COASTAL ENGINEERINC IN SOUTH AFRICA

by

K S RUSSELL

1. INTRODUCTION

The paper presents a review of the historical movement of ships around the South African coastline, traces the evolution and development of the harbours of South Africa, describes the development of coastal engineering and summarises the organisations and their activities in both basic and applied research projects contributing towards coastal works.

2. HISTORICAL

The coastal currents and winds have played a major role in the historic exploration of the African coast. The earliest reference to a circum-navigation of Africa, although unconfirmed, was that by Herodotus who, in about 600 B.C. wrote that the Pharaoh Necho (Neco), then at war with the Syrians and wishing to combine his Mediterranean and Red Sea fleets, caused a fleet of ships manned by Phoenicians to sail from the Erythraean (Red) Sea and return through the Pillars of Hercules (Straits of Cibraltar). The journey is reputed to have taken three years; wind and currents make such a voyage in square-rigged boats a possibility.

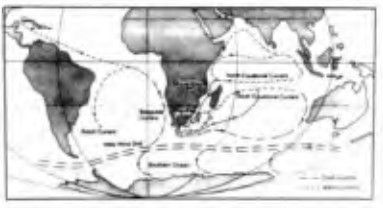

Fig.1. Ocean currents in the Southern hemisphere. The Restless Seas.

Fig.2. The earliest navigations around Africa. Southern Land. A.R.Wilcox.

National Research Institute for Oceanology, Stellenbosch, South Africa

Accounts exist of voyages on the west coast by Hanno (c.500BC) who, with a fleet of 60 ships, explored as far as Cape Palmas (Liberia), and of Sataspes (c.475BC) who, in an attempt to sail around Libya (Africa) on the west and return by the Arabian Gulf (Red Sea), reached a similar destination. The limit to these voyages was dictated, no doubt, by the square-rigged ships which could not tack against the wind, and the extent of the NE trade winds off the West African coast, the doldrums being encountered at about latitude 5° north.

Fig.3. Reconstruction of an ocean going Phoenician ship. Southern Land. A.R. Wilcox.

The Portuguese navigator Bartholomew Diaz in January 1488 rounded the Cape out of sight of land and subsequently landed at Mossel Bay. Because of his rough passage around the cape, Diaz named it "The Cape of Storms". On his return to Portugal it was renamed "The Cape of Good Hope" since it promised a sea route to the East Indies, so long a goal of the earlier explorers.

Fig.4. Diogo Cão caravel - 1483 AD. Southern Land. A.R. Wilcox.

The voyages of Diaz were followed by those of Da Gama (1497) and De Saldanha (1503), while the coast of Southern Africa was first surveyed by Perestrello (1576). On 18 July 1580, Sir Francis Drake rounded the Cape homeward bound on his circumnavigation of the world. The opening of this sea route led to extensive trade with the east coast of Africa and the Far East, but it was not until after the formation of the Dutch East India Company in the first half of the 17th century that a serious attempt was made to establish a permanent port of call at the Cape for the replenishment of supplies and repair of ships in preparation for the voyage to the Far East or return to Europe.

3. HARBOURS

The numerous bays and inlets along South Africa's 3 000 km of coastline provided convenient refuge for Portuguese, Dutch, English, French and Scandinavian vessels. Locations offering the best natural protection together with the opportunity to replenish water and food gradually emerged as potential harbours. These were Table Bay, Port Elizabeth, East London, Durban and Walvis Bay. Saldanha Bay, while providing ideal protection for anchorage, was without fresh water.

Numerous other shallow-draft harbours, most of which were located in river mouths, also developed along the coastline: Port Alfred, Port St. Johns, Port Shepstone and Port Nolloth. These harbours were important in the coaster trade active up to the 1930s until improvements in road and rail connections and the continuing increase in the size of freighters caused their gradual decline.

Major harbours developed at those locations which offered the maximum natural benefits and all have subsequently been improved by the construction of breakwaters and by dredging.

There are six major harbours along the coastline: Durban (the second largest port in Africa in terms of cargo handled), Richards Bay (190 km north of Durban, built especially to export coal but likely to become the country's biggest commercial port), East London (South Africa's only river port), Port Elizabeth (major mineral ore export harbour), Table Bay, Cape Town (its Sturrock "graving dock" is the largest in the southern hemisphere) and Saldanha Bay (110 km north of Cape Town, built especially to

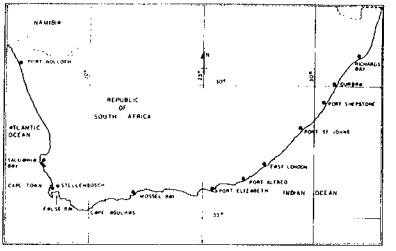

Fig.5. Location of South African Harbours.

export iron ore). Less significant are Mossel Bay (on the Cape south coast) and Walvis Bay (a South African enclave into South West Africa/ Namibia). These ports, administered by the South African Transport Services, annually handle 70 M tons of cargo and 12 500 ships with a gross tonnage of more than 300 M.

