PEAK DIFFERENTIAL TIDAL PRESSURES FOR ROCK WALL RECLAMATION AREAS

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DIFFERENTIAL TIDAL PRESSURE

Unexpected differential tidal pressures occurred during construction of a 62 Ha reclamation area at Townsville Port. The reduction in tidal flows through a new rock wall structure was in conjunction with installation of a geotextile membrane. Tidal pressures began to displace the geotextile and cover rock. This paper discusses tide data collected during various stages of construction and how it was used for estimating progressive tide differentials. These estimates assisted with forecasting potential issues.

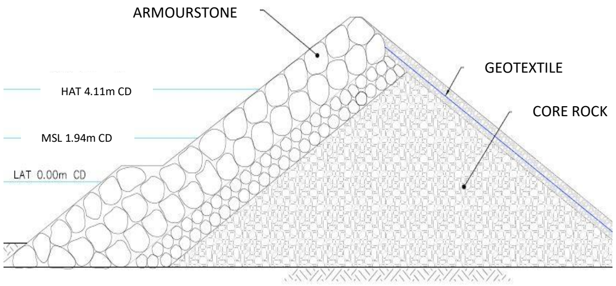
CHANNEL UPGRADE PROJECT

The Townsville Port Channel Upgrade Project has 14km of capital dredging to widen shipping channels. Due to the Ports proximity to the Great Barrier Reef there were significant legislative requirements aimed at minimising the impact on the natural environment. This includes potential impacts on water quality, sea grass and shallow reefs from release of fine sediment. A large reclamation area for placement of 3.4 million m^3 of dredge material was constructed to contain all dredge material, including fine sediment, on a permanent basis.

SEAWALL DESIGN

A rectangular reclamation area was created by building seawalls on three sides, adjacent to the coastline which made up the fourth side. The seawalls were constructed using quarried rock of various size gradings up to 8 tonnes. To prevent release of fine sediment through the rock, a geotextile membrane was installed within rock layers on the inside face the seawall. This is represented by Figure 1 below.

Figure 1. Representation of the seawall



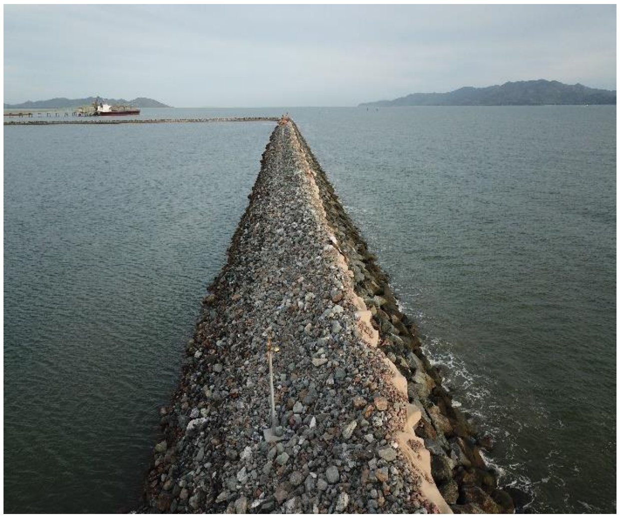
SEAWALL CONSTRUCTION

Construction began with rock placement outwards from two locations on the shoreline, then parallel to the shore, until an enclosed area, approximately 1.1km long and 0.5km wide, was created.

GEOTEXTILE MEMBRANE INSTALLATION

A geotextile membrane was installed progressively, in conjunction with completion of the rock placement work. To ensure a full enclosure, the fabric was placed from the seabed to the crest, along the entire 2.2km length of seawall. The constructed seawall is shown in Figure 2 below, and took approximately 1 year to complete.

Figure 2. The constructed seawall



EARTH FILL PLACEMENT

Dredge material will progressively fill the enclosed area, incrementally replacing sea with land. At the time of writing, dredging and reclamation work was ongoing and expected to take two years in total.

TIDAL FLOWS

There were negligible restrictions to tidal flows to and from the reclamation area when the seawall consisted of rock only. At this stage approximately 1 million cubic meters of water flowed in and out during a typical spring-tide cycle. Subsequent installation of the geotextile had a significant impact on tidal flows, reducing them to about ½ million cubic meters each spring-tide cycle. As work progressed, placement of dredge material continues to reduce the tidal flows. Ultimately all tide movement within the reclamation area will cease.

DIFFERENTIAL PRESSURES

As a result of tidal flow restrictions, sea levels outside the reclamation area differed from sea levels inside. During flood tides the sea level outside became higher, and during ebb tides the level inside become higher. Without geotextile in the seawall, a typical flood tide height difference was about 150mm during spring tides. With the geotextile membrane installed, the difference exceeded 1.5m.

