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Ask Nature to Protect and Build-up Beaches

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ABSTRACT

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The Belgian coast is protected for 50% by hard constructions including slanting seawalls and groins. Most of them were built after the extremely severe 1953 storm. The other 50% of the coast consist of dune-belts and beaches.

More than a century ago a groin field was implanted in front of the dune barrier protecting the coastal plain. But both nature and man's activities encroached on this natural defense and by the forties several east coast resorts were left without a beach at high water.

Hard structures did not provide adequate protection, they even seemed to worsen problems, and yet, some new techniques like the use of the HARO were welcome innovations. The extension of Zeebrugge harbour provided an opportunity to consider artificial nourishment using the dredgings. The approach provided some satisfaction but recharges were necessary.

Meanwhile the west coast started to show signs of erosion. Various beach protection and restoration methods were tested but discarded for a variety of reasons.

Then nourishment with a feeder berm was decided upon for the De Haan sector and has yielded excellent results. The paper, while focusing on Belgian approaches, reviews alternative approaches such as artificial reefs and dewatering, but also methods that call upon Nature to rebuild beaches, among which Berosin and Beachbuilder.

ADDITIONAL INDEX WORDS: *Erosion, artificial reefs, dewatering, Berosin, Beachbuilder, artificial nourishment.*

INTRODUCTION

Economic and social resources and interests at stake require, in the immediate future, that problems related to shoreline retreat be attended to. Coastal Zone managers are fully aware that coastal erosion should be included in any integrated management plan (TSCHIZKY, 1996; CARTER, 1994). Coastlines have shifted throughout historical times, the Zwin Inlet on the Belgian-Dutch North Sea border is facing total silting—perhaps due to artificial beach nourishment on adjoining Belgian and Dutch beaches, Harendijke, also on the Belgian North Sea Coast, has long been wiped off the map.

Man's efforts to resist the onslaught of the sea go back to classical times and the 14th century murazzi and St John's Ditch (Digue du Comte Jean) on Belgium's Coast are relatively recent. Per BRUUN (1972) wrote an account of the history, and philosophy, of coastal defense engineering works some years ago. Construction of seawalls, of earth or hard materials, has been the primary approach. (CHARLIER *et al.,* 1998). These proved costly, and required continuous maintenance and relatively frequent replacement.

As a subject of investigation the Belgian coast presents disadvantages: a mere 67 km (41.6 mi) long, an area of very dense human occupance, lined by villas, apartment houses and hotels, and "protected" by groin fields and dikes along most of its length, it has to some extent undergone manmade modification reminiscent of that of the coasts of Italy. This coastal region's development may be compared, in some ways, with that described by NAYAS and COOPER (1998) for Northern Ireland's Dundrum bay, also discussed by PAQUETTE (1998).

But small, in this instance short, does not mean insignificant. There is an advantage: it is a "natural" laboratory, even though touristic and economic considerations, projects sizes, aesthetic impact and seasonal timing pose severe constraints.

The coastline is naturally protected by a string of dunes which, regretfully, has been destroyed, over long stretches, sometimes legally, sometimes not. Efforts to abate this damage over long stretches have been hampered. Developments in sea-side resorts, which blossomed especially from the twenties on. Nature itself contributed, of course to shoreline retreat: storms often caused havoc and considerable problems resulted from those of 1953, 1976, 1990 and more recent ones.

To counter the erosive effects various approaches have been implemented: these include groins, seawalls, artificial nourishment and feeder berms (*cf.* Hilton Head Island Symposium).

While this paper focuses on problems on the Belgian coast where many of the methods here described have been tested, it intends to review several alternatives to traditional hard structures coastal defense.

During the winter storms of 1976, a beach section of 9 km in length was eroded in front of the Knokke-Heist municipality. The beach profile was restored by beach nourishment, whereby ca. 8,5 million m^3 of sand served to restore the erod-

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ed profile. In 1990, the Flemish regional government started to build coastal protection works in a coastline section at De Haan, using sandfill following the profile nourishment feeder berm concept. Beach profiles were surveyed at both locations and erosion rate were calculated based on volume computation. The total erosion rate in De Haan was compared to the previously calculated erosion rate at Knokke and showed the effectiveness of the feeder berm concept for this particular situation. This confirms the confidence in the feeder berm concept as a proposed system for coastal protection and fully supports the soft approach to coastal protection.

