COASTAL PROTECTION DEVICES - A REVIEW**

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ABSTRACT

Coastal protection devices include, but are not limited to, dune stabilization, seawalls, groynes, detached breakwaters, sand bypassing and beach nourishment. These are the "tools". The "rules" for their use comes from a knowledge of the beach processes which in many instances are site specific. Systems which work satisfactorily at one location may not necessarily work at another. A plan is made for authors to give more information on these processes when describing case histories.

The variability of the physical conditions and the non-linear nature of many of the coastal processes often dictates how coastal protection works will behave; a fact which is not always taken into account by the designer.

For coastal protection devices to be developed to their full potential requires improved instrumentation and data bases and a greater knowledge of the coastal processes than is available at the present time.

1. INTRODUCTION

This paper was prepared as an introduction to the poster session on coastal protection devices at which seven papers were presented. (Reference 1-7). These varied between the use of low cost protection measures such as car tyres, sandbags, oil drums and other devices in the U.S.A. to the use of sand filled Longard tubes as groynes and seawalls in N.W. Canada, massive boulder seawalls in Australia, groynes in Portugal, large scale sand nourishment and bypassing operations in South Africa and detached breakwaters in Japan and Israel. The common denominator in these and other studies is, I believe, in the functional design based on a knowledge of the coastal processes.

It is not uncommon to think of coastal protection in terms of dune stabilization, seawalls, groynes, detached breakwaters, sand bypassing, beach nourishment and so on. Whilst extensions to this array and an improved understanding of accepted techniques is most important, this does not represent today's "State of the Art" in coastal defense. These are simply the "tools" and not the "rules". The "rules" come from a

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**This paper is an overview of the papers discussed in the poster session on Shore Protection Devices. The papers discussed are presented in Chapters 112 - 118.

knowledge of the coastal processes. Today's art lies more with the capability to understand the relative significance of the various natural forces which make defense necessary and the ability of the engineer to use this understanding to determine the optimum defense strategy making the most appropriate use of all the devices available.

2. COASTAL PLANNING

The first coastal protection device that should always be considered is that of coastal planning. Within this context the question can be aptly asked as to why coastal protection is necessary at all? Inevitably the answer will be that man wants to use the land which nature wants to take away for purposes such as:

- Recreation
- Housing
- Industry
- Airports
- Harbours
- Reclamation

This more often than not, means that man is in conflict with nature right from the very beginning. In comparison to other forms of development the coastal region tends to be different in that the highest valued land is commonly in the area of highest risk (Plate 1).

This is in contrast to flood plain land for example which tends to have the opposite trend with property values decreasing with the increased risk of being flooded. However in some respects the two have much in common.

- A certain level of protection can be justified by the reduced damages that it will provide
- Reduction of risk encourages further development
- Further development results in increased damages which justifies a higher level of protection.

This type of development in the past has ended up with the need for massive expenditure of funds to fight a never ending battle against erosion. More careful planning by our forefathers in many instances would have avoided or reduced the problems and the associated cost.

It could be argued both then and even today that many of the mistakes have been made because of our lack of understanding of the coastal processes involved. However examples of poor engineering practice in the management of the coastal zone are still evident in almost all

PLATE 1: - HIGH VALUE DEVELOPMENT IN AREA OF HIGH RISK

PLATE 2: - DAMAGE FROM NATURAL LONG TERM EROSION

countries throughout the world and all too often it is a case of trying to provide coastal protection to a problem which could have been avoided by more careful initial planning. Much of the blame must be laid on the inability of the engineer to convince the public and the legislators of the need for such planning and the long term benefits which would eventuate.

