raise the crest of the wall in the future to adapt to long-term sea level rise. To improve the aesthetic of the upper portion of the cliff and increase stability and safety, additional 'upper cliff stabilisation' works were also investigated and developed by ICM with MBRC engineers. These works were comprised of reprofiling of the upper cliff, removal of unstable vegetation, and application of a soil binder to improve the resilience of exposed weaker soils. It has been accepted that the upper cliff faces will need ongoing maintenance to preserve the red earth appearance.

Given the eroding nature of the site, an assessment of the cliffs was undertaken, including a geotechnical stability inspection, prior to commencement of the construction works. This assessment aimed to identify any changes that may have occurred due to recent erosion to the cliff stability and profile, including notch erosion, translational collapse and loss of vegetation. The design and construction methodology were then reviewed and amended as required.

Severe notch erosion was observed in two sections along the cliff extending up to 1.6m into the base of the cliff (Figure 4). Treatment including removal of the overlying material, shotcrete filling of the remaining notch and incorporation into the shotcrete erosion protection wall.

Figure 4 – Severe notch erosion observed at the base of the cliff prior to commencement of works

The construction works were staged as follows: Preliminary works to make safe the site, including removal of near-vertical, negative slopes and undermined vegetation; Re-profiling of the cliff base where the shotcrete erosion wall is to be constructed; Installation of grouted GFRP soil nails, drainage and GFRP mesh reinforcement; Removal of any loose materials, such as sand, gravel and vegetation; and Layered application of shotcrete to design wall profile. The completed structure achieved a colour and texture similar to that of the existing cliff, whilst retaining the beach width and iconic aesthetic of the cliffs (Figure 5.

The tender to construct the works was awarded by MBRC to Australian Marine & Civil Pty Ltd and the works were completed in March 2020.

Figure 5 – Image of the completed works

Several storm events have occurred since construction of the works was completed, which has provided an opportunity to observe the performance of the structure against wave conditions that would have previously contributed to notch erosion at the base of the cliff. (Figure 6). Post-construction monitoring shows the works are performing well and are successful in protecting the lower cliff from further erosion to date. The shotcrete wall remains well integrated with the cliff face. The design and construction challenges of this project, including detailed discussion of the adopted design solution, and the performance of the completed works, are presented within this paper.

Figure 6 – Reflection of wave attack during a spring tide event (March 2020)

Monitoring of the works is on-going to further evaluate the performance in protecting the iconic cliffs from further erosion and to determine the maintenance requirements and extent of future adaptation options to address long-term sea level rise and climate change.