On the West Coast of Belgium, studies were undertaken to evaluate renewed salt/fresh water exchange with the aim to promote the development of particular ecosystems. Dismantling the dune toe protection is even planned at the French/Belgian border in De Panne, in combination with a beach profile nourishment and a restoration of some dunes. This confirms the interest for promoting natural solutions and using sand for integrated coastal protection.

Hard Structures and Environment

Generally hard structures while often protecting updrift sectors create erosion problems downdrift. This does not prevent some authors from maintaining that this "blanket" statement has not been proven in several instances for sea walls (Bird 1979).

Ever since Akle's paper in *Siren* on Togo's problems, a continuous succession of papers on similar conditions in Benin, Nigeria and the Ivory Coast Republic have been presented at international conferences. Hard structures have been built in numerous locations with unsatisfactory or negative results. Nevertheless groins may hold material on an artificially nourished beach with no natural supply and accumulate beach material in front of protruding hard beach heads. They may help in some other situations, though downdrift transport will be affected in most cases (De Rouck, 1991; Flemming, 1990). Natural headlands may play a similar role (Silvester, 1985).

Pontoons and floating breakwaters produce an effect resembling that of a rigid thin barrier plunging to some depth. Some were used on the Normandy coasts during World War II.

The low-cost of floating breakwaters and their suitability where water level differences are great or bottom conditions poor, have made them attractive wave-energy dissipators when funds are limited. Little energy is reflected. They were used, for instance, along England's southeast coast.

Interestingly a painting by John Constable titled "Floating breakwaters at Brighton" in Brighton's Art Gallery (U.K.), shows open breakwaters installed early in this century (probably in 1902).

The secondary role, as wave energy dissipators, of certain structures whose function is energy production has been praised. At the forefront of these are several wave energy conversion systems: not only do such devices "absorb" wave energy to convert it into electrical or mechanical power, they also fulfill the auxiliary role of *de facto* breakwaters.

Several permeable breakwaters have been placed along beaches of Oahu (Hawaii). De Rouck (1993) of Ghent University (Belgium) has been instrumental in developing the HARO. This flat concrete block has a large opening and both of its short sides are widened at the base; corners are asymmetrically tapered in plane. It thus achieves a high degree of porosity, when used in two layers, and good stability.

Its high porosity and lesser weight allow a 30% reduction of the amount of required concrete. The decreased wave run-up permits a reduction in breakwater crest height. The new units have been used in the Zeebrugge harbor (Belgium) extension works. Lukjeharms expressed caution based upon observations with somewhat similar blocks on the Republic of South Africa Indian Ocean coast (personal communication 1998 6th Int. Congr. Hist. Oceanogr.)

Some reservations concerning the use of HARO blocks may validly be made: the cost may be somewhat high. However, the block has good hydraulic stability and is light weight; this allows a smaller size, consequently a thinner layer, a greater porosity and cuts the quantity of concrete roughly by one third. The reduced weight permits use of a smaller crane, thus of a narrower dam. Finally only a lower dam crest is needed (Figure 1).

If the HARO provides greater linking facility and far higher hydraulic stability, and even greater resistivity to thermic variations, it has a somewhat lesser wave reflection coefficient and wave run-up than the traditional concrete cube. The best coefficient of run-up is apparently reached by accropods (0.95 vs. 0.85).

In comparative cost units of an armor layer, dolos and accropods the grooved cube being taken as the 100 basis run about 75, tetrapods 90, against 70 for the HARO. In the long run utilizing HAROs proves economical.

Reefs

Reefs provide a natural defense against the effects of wave impact. Their importance has been appropriately placed in focus by and during "the year of the reef" (1997). They may not survive, however, as sea-level rises. Besides natural barrier and fringe reefs, artificial reefs have been proposed as a coastal defense device.