DESIGN DIFFERNTIAL PRESSURE

For the purpose of design, and ultimately for stability of the geotextile membrane, the peak tide differential needs to be known in advance of construction. Geotextile supplier data sheets provide permeability and permittivity values for estimating flow rates through their fabric. However, these values apply to laboratory conditions and parameters become less certain when a fabric is installed. The insitu flow rate is dependent on other construction materials and natural elements. In the case of the seawall, bedding rock on both sides of the fabric and, over time, sedimentation and algal growth will add to uncertainty. Flow rates provided by geotextile manufacturers vary according to the product, and are in the range of 30 l/m^2/s to 45 l/m^2/s for heavier duty fabrics(1) and 15 l/m^2/s for a very heavy duty fabric(2). However, insitu values can be much lower. Recommendations can be found in the range of 5 l/m^2/s(3) to 7 l/m^2/s(4). An overestimation of in-situ flow rates will likely translate to an underestimation of tidal pressure, and potential early failures in the geotextile layer of the structure.

MODDELING

Geo-hydraulic modelling can be used to calculate hydraulic flows through composite materials. This can be applied to a seawall constructed with rock and geotextile layers. A computer based representation of a hydrological system has two key components; conceptualisation and mathematical code(5). Conceptualisation is the idealised representation of the hydrology(5). For this project the latter includes tide values, rock characteristics and geotextile properties. In the case of a reclamation, the conceptual inputs will differ for different stages of construction. For the purpose of design, a value for the maximum design load imposed on the geotextile is required. Determining all parameters throughout construction adds uncertainties within the conceptualised component of the model.

APPROXIMATIONS

Tide data collected during the Townsville Port project has been used to approximate the maximum potential tide differentials for different stages of the project. This was done by gaining an understanding the progressive time gap between high tides outside and inside the reclamation and its correlation with progressive flow restrictions during construction.

TIDE LAG

Throughout construction, tide levels and the tidal lag were progressively measured. Initially the area inside the reclamation experienced similar high and low tides relative to the outside environment. There was, therefore, minimal time lag between the high tide outside and high tide inside. As construction progressed, and flows through the seawall reduced, the area inside the reclamation experienced a reduction in tidal range relative to the outside environment. There was a corresponding increase in time gap between the high tides inside and outside the reclamation.

Analysis of tide-gauge data showed a linear relationship between the progressive placement of a flow reducing homogenous material, and tidal lag within the reclamation. This was used early in the project to identify upcoming issues. Comparison with measured inside levels are continuing as the project progresses.

APPROXIMATE MAXIMUM DIFFERENTIAL

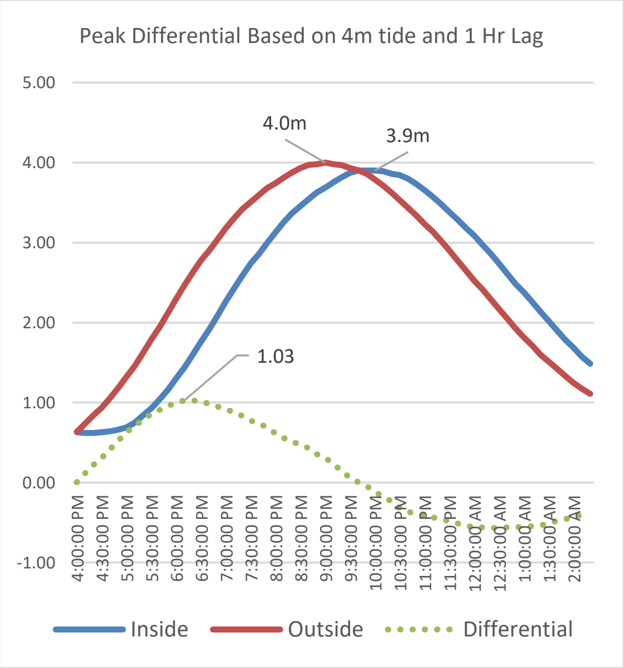
Tidal flows through the sea wall were initially close to 100%. This will progressively reduce to nil. Inversely the tide-lag began close to zero minutes and will progressively increase to 6 hours before ceasing to exist. Approximated tide differentials for the project have been calculated based on a nominated tide and incremental tide lag. The approximate differentials were calculated as follows:

A selected design tide of 4.0m was plotted using actual tide data from the nearest tide gauge, in 10 minute time steps. Various theoretical tides for inside the reclamation were plotted using the function $y=a(\sin(x))+q$, where a is the tide amplitude and q is the average tide level. Values a and q were determined as the design tide value that corresponded with the time lag being assessed. Graphs for three selected time lags are shown in Figures 3, 4 and 5 below.

