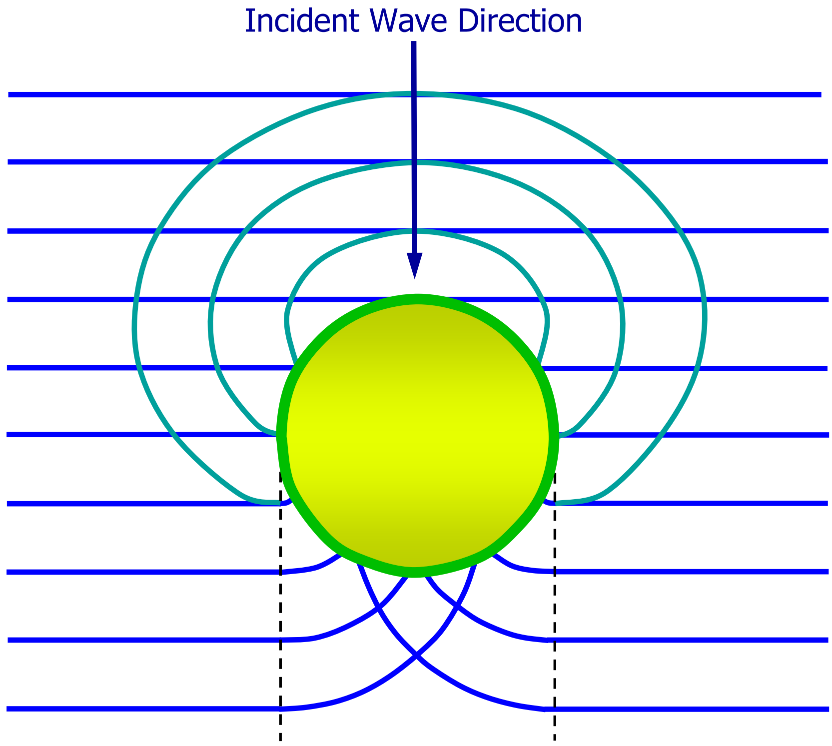
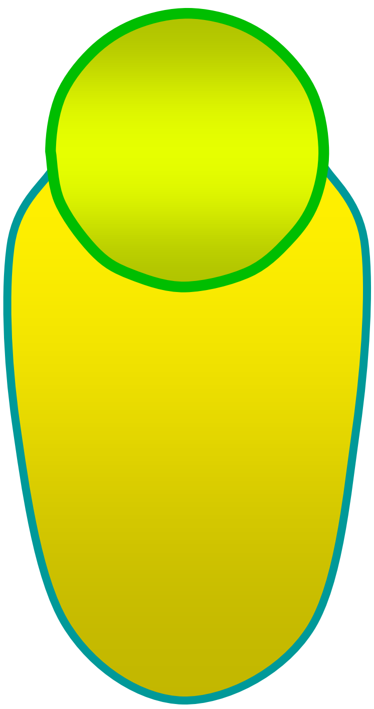
Shoreform Stable Bays

Basic Concept

Shoreform stable bays are created by installing offshore islands with a circular planform. A circular island will disturb waves and collect sediment, principally sand, in the patterns shown below.



Wave reflection and diffraction pattern for cylindrical island



Sediment accumulation pattern around a cylindrical island

The wave-disturbance pattern shown above applies only to a cylindrical island. All waves reflected from the cylindrical wall emerge as ripples, radiating outwards and dispersing their energy as they go. It is only at the wall itself that they must match the height of the incident waves. The dispersion should allow the incident waves to carry any drift sediment right up to the wall on the seaward side. As soon as this sediment reaches the island wall it will be swept from the seaward to the leeward side. The result of this will be the shoaling pattern shown in the lower diagram. Once a shoaling spit starts to form, given sufficient sand, it will continue to grow naturally.

Physical Model Study

Tank testing was carried out to study the sand accretion pattern. The tank was purpose-built with a shoaling beach and drift-recirculation channels to ensure the absence of wave reflection or drift back to the island. The wave basin was 7.0 m long, 3.5 m wide and 0.4 m deep. This represents a length scale factor of 1:100, with time and velocity factors of 1:10. The test island was placed in the centre of an elevated bed, representing the near-shore location of a full-scale artificial island.

