CONSTRUCTION OF A TOE DRAINAGE STRUCTURE AT CABBAGE TREE HARBOUR

Andrew Pearce, Tim Burch (Wyong Shire Council), Lex Nielsen (WorleyParsons)

Abstract

The Toe Drainage Structure (TDS) at Cabbage Tree Harbour (CTH) represents one of the few examples of coastline protection works to be constructed by a local government authority on the NSW Coast in recent years.

The TDS was constructed between June and September 2011. The total project cost approx. $1.5 million and was funded jointly by Wyong Shire Council (WSC) and the former Department Environment Climate Change & Water (DECCW) under the Coastal Management Program.

The objective of the project was to replace the existing damaged sub-horizontal drainage scheme installed by WSC some 10 years earlier to reduce the incidence of landslip and improve the safety to beach users in CTH. The TDS is considered an interim solution designed for a 20 year horizon until long-term sustainable options such as planned retreat come into effect as discussed within WSC's Coastal Zone Management Plan.

The innovative design for the TDS was prepared by WorleyParsons (WP) in consultation with WSC and consisted of a sloped rock revetment structure with graded filter layers capable of withstanding a 1 in 20 year storm.

The TDS is considered to have addressed many Ecologically Sustainable Development (ESD) principles via its simple design, use of limited and local natural materials, shorter duration to build and low cost compared with other design options.

This high risk project was constructed using WSC's day labour resources and was completed on time and under budget.

Background

Cabbage Tree Harbour (CTH) is located north of Norah Head on the Central Coast of NSW (Figure 1). The small pocket beach is popular with swimmers, surfers and boat users, but its northerly aspect provides exposure to seasonal storm activity from the east and north-east which has historically resulted in ongoing beach erosion.

Coupled with the storm erosion potential at the site, the site also has complex geological conditions that have attributed to the slope instability at the site. Numerous geotechnical studies have been undertaken at the site, which report the sub strata consists of aeolian sands overlying indurated and cemented sands which in turn overly clays and weathered bedrock of the Munmorah Conglomerate (SCE 2009). There is also considerable seepage and ground water movement through the fore dune system and there is a dyke intrusion that is likely to have contributed to the observed bank instability and failures at the site.

Figure 1: Cabbage Tree Harbour and the Toe Drainage Structure

In 2001 Wyong Shire Council (WSC) installed a sub-horizontal drainage scheme at the north-western end of CTH to relieve ground water flows through the indurated sand dune, to improve stability of the bank and reduce the incidence of landslip. The scheme however was subjected to continuous damage during storms, required frequent maintenance, and was purported to have contributed to the undermining of the slope (Figure 2).

In June 2007 a major storm event hit the Hunter and Central Coast regions of NSW causing significant erosion and damage to the existing drainage scheme. Due to hazards associated with the exposed drainage system, unstable slopes, and unstable property improvements located at the top of the buff, an immediate decision was made by Council to subsequently close the northern end of the beach to public access. Measures implemented to enact the beach closure included media releases, fencing, signage and full time surveillance by Council lifeguards.

To further address the imminent safety hazards for beach users and implications arising from the forced closure of a popular recreational area, a decision was also made by Council to replace the existing drainage scheme with a new Toe Drainage Structure (TDS).

Given the unique environment and coastal processes at the site, the project proved to present considerable challenges throughout the planning, design, and construction phases.

Figure 2: A photo of the original sub-horizontal drainage scheme installed in 2001 destroyed by wave erosion and embankment slippage

Design

Design Objectives

The objective of the TDS was to replace the existing damaged horizontal drainage system with a more robust and cost effective structure that would improve the safety to beach users and provide an interim solution until long-term sustainable options such as planned retreat came into effect at the Site.

The design criteria adopted included:

1. providing a similar drainage function to that of the existing scheme, allowing the cliff face to drain freely without the loss of sand material;

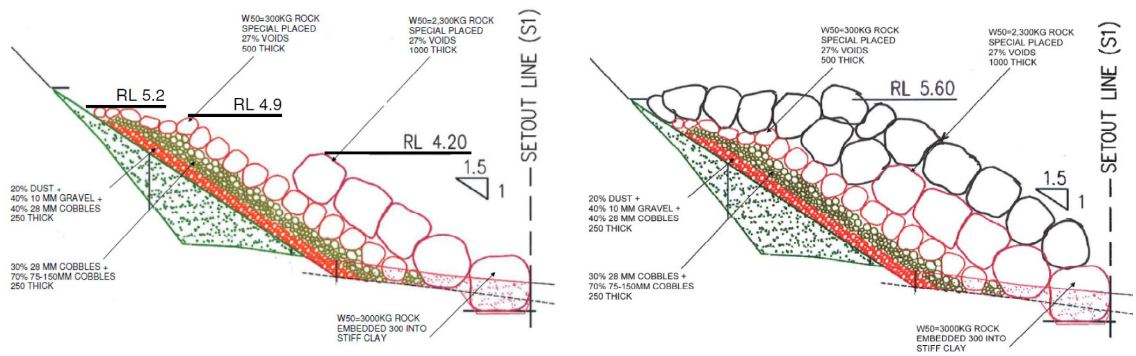
2. providing erosion protection to the toe of the slope including protection from a storm with a recurrence interval of less than 1 in 20 years with minimal damage; and,

3. providing mass at the toe of the slope that would improve the bank stability but not provide global bank stability.

