Available online at www.sciencedirect.com
ScienceDirect
Coastal Engineering 53 (2006) 1045 – 1058
Coastal Engineering
An International Journal for Coastal, Harbour and Offshore Engineers
www.elsevier.com/locate/coastaleng

Shoreline accretion and sand transport at groynes inside the Port of Richards Bay

J.S. Schoonees [a,*], A.K. Theron [b], D. Bevis [c]

[a] *Entech Consultants, P.O. Box 413, 7599 Stellenbosch, South Africa*
[b] *CSIR, P.O. Box 320, 7599 Stellenbosch, South Africa*
[c] *National Ports Authority of SA, P.O. Box 181, 3900 Richards Bay, South Africa*

Received 30 November 2005; received in revised form 8 June 2006; accepted 21 June 2006
Available online 1 September 2006

Abstract

The south-western shoreline along the entrance channel inside the Port of Richards Bay has experienced continued erosion. Four groynes were constructed to stabilise the shoreline. Monitoring of shoreline evolution provided valuable data on the accretion adjacent to two of the groynes and on the sediment transport rates at these groynes. Tides, beach slopes, winds, wave climate, current regime, and sand grain sizes were documented. The one site is "moderately protected" from wave action while the other is "protected" according to the Wiegel [Wiegel, R. L. (1964). Oceanographical engineering. Prentice Hall, Inc., Englewood Cliffs, NJ.] classification. The shoreline accreted progressively at the two groynes at 0.065 m/day and 0.021 m/day respectively. The shorelines accreted right up to the most seaward extremity of the groynes. Equilibrium shorelines were reached within about 3.5 years to 4 years, which compare well with other sites around the world. The mean wave incidence angle is large and was found to be about 22°. The median sand grain sizes were 0.33 mm and 0.37 mm. The groynes acted as total traps, the beach surveys were extended to an adequate depth, and cross-shore sediment transport did not cause appreciable net sand losses into the entrance channel. The net longshore transport rate along the study area, which is north-westbound, is only slightly lower than the gross longshore transport. The actual net longshore transport rates are 18 000 m^3/year and 4 600 m^3/year respectively at the two groynes. A rocky area limits the availability of sand at one groyne. There is fair agreement between the predicted and measured longshore transport rates at the other groyne.

Keywords: Shoreline evolution; Accretion; Longshore sand transport; Groynes; Richards Bay

1. Introduction

The Port of Richards Bay (Fig. 1), situated on the east coast of South Africa, was constructed mainly as a coal export harbour and was opened for shipping in 1978 by the National Ports Authority of South Africa (NPA). The south-western shoreline along the navigation (or entrance) channel inside the Port of Richards Bay (Fig. 1) has experienced continued erosion. This erosion endangered the road leading to the south breakwater, as well as Building 4043 (Fig. 1). Coastal processes were studied to determine the causes of the erosion and different solutions were investigated to protect this shoreline against the erosion (CSIR, 1997; Schoonees et al., 1999).

Four groynes (Fig. 1) were constructed to stabilise the shoreline along the navigation channel (Schoonees et al., 1999). These groynes successfully withstood a major storm without suffering significant damage. Sand trapped by the groynes provided sufficient protection and has continued to halt localised erosion. The shoreline evolution in the vicinity of the groynes has been monitored on an ongoing basis, providing valuable data on the accretion adjacent to the groynes, the orientation of the shoreline, and the rate of accretion. At the same time, the environmental conditions at the site are well-known. This case study therefore provides valuable information on the shoreline accretion and longshore sediment transport at both a "protected" and a "moderately protected" site.

The purpose of this paper is to document the shoreline evolution and to provide estimates of the longshore sediment transport rate along the study site. Dong (2004) stressed the importance of assessing the actual performance of groynes; this

* Corresponding author. Tel.:+27 21 883 9260; fax: +27 21 883 3212.
E-mail address: kschoonees@entech.co.za (J.S. Schoonees).

0378-3839/$ - see front matter
doi:10.1016/j.coastaleng.2006.06.006

is addressed within the constraints of the monitoring data. In addition, other aspects, like the construction of the groynes, are briefly discussed. The study area (or site) is the south-western shoreline along the entrance channel (Fig. 1). The focus is on the shoreline updrift of the L groyne (Groyne A) and at Building 4043 (Groyne C) because most of the shoreline evolution has occurred there. The study site is subjected to both swell and locally generated waves having large incidence angles.

