A Unique Solution to Coastal Erosion

Richard S Silvester PhD MIMechE

Technical Director, Shoreform Limited

7 June 2014

Shoreform Limited
The Paddock
Pringle Way
Little Stukeley
Huntingdon
PE28 4BH
Tel: 01480 456180
Email: info@shoreform.co.uk

1. Introduction

Shoreform offers a unique solution to the problem of eroding coastlines. It is based broadly on technology originally pioneered by Silvester[1], who developed the concept of **headland control** as a means of stabilising beaches. Shoreform's contribution to the technology is protected by a UK Patent[2] and a pending European application[3]. The scientific foundation of the solution is the observation that naturally stable beaches are invariably bays between rocky outcrops or headlands. If it were possible to create headlands artificially, it might thereby be possible to stabilise an otherwise eroding stretch of coastline. Artificial headlands, however, need to be well founded if they are not to be the weakest link in such a scheme. This has been recognised by previous workers[4], who nevertheless failed to find an economical way of placing an artificial headland on a sandy seabed, subject to wave action.

Shoreform has developed the idea of installing circular islands (that become headlands), tested it in the laboratory and demonstrated it in front of witnesses[5, 6]. A design has been developed in collaboration with other firms, such as geotextile fabric suppliers and contractors, leading to refinements of the most suitable concept[7]. This allows the islands to be generated from sand as the only bulk material. Schemes for using the concept have been proposed for sites in the UK and Australia[8, 9]. The response to these proposals has generated the need for computer simulation of the resultant beach morphology, as the shoreline limits for conventional breakwater shapes do not exist for the round island. This has led to a survey of available software and a specification of simulation requirements[10, 11].

A market for the Shoreform invention exists wherever there is wave-induced coastal erosion, with or without the additional threat of sea-level rise. Should there be such a threat, the Shoreform solution promises a more flexible and sustainable response to it than any alternative known to this writer. The way in which it protects the coast opens up other applications for the device, such as waste storage[12] and protection of shipping channels and waterways from siltation[13]. These arise from the shape of the islands, their intrinsic stability and the control that they allow over sediment movement. If sand can be captured and retained where it is needed, it can also be kept out of where it is not wanted. This is also the basis for other opportunities to arise, such as advance of the coastline and land reclamation.

2. Operational Principle

The effectiveness of the Shoreform concept can be illustrated using the simple diagrams shown below. Its full performance depends upon beach spit development. Beach spit growth has been observed all around the world, especially where there are barrier islands. An excellent summary of the process may be found on pages 263-266 of Silvester & Hsu[4]. They show that waves are refracted into the shoaling region at the head of the spit, causing further deposition and thereby extending the spit. If the circular island can produce the onset of a shoaling spit, then sand accretion at the head of the shoal will continue the growth into a fully fledged spit. This is then the basis for a landbridge to the shore.

The simplest case of a circular planform is a cylinder, for which the wave disturbance pattern is illustrated in **Figure 1**, with incident waves arriving from the notional north (seaward side) in the diagram. The reflected waves radiate like ripples from the seaward face of the cylinder to produce the diamond-crested pattern shown below. However, it is only at the island wall itself that the reflected waves develop their full height, as demanded by the reflection boundary condition. Reflected crests are otherwise diffracted into the seaward space, as are the incident waves into the leeward space. All diffraction processes are smooth, gradual and identical for all angles of incidence. The implications of this disturbance pattern for sediment transport depend to some extent on the initial distribution of sediment around the island. However, we might expect any sand near the seaward face to be transported quickly around to the leeward face by the combined energy of incident and reflected waves. It would then be deposited there by the gradually diffracted (subsequently refracted) incident waves.