The term designates man-created reefs constructed by plantations, *e.g. Laminaria* or *Macrocystis,* but also beds of artificial fronds. Artificial reefs with natural plants appear to offer some protection and to favor berms build-up. Though still on the market, those "planted" with synthetic fronds have not been recognized as effective, notwithstanding extensive testing (Jenkins, 1987; London, 1985). In The Netherlands and France, positive results were achieved in reducing scouring near man-made structures and improvements could be made by lengthening the fronds and increasing their density in the bundles. In the United States emphasis was placed on reducing shoreline erosion. Experiments at Fort Belvoir, VA, at Cape Hatteras Lighthouse, NC, Stone Harbor Point, NJ, Naples, FL, and in about 50 other locations have been negative, though manufacturers' understandably claim, otherwise. A rather positive report by Hall has been seriously challenged.

But artificial seaweed fields present two disadvantages: an

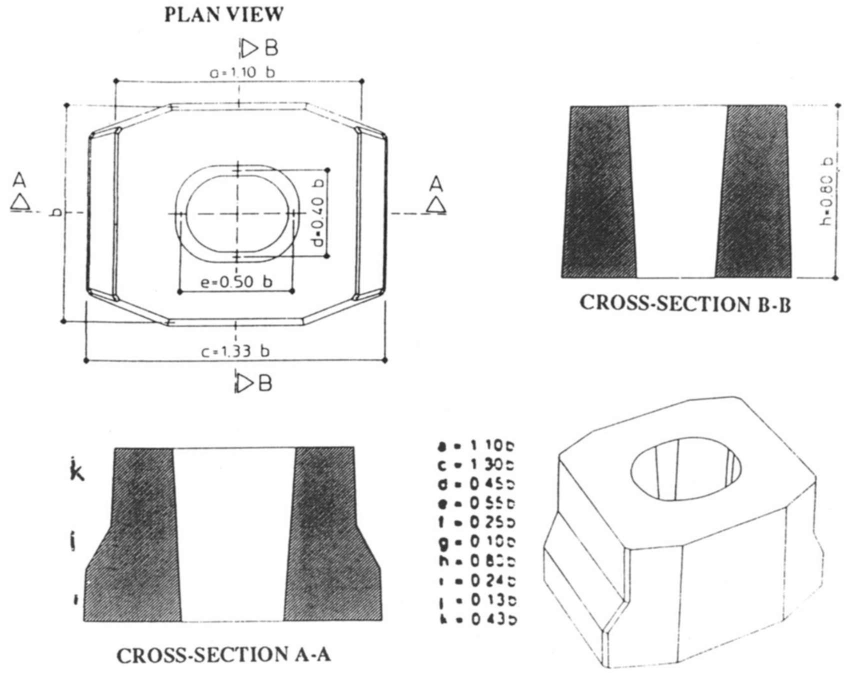

Figure 1. *The HARO.*

effective field, even if placed so that it would not be a navigational or recreational hazard, would be more expensive than other beach protection methods, and it appears to have unfavorable effects upon beaches and shorelines further downdrift.

Wave attenuation could be achieved by large kelp beds. Over 0.8 km (0.5 mi) wide and several kilometers long, in water 15.25 m (50 ft) deep, such beds could theoretically reduce wave height by half as far as 0.8 km (0.5 mi) into the field. They play a role comparable to that of porous breakwaters.

A small retardation of bottom oscillations by artificial seaweed can lead to a large reduction in sediment transport, hence formation of bars and shoals over a seaweed bed could be expected. Yet, ROGERS (1985, 1989) maintains that, there is not a single documented case where artificial seaweed has been successful in controlling shoreline erosion. Marshgrasses have controlled erosion in estuarine settings, where there is relatively low wave activity. Success has been reported along shorelines with fringed not covered marshes.

KAWAKAMI and his co-workers (1995) nevertheless claim satisfactory results near Kaike Beach (Japan), though for one of Japan's longest beaches, Kashima-nada, the headlands solution was selected. These divide the beach in small pocket beaches, about a kilometer long each, so that the littoral sand drift is confined in a "pocket beach". The so-called "cell" approach is apparently akin. A cell or sand pocket is a site where beach profiles are healthy and attenuate wave energy before they reach cliffs (LARCHER, 1995; BRAY, 1994, 1995; SIPKA, 1997).