3. THE DIFFERENTIAL LITTORAL DRIFT COASTLINE

One of the most difficult coastal erosion problems is that pertaining to the differential littoral drift coastline resulting from a change to the littoral supply (Reference 1,5) or because of the natural configuration of the coast as exemplified by the Byron Bay embayment in northern N.S.W., Australia (Reference 8). At Byron Bay the littoral input is 15,000 m^3/year whilst the output is 200,000 m^3/year. As a result the whole of the embayment is eroding at rates between 1 to 5 m/year, except where the coastline is held by retaining structures such as groynes, seawalls or training walls. The end result of a small village built in the path of the sea is shown in Plate 2. The long term fight against erosion has been lost with seawalls gradually being outflanked and finally succumbing to the forces of the sea.

The owners of these homes undoubtably agree with the second demand for coastal protection suggested by Per Bruun (Reference 9) "Thou shall protect it against the evils of erosion". However, on further thought is erosion all that evil? Most modern day coastal protection strategies start with a statement of the sediment budget relating sand supply to and sand losses from a coastal region; and are aimed at reducing losses (by the use of groynes, detached breakwaters, dune stabilization, or bypassing plants for example) or by increasing the supply (by beach nourishment and sand bypassing for example). When we look at the sediment budget on an eroding coast one of the major supply terms is the coastal erosion itself which implies that if an eroding section of the coastline is protected by any method other than beach nourishment accelerated downdrift erosion will result. It is for this reason that it is difficult to simultaneously satisfy Per Bruun's second demand for coastal protection as set out above with the seventh "Thou shalt not steal thy neighbour's property, neither shalt thou cause damage to his property by thy own protection".

How do you provide protection to a shoreline such as Byron Bay?

- By beach nourishment provided there is an unlimited quantity of sand available which there isn't

- By seawalls or dykes provided you are happy to convert a sandy recreational beach into an artificial rocky coast which you are not

- By use of structures such as groynes, detached breakwaters, artificial headlands designed to equalise the littoral drift over the entire physiographic unit provided you can afford the cost which you can't.

In practice the cost of any of these options is often prohibitive, except in very densely populated areas or where they are associated with major harbour and port development.

A lower cost solution (particularly for relatively undeveloped sections of the coast) would be to provide protection to some sections of the coastline and accept accelerated erosion at others. This requires the acceptance by government and the public to changes in the configuration of the coastline. Under present legislation and the land rights of private individuals this is not easy to achieve. This cause has not been helped by the tendency for engineers in describing coastal protection case histories to give so little detail of what has or will happen outside of the area of immediate protection.

4. NATURE AS A SCALE MODEL

Nature provides many examples of coastal protection and coastal erosion. It is common to use small scale hydraulic models to assess the effect of large scale engineering works (Reference 7). Sometimes it is forgotten that a model does not have to be smaller than the prototype as the powerful principals of similarity and dimensional analysis are completely reversible. For Froudian scaling the length scale is proportional to period squared and consequently laboratory and nature provides a wide range of examples which can be scaled both up or down. Consequently the model studies of detached breakwaters undertaken by Rosen and Vajda (Reference 7) have much in common with the studies undertaken by Edge (Reference 2) in bays and lakes and those of Toyoshima (Reference 1) for the Pacific Ocean.

Consider the tidal inlet. In Australia such inlets at coastal lagoons, creeks and river systems are often closed off by the longshore transport under wave action, only to later break out during high fresh water or flood flows. From the study of the effect of artificially opening of the entrance of a small tidal lagoon at Dee Why, (Reference 10), Gordon was able to identify and to quantify a rather unusual cause of beach erosion at a much larger scale which can be typified by the conditions at Tathra in southern N.S.W. (Reference 11) as shown schematically in Figure 1.

This beach is a relatively small pocket beach contained between two major headlands. The Bega river, which is known to supply sand to the coast, enters the system at the northern end. As for most Australian rivers, daily flows in the Bega River vary from zero to very high flood flows. During relatively low river flows a plug of sand is moved from the beach resulting in shoaling of the mouth. During major floods this plug of sand is flushed far out to sea to form a shoal of mixed marine and fluvial sand. In the post flood period much of this sand bypasses the Tathra system under the predominant southerly wave climate. During the same period beach sands are moved in to reform the shoals at the entrance. As a result rapid erosion of the beach results after each flood event which slows down as the shoals are re-established.