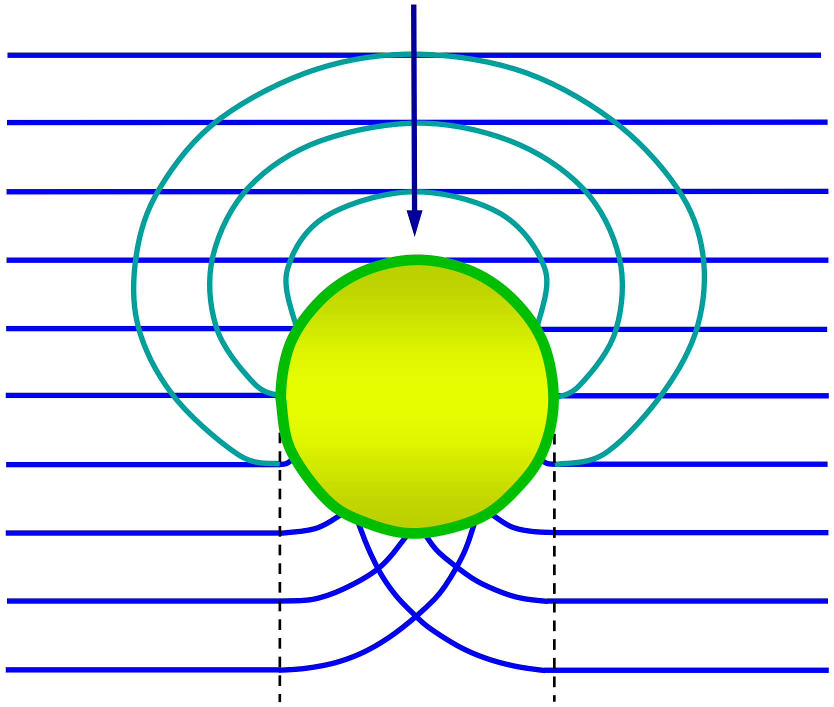

Figure 1 – Wave reflection and diffraction pattern for cylindrical island

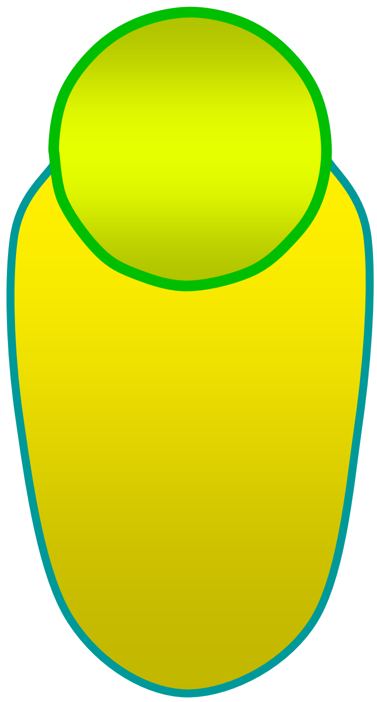

Figure 2 – Shoaling pattern for diffraction around cylindrical island

Figure 2 shows the spit that would be expected to develop if enough sand were available to build it. In the tests[5], only the early stages of accretion and scour were observed, though it has been found generally that where sand starts to accrete, it will continue to do so until a beach is formed. This is due to the shoal itself dissipating wave energy and collecting any remaining sediment. This beach-development pattern is unique to islands of circular planform, not necessarily perfectly cylindrical but preferably with steeply sloping sides. The leeward shoal, found to be at least as wide as the island diameter, would make it possible for a landbridge to grow from island to shore and shore to island simultaneously. However, growth from the island occurs at the expense of sediment on the seaward side, potentially undermining it in this region. Efficient protection of the seaward foundation depends on the width and severity of this scour region, which can be reduced by transforming the cylinder into a cone. This allows the seaward face to be secured by simple and inexpensive measures.

The above explanation shows that, given enough sand supplied seaward of a Shoreform island, the growth of a surface penetrating leeward spit is inevitable. The most critical stage in such growth is the very beginning, which has been tested in the laboratory. Spit formation implies a landbridge, as the shore represents the only barrier to indefinite growth of the spit. The landbridge then captures drift sediment to form a bay between it and the updrift shoreline. Within an initial array of islands along the coast, the updrift shoreline would itself be joined to another landbridge to form a complete bay between headlands. **Figure 3** shows what might be expected for two such headlands.