The irregularity of coastal cells impedes parallel spreading of sediments along coastlines. The cell morphology determines two kinds of transit: one within the cell, and one between cells. There is hardly any transit between cells under normal wind and sea conditions, with the only noticeable transit within the cell abutting against its limits, with no escape beyond the cell downstream boundary.

Artificial Beach Nourishment

This approach has found wide acceptance, and is heralded as working with nature instead of against it. CHARLIER and DE MEYER (1998) published an extensive review of projects. The results have been monitored and the impacts, principally on ecosystems, assessed. Impacts have been examined by LANDFORD among others (1989). Opponents to the methods object to costs and the need to recharge more or less frequently. PSUTY (1995) of New Jersey's Rutgers University reported on mitigation instead of nourishment at *Littoral '95* (Nantes).

Artificial nourishment with construction of a feeder berm has been tested and proven to be a considerable improvement. Most of the material excavated in the USA is not polluted, and offshore berms are a beneficial alternative to the traditional disposal of dredged material. Underwater berms are constructed in deeper waters, and these "stable berms" are less subject to waves and currents, with the expectation that the material remains in place. A larger variety of dredged material can be used. The feeder berm, placed in the area between the surf zone and the 9 m (±30 ft) isobath, requires quality sand; the material is expected to move downdrift, though remaining in the nearshore coastal region. The objective is less attenuation of wave impact than addition of

Figure 2. Beach at De Haan after nourishment and placement of berm (Belgium) (Photo: Haecon, nv).

sand, production of a lesser underwater slope and reduction of the erosive action on the shoreline. (Figure 2).

Mounds thus built remained stable near Norfolk Virginia. In Agadir (Morocco) and Mobile, Long Island (U.S.A.), the method proved successful.

Monitoring techniques apply to both the feeder and the stable berms. In the case of the feeder berm, material will move downdrift while a little stable berm is expected to remain stable. An unacceptable movement would lead to a return to conventional open-water disposal. Bathymetric surveys will be used to measure berm elevations and side-scan sonar will help define the boundaries of the berms.

To track sediment movement, grab samples of surface sediments will be taken. In addition, divers will take core samples to assess consolidation of the berm material. Waves and currents will be measured and bottom currents tracked, using bed drifters, and wave climate in the vicinity of the berms will also be measured. Aerial photography and satellite imagery will measure any large movement of the berms and detect turbidity plumes that may develop in the stable berm. Effects of the stable berm on fisheries will be evaluated.

In a paper by De Wolf and others (1997) read at *Coastal Zone '97* a report was made on a very successful beach reconstruction at De Haan, Belgium. Another paper, at this conference, by Malherbe and Lahousse (1998), provides a detailed update and assessment of the project.

Early in 1991, a feeder berm of approx. 2,200 m (7,216 ft) long was put in place for the first time in Europe near De Haan (a.k.a. Le Coq), Belgium. Using two trailing-suction split-hopper dredgers, some 600,000 m^3 (21,200,000 ft) of sand were used to build a longshore bar constructed at 600 m (1,968 ft) from the shoreline on the low water bar. In mid-1992, a profile nourishment restored the beach profile between the dike and the feeder berm. Due to the distances to cover, a booster station and a double line on the beach were put in place. As part of the deepening of the access to the port of Ostend, sand, with a size of about 200 microns diameter, was dredged, transported and dumped to build the feeder berm.

The De Haan project has three stated aims: keeping navigation channels open in what is considered as the busiest seahighway in the world and guaranteeing access to the coastal harbors, providing flood protection on the shore and to the adjoining hinterland, and addressing the needs of tourism and recreation.

The Fourth Alternative

Ten years ago Adams (1989) predicted that by beach dewatering from 25 to 50% savings would result, depending upon original re-nourishment duration and cost, compared to other methods. All trials so far have not elicited equally enthusiastic comments. The principle was enunciated as early as 1948 (Bruun 1989). It has been shown that treated areas in Denmark and Florida fare better than adjoining ones and that no downdrift erosion resulted. Controlled facilities have also been established in England, Spain and Japan. Denmark has however suspended further use of the system (*personal communication* from Bruun, May 1998).