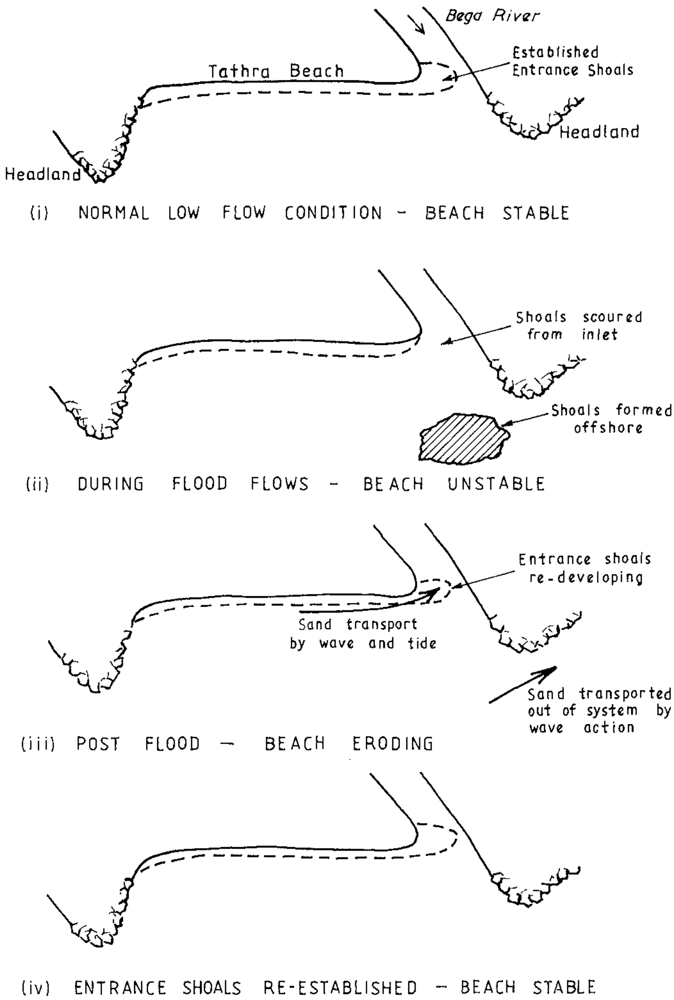


FIGURE 1: EROSION OF TATHRA BEACH AS A RESULT OF FLOOD FLOWS
(SCHEMATIC ONLY)

If it is accepted that nature provides us with many examples of both coastal erosion and protection it is surprising that not more use is made of this model, and to use conditions in bays and lakes to make quantitative predictions of what will occur in the ocean or vice versa. This technique was used by the author with some success to transfer the known behaviour of the sand bypassing system at Channel Island (Reference 12) to a less exposed region in Western Australia (Reference 13).

One of the reasons the technique is not used more often is, I believe, because many papers on case histories do not give sufficient detail of the physical parameters such as wave climate and its variability, local currents, tides, sediment characteristics to enable such scaling to be undertaken with confidence.

5. VARIABILITY OF COASTAL PROCESSES

The variability of the coastal processes often means that coastal protection is site specific. One form of protection which may work effectively at one location may be totally ineffective at another. Per Bruun (Reference 9) noted that when the techniques of the successful Dutch groynes were transferred to Denmark they did not work and large scale downdrift erosion resulted. It was suggested that this was because the Dutch groynes were supplied with sand by tidal currents whilst the Danish groynes were not.

This point can be further illustrated by the behaviour of the coastline adjacent to three natural detached breakwaters formed by offshore islands in Australia as shown schematically in Figures 2-4.

The first example is at Palm Beach near Sydney in N.S.W. (Reference 14). The coastline has a near zero net littoral drift. Because of the wave protection provided by an offshore island a shore connected tombola has developed. The tombola is of sufficient height and width not to be breached by even the largest storm and it forms a natural sand breakwater to a recreational harbour in its lee. Aside from normal changes in the beach profile resulting from rough and calm weather conditions the beach system is relatively stable.