The fishing fleet consisting of 6 300 vessels of various sizes continues to utilise the several shallow draft harbours which are controlled by the Fisheries Corporation.

TABLE BAY - "TAVERN OF THE SEAS"

Fig.6. Aerial photograph of Table Bay Harbour and Cape Peninsula.

It was on 6th April 1652 that Jan van Riebeeck landed on the shores of Table Bay to set up a transit station for ships of the Dutch East India Company. The voyage - one way - from Holland to the Indies averaged about 6 months with appalling loss of men and ships. Although a number of jetties, dating from 1656, were originally built, the first significant coastal structure in South Africa was an uncompleted rubble mound breakwater. This breakwater, financed by taxing farmers delivering produce to the town through the use of their wagons to haul stone from the quarry to the breakwater, was started in 1743 but soon abandoned. Construction of a 546 m-long breakwater and excavation of a dock was inaugurated by H R H Prince Alfred on 17th September 1860. The dock, now Alfred Basin, was opened in 1870. Following the discovery of gold in the Transvaal, the breakwater was extended and the Victoria Basin was completed in 1905, with a water area of 27 hectares catering for ships up to 13 500 tons. No further development took place until after the First World War although ships of 18 500 tons were rounding the Cape regularly. In 1929 new quays were constructed which form part of Duncan Dock. Duncan Dock, developed between 1937 and 1945, provided an additional 195 hectares of water area 12 m deep and a total of 1 830 m of quay wall. A tanker basin was added in 1965, and by 1972, seven additional deepwater berths had been added. Construction of the Ben Schoeman Basin commenced in 1969 and it became fully operational in 1978.

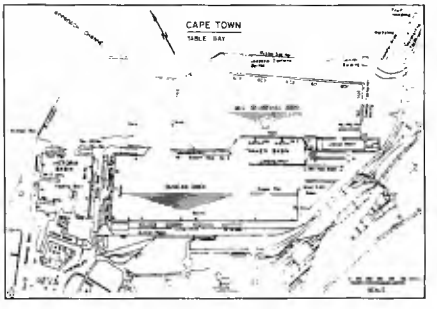

Fig.7. Lay-out of Table Bay Harbour.

DURBAN HARBOUR - "PORT NATAL"

Vasco da Gama sighted the coast, which he named Natal on Christmas Day, 1497. The Portuguese made no attempt to establish a settlement in Natal and there are many accounts by survivors of the many ships which foundered on the desolate coast and of their perilous journey to Lourenco Marques. In the later seventeenth century, survivors from the "Good Hope", together with survivors from the "Bonaventure" and "Stavinesse" built a boat and sailed to the Cape in 12 days. From descriptions of the bay and the rich trade in ivory the Dutch East India Company decided to develop the bay but changed their decision, as recorded in the Cape Town Archives.

"The East India Company would have taken possession of this fertile land (terra de Natal) years past, but for at the mouth of the port, a reef or sandbank that no galliot could get over without touching".

It was not until 1824 that the port began to develop; at that time the brig "Salisbury" was blown over the bar and grounded on what is now Salisbury Island. The first survey of the entrance was undertaken by Haure in 1831. Records of this and of subsequent surveys are still available in the Africana Museum.

In 1850, the first harbour engineer began to build two breakwaters designed to force the flow of the water down the channel and to scour the entrance. By 1854, a survey showed a depth of 6,4 m, but this was no permanent solution; in 1868 the depth had decreased to 3 m and by 1882 was reported to be 1,8 m. Sir John Coode in 1877 published a detailed description of the stability of the tidal entrance indicating the two opposing forces, the waves due to wind piling up sand in the entrance and the tidal currents and river flow scouring the entrance. He undertook an "estimate" of the tidal prism (quoting the tidal volume to be 18 794 737 yds^3) and by comparison with the entrance areas at Dunkirk, Calais, le Havre, Madras and Algiers suggested that the entrance width be reduced from 800 ft to 600 ft with a flow area between 1 300-1 400 yds^2 to produce a stable entrance. Many alternative schemes were proposed. In 1882 a new attempt at construction of piers was launched under a joint Milne and Coode scheme. Dredgers were purchased in 1889. By 1892 the sand bar was dredged to 4,4 m and the southern training wall extended by 474 m and by 1900 the depth of the bar had been increased to 5,9 m. Dredging thus far had been confined to the removal of obstructions after gales, in 1902 systematic dredging of the entrance and to provide a sand trap at Cave Rock updrift of the breakwater commenced.

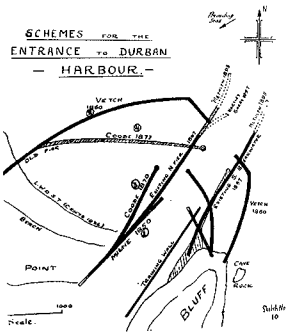

Fig.8. The numerous schemes suggested for the entrance to Durban Harbour.