Section 2 of this paper deals with the environmental conditions at the site. Section 3 summarizes the construction of the groynes while Section 4 treats the measured shoreline changes adjacent to these two groynes. Section 5 discusses the longshore sediment transport in the study area. Conclusions to the study are provided (Section 6).

2. Environmental conditions at the site

2.1. Tides

Tides are semi-diurnal at Richards Bay. The average neap tidal range is 0.52 m while the mean spring tidal range is 1.80 m. The mean high-water spring tide level is approximately +2.0 m to chart datum of the port (CD_{port}) or +1.1 m to mean sea level (MSL). (CD_{port} is 0.90 m below MSL.)

2.2. Beach slopes

A bathymetric survey of the nearshore zone of the study area and the adjacent entrance channel was conducted on 30 November 1995 before construction of the groynes. This survey (Figs. 2 and 3) shows that the beach and nearshore profiles are characterised by a flat upper beach, a steep channel side slope and an almost horizontal channel bottom at approximately −21 m to CD_{port} (CSIR, 1997; Schoonees et al., 1999). The upper beach slope (slope from the shoreline to the deepest point of the upper beach) is approximately 1/74. (The beach surveys also shown in Figs. 2 and 3 are discussed in Section 4.2.)

2.3. Winds

Wind data collected near the entrance of the port indicate that the dominant winds are north-north–east, north–east, south–west and south-south–west. These dominant winds all blow essentially in onshore and offshore directions along the site; that is, approximately normal to the entrance channel. The wind data were used to compute locally generated wind waves.

2.4. Wave climate

Wave recordings are presently conducted by means of a directional wave buoy, which is situated just outside the entrance to the port. A brief assessment of the wave climate on the exposed coastline of Richards Bay (based on earlier measurements) can be found in Laubscher et al. (1991) and Coppoolse et al. (1994). However, the study area is located inside the Port of Richards Bay and, as such, the focus is on the wave climate there.

Both wind waves and swell penetrating the port were considered in determining the wave climate (CSIR, 1997; Schoonees et al., 1999).

The ACES model, as described by Leenknecht et al. (1992), was used to compute the wind wave characteristics, based on the wind velocities and persistences combined with fetch lengths. The wind waves have low significant wave heights (mean about 0.10 m and a maximum height of only 0.29 m) and short periods (typically between 1.0 s to 1.5 s with a maximum period of almost 2.1 s). The directions of the wind waves correspond to the wind directions, being usually north-north–east, north–east (which are onshore along the site), south–west and south-south–west (which are offshore).

Swell heights and periods were derived at two positions (Points Y and Z; Fig. 1) along the centreline of the navigation channel. Results from previous physical model studies (CSIR, 1990) were used. Exceedance curves were plotted for Points Y and Z. These curves were then used to predict the swell wave heights in the study area (Table 1).

The wave heights contained in Table 1 show that there is only a gradual increase in wave height from low return periods to high return periods. Wave penetration studies (CSIR, 1990) showed a linear decrease in wave height between Point Y (which is very calm) and Point Z (which is partially protected). This means that the site at Groyne A can be classified as “moderately protected” according to the Wiegel (1964) system, in which a site is either “exposed”, “moderately protected” or “protected”. The site at Groyne C is “protected”.

Typically, the peak swell wave periods vary between 8 s and 16 s, with a median peak period of 12 s. A comparison of wind waves and swell shows that swell is the dominant source of wave energy in the study area.

A few vertical aerial photographs taken between 1975 and 1995 (CSIR, 1997) were used in the design of the groynes to measure wave incidence angles near the location of Groyne A. A mean wave incidence angle of 43° clockwise from north was found. That is, the crests of the waves are orientated 133° clockwise from north. By using the average orientation of the shoreline before Groyne A was constructed, it means that the wave incidence angle relative to the shoreline is about 9°.

2.5. Current regime

Currents usually transport the sediment mobilised by wave action. Knowledge of the current regime is therefore necessary to understand the occurrence of erosion and accretion in the study area. Currents are normally generated by tide, wave, and wind action. Although the tidal flow through the navigation channel is considerable, the cross-sectional area of the channel is also large. Tidal currents are therefore weak, ranging from a peak, depth-averaged current of 0.03 m/s at neap tide to 0.17 m/s at spring tide along the centre of the entrance channel as found by means of hydrodynamic modelling (CSIR, 1998, 2000). The profile of the channel is such that the tidal flow is concentrated in the deeper part of the channel with small tidal flow on the upper slope close to the shoreline along the study area.