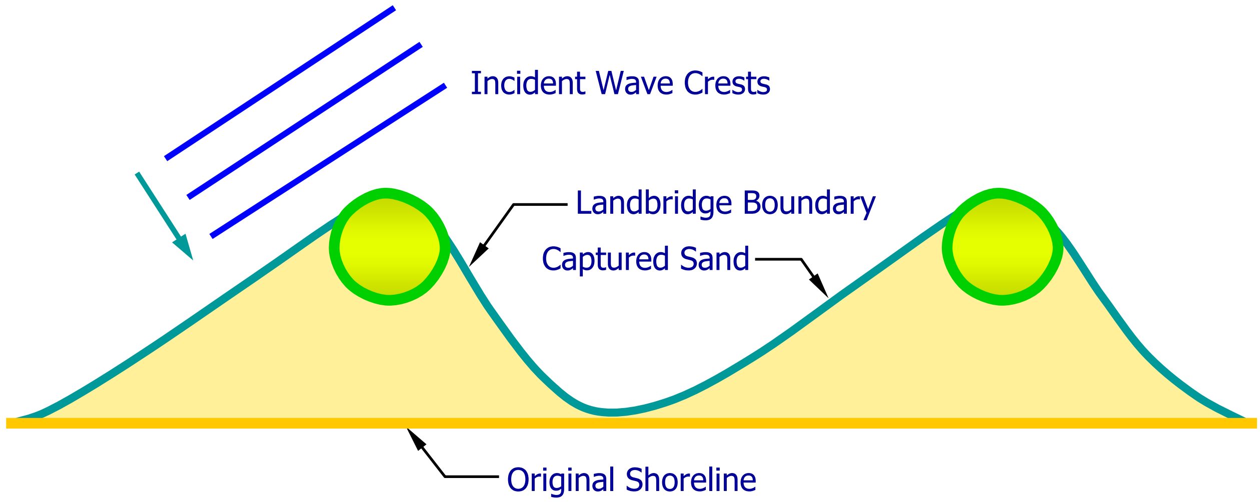

Figure 3 – Beach potentially accreted between round headlands, given sufficient sand

In the above illustration, the landbridge would be formed parallel to the direction of the waves that carry the sediment, whereas sediment captured by the bridge would create a beach normal to these waves. The result is a beach line much further seaward than anything that could be expected of linear breakwaters or groynes. The bay shapes for linear structures are limited by vortex action that occurs near their tips, keeping sediment suspended there and preventing beach formation[14]. The truly stable bay shape for the above arrangement may be altered[15] by a repeated cycle of storms (eroding some of the beach material and depositing it as an offshore bar) and gentler waves, returning the bar to the bay system. Some bar material may migrate from one bay system to the next but vastly less than would drift downcoast in the case of a long straight beach, even if it has been recently renourished.

3. Alternative Technologies

These are the conventional approaches to coastal erosion, such as seawalls, groynes, breakwaters, beach renourishment and managed retreat. They may be deemed approaches to the problem (rather than solutions) as their weaknesses have been thoroughly exposed in the technical literature[1, 4]. The basis of these weaknesses is the way that hard linear structures and steep underwater walls disturb the waves, reflecting them in a way that encourages erosion. Seawalls, in particular, reflect obliquely incident waves so efficiently that their foundation is undermined. The seabed material in front of them is systematically swept down the coast, especially near the ends of the wall. Vortices shed by wave action in these regions can penetrate to depths far greater than those accessible by waves alone. This is a problem relevant to all kinds of linear structure, including groynes. Although groynes reflect waves in a way that sweeps sediment to the shore on their updrift side, the same is not true of the downdrift side. On this side (near the end) vortices are shed, eroding the seabed and worsening the situation for downcoast regions. In the event of storm-waves removing some of the beach, groynes have been known to promote rip-currents that take eroded material further offshore than without the groynes.

Offshore breakwaters, installed parallel to the coastline, suffer from the same problem as seawalls, especially if they are expected to prevent waves reaching the coastline at all. In such instances, they may be installed too close together, with disastrous and expensive consequences[16]. Giving them a wider spacing, however, can turn them into the headlands of conventional stable-bay technology. This is better than nothing, with successful examples of its application well documented[17, 18]. However, neither of these cases shows evidence of a preferred drift direction, though some such drift must have been present to cause the original erosion problem. Proponents of stable-bay technology accept that some kind of bed-protection must be provided both along the wall and around the ends of conventional headlands, whatever their shape or orientation[4]. The Shoreform circular island has no ends, hence no vortices, and needs only a narrow band of bed protection on the foot of its seaward face.

Beach nourishment has become a fashionable alternative to hard defences, especially as beaches are only now being recognised as the best defence against coastal erosion. Nourishment is also likely to be needed with any defence scheme (including one involving the Shoreform invention) if rapid advance of the existing shoreline is desired. Nevertheless, the main problem with unsupported nourishment is that sediment newly dumped on the shore creates an unnaturally steep seabed profile. This tends to be found on offshore bars, rather than on beaches. It allows waves to be reflected, rather than gently dissipated, at the face of the newly dumped sandbank, which is then taken more quickly downcoast than before the renourishment. Some means is needed of holding the sand in place. The Shoreform island shape enables this to happen, as the newly supplied sand is encouraged to find a stable location near the shoreline where it is needed. It works well with sand placed seaward of the islands.