Test tank and cylinder viewed from wave machine end

Side view of wave making machine

Development of waves over the shoaling bed

The wave machine was built to produce waves in deep water (240 mm) with a 1-second period (scaling up to 10 s) and a deep-water height of 40 mm (scaling up to 4 m). Linear theory predicts an increase of height to 50 mm in the passage from deep water over the shoaling bed to the 45 cm depth at the test shelf. The breaking height at this depth is estimated to be 38 mm and waves were observed to break just upon reaching the test shelf, exhibiting a final height of 40 mm over the test shelf. This was enough to move the sand and thereby model sediment accretion patterns. The shoaling bed proved effective, in that it enabled the short-period wave components produced near the wave machine to feed their energy into a simple 1-second swell over the test bed, similar to the way that swell develops in the sea. Any waves passing the model island were dissipated over the 1:20 beach just beyond the test shelf. Over the test shelf, the waves produced a substantial drift current that was allowed to recirculate back through the side channels to the wave machine. The pumping action of the wave machine was designed to match the drift.

Sand Movement Pattern

The sand movement pattern for the model cylinder confirmed expectations. The first step in examining this pattern was to place a layer of sand just seaward of the model island. This could represent drift sediment brought by ocean swell to the island from a local offshore bar, produced by erosion of beaches further upcoast. In the absence of such drift, it could also model sand placed seaward of the island, as is needed to promote the growth of a stable shoaling spit.

Initial distribution on the seaward side of the cylindrical island

Pictures of subsequent sand movement show why it is vital to place sand seaward or updrift of the circular island. Most of the sand has been removed from the updrift side, especially from near the wall, to form the start of a shoaling spit all the way round on the leeward side. This shoal was found to be stable against wave erosion long after the sand migration had ceased.

View from seaward side of cylindrical island after 77 hours of wave action

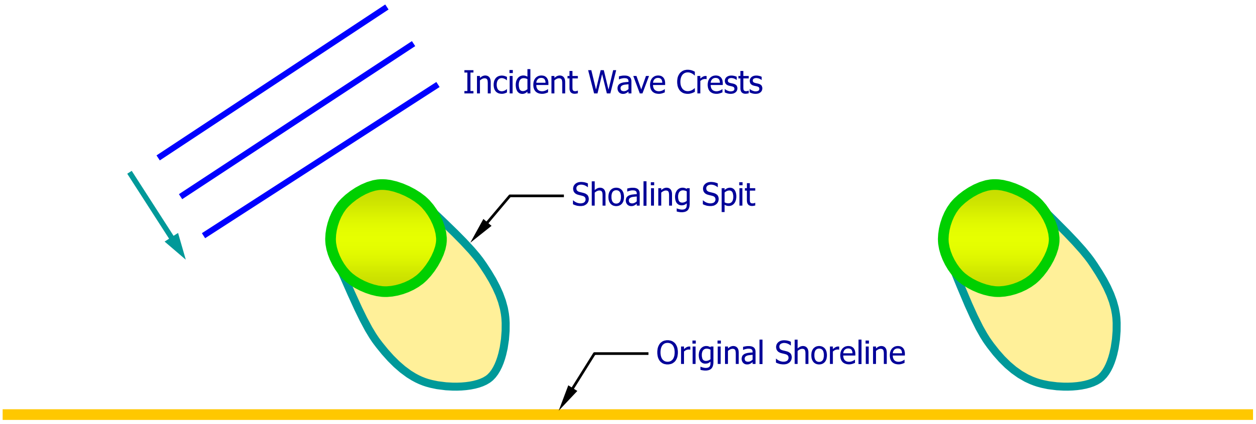
View from landward side of cylindrical island after 77 hours of wave action

The scour near the wall on the seaward side of the cylinder could be severe enough to undermine its foundations. It was decided to test a conical island to see if it could alleviate this problem. A linear breakwater model was also included for comparison. A sand bar was initially spread evenly right across the tank. Both the conical and cylindrical models accumulated sand on their leeward sides, unlike the linear structure, despite its 45° slope and rounded ends. As the waves were normal to the linear orientation, sand was not removed from the front of the breakwater model. In the field, however, it would be swept away by oblique wave action in one direction or the other, neither of which would enable a leeward shoal to form. In contrast, each of the circular models encouraged leeward spit formation, along with a reduced width of scour for the cone.