The beach dewatering system has been marketed under such varied names as *Stabeach, Ecoplage* and *Beach Management System*. Environmentally acceptable, the drainage system brings about an "artificial interplay with nature's morphology through a localized slowdown of one natural process and speed-up of another, thereby tipping the balance off erosion." The permanent pipes and pumps are buried. Ves-

TERBY (1997) in his analysis of the state-of-the-art suggests combining the coastal drain system with beach nourishment. Weather conditions are no impediment to the work of the pumps, yet when they are stopped the "renewed" beach will play the role of a feeder station for the downstream coast.

The Fifth Alternatives

Other systems claim beach rehabilitation; some have been tested in the field, others, due to lack of funding have only proven their efficiency in the laboratory. Among the first is BEROSIN (1995), "better erosion inhibitor", consisting of a site-tailored flexible geo-textile curtain anchored to the bottom. It traps transported material in front and underneath. "Stabilito" supposedly creates a groin from bottom deposits. Sandpouches filled with sand are placed outside the breaking zone and lead to the building of a sand hump, in fact a berm or submarine dune.

The Beachbuilder (BEARDSLEY, 1998) uses a thin flexible flow control sheet (elastomer for instance) which is tethered in place over a portion of the surf zone surface.

The surf rushes beneath it while scouring the bottom surface, transporting loosened sand particles towards the shore and unto the beach. The environment friendly scheme has been scheduled several times for testing on the New Jersey Atlantic Coast. It has also generated interest on the Mexican Cancun Coast, the Rio de la Plata estuary and in Westport MA.

Other approaches free of external additives include setting up an artificial transit, and stabilization or creation of dunes. Dunes can be protected by sand filled geotextile skin "sausages" or Longard tubes. Longard tubes and sand-filled geotextile "sausages" may be used to make groins as well as protect dune bases.

The sausages have been used at Bredene in Belgium where they showed some efficiency in stopping further retreat and erosion of dunes at the beach's edge. Similarly the Cornic approach buries geotextile envelopes filled with sand to protect dunes. These can also be stabilized by injection of a gel, implantation of artificial "algae", or natural algae culture.

The Principia-Monaco process, a wave attenuator, and the electrolytic rock process have been mentioned by the French Technical Services for the Maritime Navigation and Equipment Transmissions, and Central Office of Sea Ports and Waterways. No specifics nor details, however, were disclosed at Bordomer '97.

Concrete tetrahedron and sand-filled geotextile containers, proposed as alternatives, to, among others beach nourishment, offer advantages (ZADIKOFF *et al.*, 1998). Tetrahedrons made exclusively of concrete or of a concrete and rubber mix can be used in submerged breakwaters and artificial reefs. The containers can play a role in erosion control, dune restoration, sediment retention, toe scour protection and submerged breakwaters.

Containers forming "sills" can be covered with compatible sand, thereby alleviating concerns about aesthetics, and planted with dune vegetation. Undercutting of dune escarpment at the toe is thereby prevented. Even when containers move seaward, they offer resistance. Used as submerged breakwaters, wave energy is cut as waves are tripped.

Bypassing and compensation dredging can be considered either as methods in their own right or as complements to artificial nourishment. Whether this should be considered a protection "method" or a mitigation approach is perhaps academic. However, the procedure has met with some success in some sites, and particularly in northern France. In step with the philosophy of letting Nature run its course, breaches have been made into the hard structure protection works. This lets the sea enter the dune barrier at high tide.

On the French-Belgian border near De Panne, constructions put in place to protect the dune toe are being removed and the tide is now able to roll in, allowing the sea to occupy areas it covered regularly in the past. Dissipation of energy has proven favorable to the erosion problem, which developed on the Belgian West Coast.

Reconstructed wetlands are additions to shore protection schemes that provide ancillary benefits such as water quality improvements, buffer zones, and biologically diverse sanctuaries for terrestrial and aquatic species. The plants provide enhanced erosion resistance through their soil mass and wave energy level reduction.