The peak differential for each tide-lag interval was calculated. As the tide lag increased, the peak differential increased. It is expected as reclamation work continues to advance, the tide differential will begin to decline. Ultimately all tidal flows into the reclamation will cease.

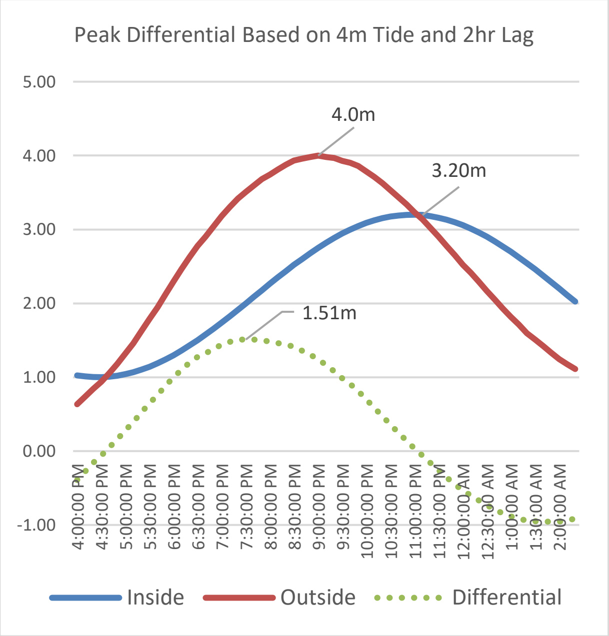
For a 4m tide with a tide lag of 1 hour, the reclamation area peak level was estimated to be 3.9m. The expected maximum difference during the tide cycle is 1.03m occurring about 6.15pm. Refer Figure 3 below.

Figure 3. Inside high tide lags by 1 hour



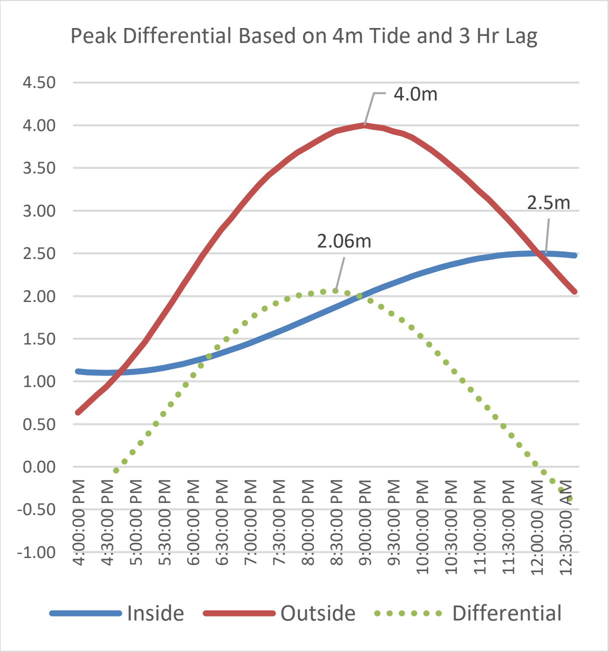
For the same 4m tide but with the tide lag increased to 2 hours, the reclamation peak level reduced to 3.2m. The expected maximum difference during the tide cycle increased to 1.51m. Refer Figure 4.

Figure 4. Inside high tide lags by 2 hours



For the 4m tide and tide lag of 3 hours, the reclamation peak level reduced to 2.5m and the expected maximum tide difference during the tide cycle became 2.06m. Refer Figure 5.

Figure 5. Inside high tide lags by 3 hours



POTENTIAL APPLICATIONS

This method of approximating the maximum differential could be used in conjunction with geo-hydraulic modelling to help validate the model. It can also be used during construction. As dredge material placement progresses (as seen in Figure 6 below) flow rates in and out of the reclamation continue to reduce. Ongoing approximations can be assessed against design parameters.

Figure 6. Reclamation works in progress

LIMITATIONS

The approximation method presented above uses a design tide to estimate the maximum differential. Judgement will be needed to determine an appropriate design tide. For worst case, the Highest Astronomical Tide (HAT) would be used, however, this would likely lead to an overdesign where there is a very low probability of the critical flow reduction coinciding with the HAT. This method of estimation only applies to a large reclamation project, constructed over a long period, e.g. where reductions in flow rates occur across a number of tide cycles.

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