The second example is on the Warilla-Perkins beach system to the south of Sydney (Reference 15). The total beach system is bounded by two major headlands which inhibit any significant movement of sediments into or out of the embayment. An offshore island within the embayment separates Warilla beach from Perkins beach. During calm weather sand is moved from both beaches into the lee of offshore island to form a tombola which eventually becomes connected to the island to form a groyne which inhibits further sand movement. During storms, which are dominantly from the south, the tombola is breached and the sand (some of which originated from Warilla) is transported northwards onto Perkins. The process then repeats itself. Consequently Warilla beach is suffering continuous erosion whilst Perkins is continuously accreting. The offshore island, which is acting as a detached breakwater, is obviously the cause of the erosion of Warilla beach.

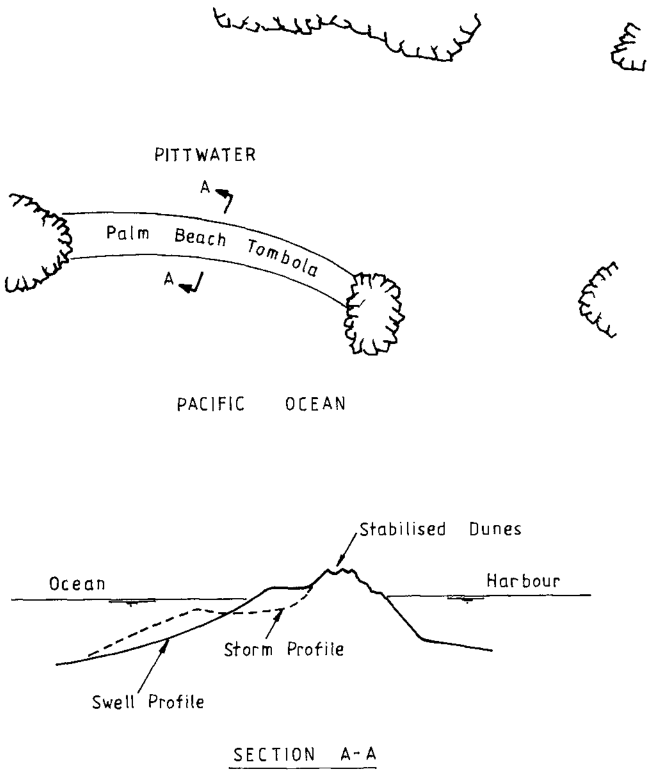
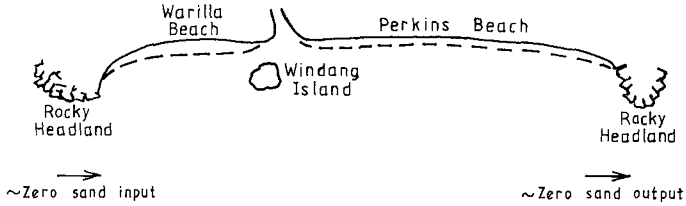
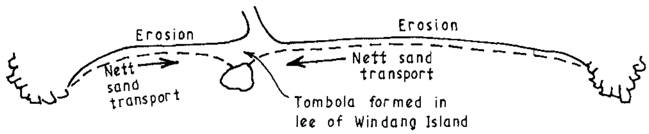


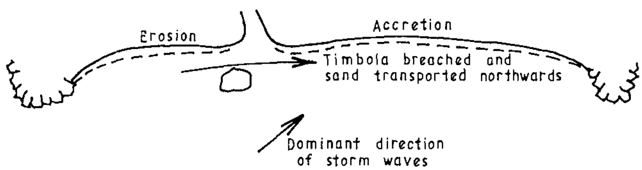
FIGURE 2: PALM BEACH N.S.W
(SCHEMATIC ONLY)