Design Overview

The final design for the TDS prepared by WorleyParsons, consisted of a 110m long flexible sloping revetment comprising layers of graded rock, founded in stiff clay, to ensure adequate filtering of the dune seepage while maintaining an acceptable level of coastal protection using available local quarry rock (Figure 3).

While the mass gravity filter structure was designed to control the release of natural seepage from the hill side above and to enhance its resistance to toe erosion under wave and tidal action, the design does not purport to stabilise the indurated sand dune behind but provides some improvement to the global slope stability of the dune and provides protection to its toe from wave scour.



Stage 1: 0–15 year Design Life **Stage 2: 15–50 year Design Life**

Figure 3: A typical section of the Toe Drainage Structure (WP 2011)

Construction Staging

Due to limited funding the TDS was designed so that it could be constructed in two (or more) stages:

- **Stage 1** – 0 to 15 years design life: Filter layers and under-layer constructed to RL 5.2 m AHD with a single layer of rock armour constructed to RL 4.2 m AHD.

- **Stage 2** – 15 to 50 years design life: A second layer of cover rock armour is added for the 2-layer revetment to reach an elevation of RL 5.6 m AHD.

The staging recognised that the design criteria will increase with time as projected climate change impacts on sea levels progress and, in extending the design life of the structure, the design storm event becomes more intense for the same level of risk of damage.

It is noted that should the amount of sea level rise, being the predominant factor for assessing the design wave condition vary from that assumed in this design, then the design criteria may indeed vary. The final design has been based on a worst case scenario for a 50 year planning period.

Available Rock Material

The TDS was designed using rock materials available from local quarries.

The selected armour and under-layer rock was a rhyodacite available from Boral's quarry at Seaham. The filter layers comprised of basalt from Boral's Peats Ridge quarry.

Both the basalt and rhyodacite have excellent rock properties in respect of wet/dry strength, water absorption, particle density, sodium sulphate soundness and Los Angeles abrasion and are very well suited to this coastal revetment structure.

Non-Conventional Aspects of the Design

With the objective of optimising the use of the available local rock material and keeping the design as simple as possible for ease of construction and to keep costs down, the design of the TDS departs from a conventional coastal revetment design in the following respects:

- For the Stage 1 (0–15 year design life) condition, the rock armour comprises a single layer of D50 = 1100 mm diameter rock (2,300 kg), which is tightly packed to achieve an in-situ density of around 1.9 t/m^3 (27% porosity). The rock armour stability coefficient for this condition has been reduced to 1.4 (in lieu of 5.8 for a double layer placed with the long axis normal to the slope) in recognition of the single layer.

- Likewise, the top layer of the rock armour under-layer comprises a single layer of 500 to 600 mm diameter rock (300 kg), which is tightly packed to achieve an in-situ density of around 1.9 t/m^3 (27% porosity).

- The rock armour under-layer comprises one 500 mm layer of rock overlying a 500 mm graded filter in lieu of the normal 2 layers of uniformly sized rock and often-used geotextile. The total thickness of this rock under-layer is 1000 mm and comprises a single layer of 550 mm diameter rock overlying a 250 mm thick layer of 28 -150 mm diameter cobbles (a combination of 30% of 15–28 mm gravel and 70% of 75–150 mm cobbles) overlying a 250 mm thick layer of 2 to 25 mm gravel (a combination of 20% of quarry dust, 40% of 5–9 mm gravel and 40% of 15–28 mm gravel). Normally, the rock under-layer for this armour would comprise two layers of 550 mm diameter rock, the layer being some 1000 mm thick.

- The extent of damage from a design storm has been accepted at 5–10% in lieu of 0–5%. This allows for a reduction in the design wave height for armour sizing by a factor of 1.08 (CERC 1984).

- For the Stage 1, 15 year design life condition, the rock armour extends to an elevation of 4.2 m AHD, allowing some acceptable overtopping beyond this level given that the slope is protected by 300 kg rock to 5.2 m AHD fronted with a 2 m wide berm.

- For Stage 2 (15–50 year design life), the rock armour comprises a double layer of 1100 mm diameter rock (2,300 kg), which is tightly packed to achieve an in-situ density of around 1.9 t/m3 (27% porosity). The rock armour stability coefficient for this condition has been reduced to 4.6 (in lieu of 5.8) in recognition of the fact that the rock is not of a parallelepiped shape. Also, 5–10% damage is tolerated for the design event.