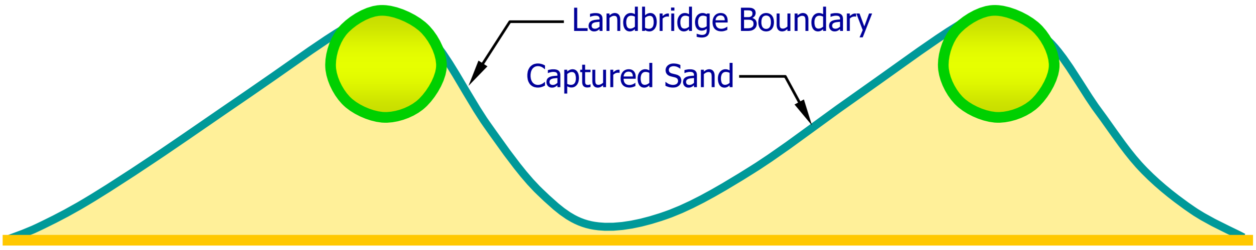
Simultaneous test of alternative headland shapes – 2 hours of wave action

Full-Scale Performance

The full-scale performance of Shoreform islands can be predicted from the model test results, assisted by some understanding of how shoals and spits develop. Given enough sand to feed the process, a shoaling spit will continue to grow, once it has started. Waves will be refracted into the head of the spit, feeding it with yet more sand. This will continue until the spit penetrates the water surface to form a beach. The beach refracts waves and dissipates their energy, allowing it to accumulate yet more sediment, if it is available. The circular island's capacity to funnel sand from offshore to the leeward side is all that is needed ensure the growth of the spit, as long as there is enough sand supplied on the seaward side, either from natural drift or artificial replenishment. The spits will eventually reach the shoreline and form landbridges, capable of capturing any drift sediment coming their way. Some of this drift could emerge from the upcoast landbridge, which is in turn fed from the offshore supply. The result is a stable bay shape less indented than would be possible with linear breakwaters, along with more robust headlands.



Approach of shoaling spits to shoreline, eventually forming landbridges



Beach accumulated between round headlands, given sufficient sand

Island Construction

A sound method for headland construction has been developed, in partnership with a geofabric company, using large geotextile containers filled with sand. The design ensures protection of the seaward foundations from the scouring action that provides the sand to form stable landbridges. Shoreform stable bays are created by the wave patterns reflected and refracted from artificial islands that eventually become headlands. It is vital that these islands are able to withstand repeated storms and high tides without suffering significant damage. Once a typical island shape and size were determined, several alternative construction methods were considered.

Rock armour is probably the most common material used in coastal defences. However, to be certain that the stones will remain in place, they have to be large as they rely on gravity to keep them stable. Should a stone become dislodged, it can pose a threat to the structure, especially if it's thrown about by the waves. Being natural stone, elements come in all shapes and sizes, which can make it difficult to achieve a good connection between adjacent units. As this is essential for achieving the right shape of island and ensuring its stability, this option was abandoned.

A design was also proposed using precast concrete segments to form the external wall geometry. This would use much less structural material than the rock armour method and could be made to let in the sea or be filled with sand after construction. However, the segments would be massive, so that moving them into position offshore, locating them accurately and anchoring them to the seabed would all be challenging, with a high risk of delay, overspending or failure. The glass-fibre composite option was considered after abandoning precast concrete. The segments would be much lighter and hence easier to deploy but would need to be firmly fixed to the seabed and back-filled in order to maintain their shape and position. This was judged to be too uncertain.

Synthetic geotextile bags have been used in coastal engineering for many years in many ways and have proved to be very durable if structural analysis is carried out thoroughly. We were fortunate to have expert assistance from a leading geotextile company together with consulting engineers who specialise in geotextile structures. Furthermore, being a relatively soft structure, it is more visually compatible with the landscape and eco-friendly. If there is any superficial damage it can usually be repaired quickly at little cost. Sand-filled bags are straightforward to transport onshore or at sea and when laid in position they settle into the seabed or adjacent bags. This makes for a robust connection between adjacent units, hence a stable structure and our preferred design.