(i) INITIAL CONDITIONS IMMEDIATELY FOLLOWING A STORM



(ii) CONDITIONS UNDER CALM WEATHER FOLLOWING A MAJOR STORM



(iii) CONDITIONS DURING A MAJOR STORM

FIGURE 3: WARILLA/PERKINS BEACH SYSTEM
(SCHEMATIC ONLY)

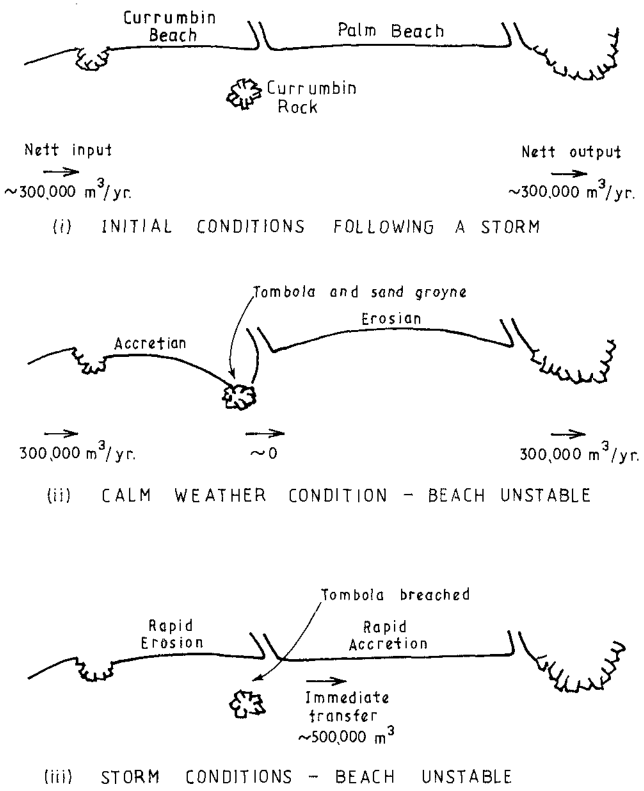


FIGURE 4: CURRUMBIN/PALM BEACH SYSTEM QUEENSLAND. (SCHEMATIC ONLY)

The third example is at Currumbin on the Queensland Gold Coast (Reference 17,18). The situation is similar to the previous example in that an offshore island which acts as a detached breakwater separates the beaches of Currumbin and Palm Beach (Queensland) and basically behaves in a similar way. During calm weather a tombola is formed in the lee of the breakwater eventually becoming connected to the island after which it acts as a groyne. During storms, which are again predominantly from the south, the tombola is breached and sand is transferred northwards. The basic difference between the Warilla/Perkins and Currumbin systems is that for the latter there is a net littoral drift of some 300,000 m^3/year (Reference 19). Surveys (Reference 17-18), have shown that during calmer weather practically the whole of the littoral drift over a period of years may be stored on the beaches to the south only to be transferred to the north within days during a storm. As a result the beaches to the north tend to erode during calm weather and build up during and following a storm, a paradox to that normally expected.

A further consequence of this action is that the sand is supplied to the coast in slugs. Tracer measurements by Chapman and Smith (Reference 20) indicate that these slugs maintain their identity over a substantial period of time and over long distances. Consequently at any given time some sections of the coastline tend to be under-nourished whilst others are over-nourished.

Plate 3 shows the end result of two houses at Wamberal on the N.S.W. central coast which were unlucky enough to be sited opposite a rip current on an under-nourished section of the coastline when a moderate storm occurred. Some weeks later the system had moved some 200 m to the north as indicated by the undermining of a flexible gabion mattress placed as toe protection in front of a Seabee seawall (Plate 4). The importance of toe protection, the desirability of flexibility of toe armour and the need to allow for the variability of the physical processes in seawall design (Reference 4) is obvious.

As coastal processes differ from site to site, no all embracing rules can be set down for the design and use of coastal protection devices. It is important that papers describing case histories of coastal protection give sufficient detail of the coastal processes to adequately assess their use in other areas.