- As the revetment toe is dug in and founded on firm clay at around 0 m AHD, there is no requirement for a self-launching toe. However, the leading edge of the revetment toe comprises a larger rock than the remaining armour, being a 3 tonne rhyodacite boulder (in lieu of 2.3 tonne armour rock), which is to be keyed into the clay hardpan by 0.3 m.

Construction

Some of the challenges posed with the construction of Stage 1 of the TDS included site access difficulties and working in a dynamic coastal environment. The sole access to the site was via a steep public road leading to a public boat ramp from which access to the beach was attained. All equipment then had to traverse from the southern end of the beach to the north across the intertidal zone. Once on the beach challenges included working around the public, waves, tides, and unstable dune slopes.

The TDS also had to be constructed in full view of the local community, some of which publicly opposed the project. Given all the construction and social issues, Council considered these risks would be best managed using Councils own in-house staff resources complimented with specialist hired plant and machinery as required.

Initial cost estimates and work programs assumed construction staff might be restricted to as few as four hours per day working normal business hours and around tides. Planning for extended work days and out of normal business work hours was made, however staff found once the work progressed they were able to work much longer hours each day than anticipated due to the use of specialized machinery adopted for the works and limited storm activity experienced throughout. Staff also found utilizing the large armour rock to temporarily line the lower section of the beach effective in retarding wave run-up and tidal activity (Figure 7)

Machinery used to construct Stage 1 of the TDS included two 20 tonne excavators working on the beach in CTH to place materials, a 12 tonne excavator receiving and loading materials from a stockpile site nearby in Mazlin Reserve, and three THWAITES 9 tonne power swivel dump trucks which transported the materials from Mazlin Reserve to the beach in CTH as required. The all-terrain trucks were able to work through mid-high tides and proved to be a key factor in delivering the project ahead of schedule and under budget.

In total 780 tonnes of gravel filter materials were used, 365 tonne of under layer armour rock (500 – 600 mm diameter) and 1535 tonnes of outer armour rock (1000 – 1200 mm diameter) Graded filter materials were delivered separately and blended on site in Mazlin Reserve. The blending process and placement of the graded filter layers was undertaken seamlessly and eliminated the need for placement of an additional geotextile layer which expedited construction and eliminated a potential slip plane, which was considered important given the history of slip failures at the site (Figure 4).

The original construction program and cost estimate for Stage 1 of the project was six months and approx. $1.95M. Stage 1 of the TDS instead was completed in four months between June and September 2011, and cost approx. $1.5 million or $13,600/m.

Monitoring

As part of Council's ongoing performance monitoring of the TDS, Council surveyors installed 22 control points in September 2011 along the TDS and at different heights to record any movement overtime of the large armour rock.

In September 2012 a follow-up survey was undertaken. In the 12 months prior there had been moderate storms and Council was interested in confirming whether the large armour stone had moved considerably. The results of the survey confirmed that the structure had only moved a maximum horizontal distance of 26 mm and a maximum vertical distance of 33 mm. This was considered a tremendous result and proof that the structure had been designed and constructed to a high standard.

A second follow-up survey is planned for early November 2013.

Ecological Sustainable Development

The TDS is considered to have addressed many Ecologically Sustainable Development (ESD) principles.

Compared with previous designs for the TDS, which comprised rock filled gabion wire baskets founded on a fibre-reinforced concrete slab and geotextile enclosed gravel drains, the adopted design eliminated the use of foreign materials, such as wire mesh, geotextiles and concrete, relying solely on the placement of natural rock soured from a local quarry.

These design changes led to considerable savings in materials and costs, and the overall timeframe to construct which minimized impacts on the environment, local community and beach users.

The design of the TDS which provided for staged construction also means that the structure can easily be built upon in the future, should an extended design life be required, or in response to changing conditions reducing whole of life cycle costs.

Conclusion and Lessons Learnt

The TDS at CTH represents one of the few examples of coastline protection works constructed by a local government authority on the NSW Coast in recent years.

It's simple yet innovative design relying solely on the placement of natural rock sourced from local quarries has proven to provide a cost effective and easily constructed solution that has met the design objectives and led to reduced impacts on the environment, local community and beach users. In turn, the project was well received by the community who also took a keen interest in the construction phase of the project.

A significant portion of the actual savings for this project were identified during the design phase, and the project highlights the importance of undertaking constructability reviews during the design phase to identify proposed construction methodologies, materials and plant that will be required to execute the project.

When building structures in dynamic coastal environments such as CTH, the project also highlights you need a bit of luck with the weather!

Acknowledgements

All Council staff and sub-contractors involved in the project who did a tremendous job.

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Figure 4: A photo of the placement of the graded filter layers (July 2011)

Figure 5: A photo of the 20T excavators working in tandem on the beach in CTH (July 2011)

Figure 6: A progress photo of the construction of the TDS at north end of CTH (July 2011)

Figure 7: A progress photo taken during one of the few days lost to adverse weather. Note the armour rock used to form a temporary barrier to protect the work (July 2011)

Figure 8: A photo of the completed TDS from beach level looking north (September 2011)

Figure 9: A photo of the completed TDS looking north (June 2013)