Conclusion

This review of coastal protection methods makes no claim of being comprehensive. Forty have been reported by MCQUARRIE and PILKEY (1998). Nor does it wish to promote one system above another. It does intend to show that hard structures are no longer favored, nor are they the only solution to the pressing demands of shoreline protection and/or restoration.

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□ RÉSUMÉ □

Si le littoral belge de la Mer du Nord n'est que de longueur plutôt restreinte, il n'empêche qu'il constitue un excellent laboratoire particulièrement pour étudier l'efficacité de certaines méthodes de protection côtière. Protégé depuis plus d'un siècle par des champs d'épis devant un cordon de dunes hélas fort entamé par la construction immobilière, des digues et quelques ports, ses plages n'ont cessé de reculer à un rythme accéléré par les activités touristiques.

On s'est écarté depuis plus d'une décennie de l'emplacement et de la remise en état des ouvrages "durs en faveur de l'alimentation artificielle des plages, même si de nouvelles techniques ont été introduites, telle l'utilisation de blocs dits HARO. L'extension du port de Zeebrugge offrit l'occasion d'inaugurer cette démarche, de grandes quantités de matériaux dragués étant disponibles. Ce sont les plages quasi entièrement submergées aux marées hautes de Heist, Duinbergen, Albert-Plage, Knokke, Le Zoute et Lekkerbek qui ont bénéficié de ces travaux. Certes il a fallu périodiquement faire des recharges, mais l'opération, alors la plus grande au monde, s'avéra bénéficient et entièrement justifiée du point de vue touristique et économique. La côte ouest longtemps intouchée fut plus récemment attaquée par l'érosion. Ici aussi il fallut intervenir.

Depuis la technique du "banc de sable nourricier" [berme] a été mise à l'essai dans le secteur du Coq (De Haan) et s'est avérée un grand succès. Mais d'autres méthodes ont été également proposées. Il s'agit de la déshydratation des plages, de l'installation de récifs artificiels, mais aussi de démarches où on fait l'appel à la nature, tels les systèmes Berosin et Beachbuilder. La communication propose un tour d'horizon d'un certain nombre d'alternatives.

□ SAMENVATTING □

De Belgische Kust heeft eerder een beperkte lengte maar biedt een natuurlijk laboratorium. Verschillende kustverdedigingsmethodes werden er beproefd. De duinengordel is fel aangetast door woningbouw. Meer dan een eeuw geleden werden golfbrekers (strandhoofden) aangelegd in zee, maar dit belette niet dat de stranden van de Oostkust practisch verdwenen bij elk hoog tij. Toen tot de uitbreiding van de Haven van Zeebrugge werd besloten, bood zich een unieke kans aan om strandvoeding te beproeven vermits men plots over een grote hoeveelheid gebaggerd materiaal beschikte dat hiervoor kon aangewend worden.

Sedertdien heeft men nabij De Haan een andere aanpak getoetst: strandvoeding met behulp van een "voedingsbank" [berm], op korte afstand van de laagwaterlijn aangelegd. Er was tevredenheid over het resultaat. Dit referaat bekijkt ook andere alternatieve methodes: ontwatering, artificiële zeewierklippen, maar ook Natuurlijke voedingssystemen zoals deze voorgesteld door Berosin en Beachbuilder.

□ ZUSAMMENFASSUNG □

Durch die belgische, and später flämische Regional, Regierung wurde Abschächtzungen der Küstenabtragung und der Strandbildung seit längeren Zeit durchgeführt. Diese Messungen waren notwendig durch die immer fortschreitende Strandzerstörungen längs der ost, und später auch west, Nordseeküste.

Die Verfasser diskutieren den Einfluß der Molen auf Wellen und Gefolg von Einsatz verschiedenen Strandverteidigung- und Wiederaufbau- Methoden (Entwaßerung, Algenklippen, Berosin, Beachbuilder, usw.). Der Sandersatz mittels Aufschwemmungen, besser noch mit Bermen wie für Beispiel im Küstresor De Haan (Belgiën), scheint für die Erneuerung des Strandes fördernde Wirkung zu haben.