6. NON-LINEARITY OF COASTAL PROCESSES

Closely related to the variability of coastal processes is the highly non-linear nature of these processes. The C.E.R.C. equation indicates that longshore transport is proportional to wave height squared. Einstein's equation indicates that bed load transport in rivers is proportional to discharge squared and velocity to the fourth power. In other formulae the power may differ but it is always substantially greater than unity. Consequently the larger events play a major role in the movement of sediment to and along the coast. For example a flood with a flow of 10 times the average can carry 100 times the sediment load of the average flow.

PLATE 3: - DAMAGE RESULTING FROM SHORT TERM CHANGES

PLATE 4: - SCOUR BLANKET PROTECTING SEAWALL AGAINST SHORT TERM VARIATIONS

Currents induced at coastal protection works will obviously have a very significant effect on how these protective works behave.

An example of using the non-linearity of coastal processes to advantage is at Durban (Reference 21) where an artificial offshore sand bar was constructed to protect the beaches. The sand was obtained from dredging of the nearby harbour. Small to moderate waves pass over the bar with little change to the natural surfing and recreational use of the beach. Under storm conditions the sand bar acts as a submerged breakwater forcing the waves to break and dissipate a proportion of their energy. As sediment transport is approximately proportional to wave height squared there should be a rapid response to the reduced wave height.

The non-linear nature of many of the coastal processes and the variability that this produces is not always taken into sufficient account in the design or the description of coastal protective works.

7. THE FUTURE

More initiative and lateral thinking is needed in the design of coastal protection works if the engineer is to be more successful than he has been in the past. Dune stabilization, seawalls, groynes, breakwaters and artificial nourishment will continue to be important tools. However this should not blind the engineer to other methods which might be equally or more effective.

If erosion is accepted as an ally as well as an enemy restructuring the shape of the coastline by providing sacraficial land has much to commend it.

At Port Botany (Reference 22) and Phillip Point (Reference 23) configuration dredging has been used to change the wave refraction pattern and redistribute the wave climate to that more suitable for port operations. If configuration dredging has been successfully used in these two examples, it can obviously be considered in association with offshore beach nourishment programmes to deflect wave energy onto headlands or rocky sections of the coast whilst reducing wave energy or changing wave direction along the sandy beaches.

As the relationship between sediment transport and velocity is highly non-linear methods aimed at breaking up destructive currents whether they be rip, flood, tidal currents, or currents induced by coastal protection works must potentially be a very powerful tool.

Coastal protection devices need to be extended beneath the sea surface. At Collaroy in Sydney coastal process studies have indicated that a major cause of the beach erosion is the result of gaps in a natural offshore protective reef, (Reference 24) which if closed would go a long way towards eliminating the problem.

Seawalls do not have to be immobile. A sand breakwater has been constructed at Salamander Bay South Africa (Reference 25) whilst a breakwater of run of the quarry rock has been constructed at King Island Australia (Reference 26). Beach nourishment is a seawall of sand and shingle beaches serve the same purpose. There would appear to be a wide range of options within these limits awaiting future development.

It is now possible by the use of chemicals to turn sand into beach rock at relative low cost (Reference 27) which opens up many possibilities for the future.

These are but a few of the options which are or may become available in the future.

8. CONCLUSIONS

I would reiterate my introductory remarks. Coastal protection devices are simply the tools, the rules for the use of these tools came from a knowledge of the local coastal processes pertaining to each specific site. It is only when these processes are known will the engineer be able to develop coastal protection devices to their full potential. Much work and improved instrumentation and data bases are needed to refine the knowledge in this area.

9. ACKNOWLEDGEMENTS

Messrs. M. Geary and A.D. Gordon are co-authors of this paper. Both are engineers with the Coastal Branch of the Department of Public Works, New South Wales, Australia. Many of the examples referred to in the paper are taken directly from coastal process studies with which they have been associated. Their assistance and that of the Department of Public Works is gratefully acknowledged.

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