Managed retreat is an admission of defeat and evidence of the dearth of solutions to coastal erosion, as well as the concomitant threat of sea-level rise. Sea-level rise is a controversial topic, as is the global warming to which it is attributed. Nevertheless, if coastal erosion can be stopped, then there exists a basis for dealing with sea-level rise, if and when it occurs. The Shoreform idea is to develop a robust coastline, which can then be allowed to rise stably with the sea level. There will not then be the need to relocate coastal property further inland. The ability to deal with catastrophic events will also be improved, as the protective beach can be made wide enough to serve as a buffer against the severest of storms or tsunamis. As the islands themselves can be made principally of sand, securely held in strong fabric containers, the solution could not be simpler or more convenient to implement.

4. Summary

Conventional marine structures, such as seawalls, groynes and breakwaters, are unable to stop coastal erosion. Beach replenishment can replace the sand that was lost but this must be repeated as often as it is lost, unless some means can be found to hold it in place. Shoreform has developed just such a system, in the form of artificial islands of circular planform. These disturb the waves in an entirely new way, allowing sand to accumulate in their lee to form landbridges between them and the shore, turning the islands into headlands. This allows bayed beaches to form between successive headlands. Each bay is stable and does not need to feed on drift sediment, other than that from within the bay.

Storms may periodically remove sand from the beach but they deposit it as a bar within reach of the bay, ensuring its return to the original beach. The erosion of the beach to form an offshore bar, followed by the return of the bar to the beach, is quite natural. The beach is therefore cyclically stable, retreating and advancing with each cycle of storm and calm. The islands are constructed from sand-filled geotextile containers, easily protected from the forces that undermine other marine structures, yielding an inexpensive solution to coastal erosion. Shoreform stable bays are formed and maintained by natural processes, creating an attractive, long-lasting and environmentally friendly coastline.

5. References

1] Silvester R, **Coastal Engineering**, *Developments in Geotechnical Engineering*, Vol. 48, Elsevier Scientific Publishing Company, Amsterdam (1974).

2] Shoreform Ltd, **Sediment Accretion Device and Method**, *United Kingdom Patent Office*, UK Patent GB2442847B (29 September 2010).

3] Shoreform Ltd, **Sediment Accretion Device and Method**, International Application PCT/GB2008/000398, Agent's File Reference P7719.WOP (2008-02-05).

4] Silvester R & Hsu J R C, **Coastal Stabilization**, *Advanced Series on Ocean Engineering*, World Scientific Publishing Co. Pte. Ltd, Singapore (1997).

5] Silvester R S, **Demonstration of Circular Headland Concept**, *Shoreform Ltd internal report* (16 August 2010).

6] Silvester R S, **Live Demonstration of Circular Headland Concept**, *Shoreform Ltd internal report* (20 May 2011).

7] Silvester R S, **Construction of Conical Island from Geotextile Containers**, *Shoreform Ltd internal report* (15 May 2014).

8] Silvester R S & Ball P E, **Proposal for Sea Defence Work at Happisburgh - 3rd Revision**, *Shoreform Ltd proposal document* (5 September 2011).

9] Silvester R S & Ball P E, **Palm Beach (Gold Coast) Protection Proposal**, *Shoreform Ltd proposal document* (9 August 2013).

10] Ponton S J, **Headland Simulation Software Review**, *Shoreform Ltd internal report* (12 June 2013).

11] Silvester R S, **Simulation Requirements for Circular Headland Invention**, *Shoreform Ltd internal report* (26 July 2013).

12] Silvester R S, **ILW Disposal Options**, *Shoreform Ltd internal report* (20 January 2009).

13] Silvester R S, **Reducing the Need for Shipping Channel Dredging**, *Shoreform Ltd internal report* (21 October 2013).

14] Silvester R S, **The Point of Diffraction in Headland Bay Beach Formation**, *Shoreform Ltd external report* (18 December 2012).

15] Silvester R S, **Principles of Headland Design in Stable Bay Systems**, *Shoreform Ltd internal report* (5 July 2013).

16] Toyoshima O, **Design of detached breakwater system**, *Proceedings 14th International Conference on Coastal Engineering*, ASCE 2: 1419-1431 (1974).

17] Silvester R & Ho S K, **Use of crenulate shaped bays to stabilise coasts**, *Proceedings 13th International Conference on Coastal Engineering*, ASCE 2: 1347-1365 (1972).

18] Silvester R & Searle M, **Headland control to prevent cooling water sand incursion**, *Proceedings 5th Australian Conference on Coastal and Ocean Engineering*, 135-138 (1981).