This virtually solved the bar problem and by 1906 there was a depth of 10 m in the entrance. An average of 700 000 m^3/year

has been dredged in the entrance and sand trap since the early 1900s. Interception of this south to north sediment transport and development of the beach eventually led to severe erosion on the premier bathing beaches north of the harbour. In 1938 a sand by-passing scheme was introduced by which sand dredged from Cave Rock bight was transported by the dredger to a dolphin inside the entrance and pumped via a booster station onto the north beaches. In 1949, two pipes were laid under the harbour entrance through which sand, dredged from a jetty in Cave Rock bight, was syphoned directly to the booster station. This scheme was abandoned in 1954 and the scheme using the dredger re-introduced. At present some 100 000 m^3/year of dredged material is pumped from the dredger into a storage hopper loaded north of the north breakwater, for discharge at a number of intermediate sites along the beach.

The breakwaters have been considerably strengthened and improved over the years, the taper in the North Pier, due to Hartley and Barry, was removed during 1941 as it was considered to be a danger to shipping.

PORT ELIZABETH HARBOUR - "SETTLERS PORT"

Although visited by Diaz in 1488, Algoa Bay was little used since it provided scant shelter and little trade for ships. The 1820 settlers landed in Port Elizabeth by surf boat and sailing barges brought up to a warp secured to the beach. It was not until 1837 that the first jetty was begun using the remains of the wreck, as support for the deck of the jetty. This jetty, completed in 1841, measuring 147 m of timber jetty and 63 m of masonry approach, was totally destroyed in 1843 during a south-east storm. In the 1860s a 400 m-long solid breakwater was built at the mouth of the Bakens River; the work was a complete failure due to build-up of sand to the south of the structure and eventual shoaling in the lee.

The main breakwater was commenced in 1922 and completed in 1933. This breakwater was constructed from the top of an existing open piled Dom Pedro jetty which was filled with quarry material only after completion of the breakwater. A further expansion of the port commenced in 1975 included a 335 m curved extension of the breakwater and a 3 km-long approach channel 900 m wide, with a dredged depth of 14,5 m for the deeper-draught bulk carriers and container ships.

Fig.9. Buffalo River and East London Harbour.

EAST LONDON HARBOUR - "PIONEER PORT"

East London is the only South African river port and is located on the Buffalo River. A survey party, sent in 1689 by Simon van der Stel to explore from Table Bay to Delagoa Bay, found that the mouth of the Buffalo River formed a natural harbour but extensive

sandbars were located in the entrance - thus for centuries development of the port was prevented.

The town of East London was established in 1848.

By 1893 dredging had sufficiently deepened the entrance to allow ships of up to 8 000 tons to enter the port. In 1927 construction commenced of the present turning basin which was completed by 1937 and subsequently enlarged between 1959 and 1961.

RICHARDS BAY HARBOUR

Richards Bay is named after Rear Admiral Sir Frederick Richards who in 1879 landed troops during the Zulu War. During the early 1900s the British undertook hydrographic surveys along the coast to locate a possible bunker station, (to be linked by rail to an inland coal course) for the Royal Navy. In 1902, Richards Bay was surveyed by Cathcart Methven, the harbour engineer for Durban, who rated the bay to have more development potential than Durban Harbour. Methven proceeded to design and provide a cost estimate for the harbour at slightly more than £1M. The scheme was, however, never realised. Richards Bay was the first new South African harbour to be constructed since Union, at a total capital investment for the harbour works of some R200M.

Fig.10. Aerial photograph of Richards Bay Harbour.

The entrance channel, dredged on the alignment of an old submerged gorge, presently provides depths required for the handling of 150 000 t bulk carriers. The approach channel has a length of 3,5 km, width 400 m and depth -24m outside the breakwaters and 6,1 km, width 300 m and depths 24 m to 19 m inside the breakwaters. The main south breakwater extends 1,3 km offshore and the north breakwater 0,6 km offshore. The breakwaters are rubble-mound structures protected by dolos blocks. Dolos sizes range from 5 to 30 tons and a total of 42 200 blocks were used in the construction. Dredging of the entrance channel and harbour area involved a total volume of 160M m^3 of spoil material and a further 35M of dredge material used for reclamation.

As at Durban, the south to north sediment drift of 800 000 m^3/year is intercepted by a sand trap located adjacent to the south breakwater; some 400 000 m^3/year is by-passed by the dredger by being pumped onto the north beach while the remainder is dumped at sea. At present some 28M t of coal are exported per year and this is expected to increase to 44M t by 1987. Additional coal berths are presently under construction.

SALDANHA BAY

Saldanha Bay was named after Antonio de Saldanha - although he never visited it. The name was originally given by de Saldanha in 1503 to what is now Table Bay; the Dutch subsequently gave the name to the present Saldanha Bay.

Saldanha Bay provided the best natural anchorage along the entire coastline but was not developed since it totally lacked fresh water. The bay was the scene of major conflict between the Dutch/French and English exploiting the numerous seals and later guano (used as fertilizer). One report records that during August 1844 some 300 ships were concentrated in Saldanha Bay to mine guano and that Skaap Island had been divided into segments "like a cake" to avoid fighting between the different nationalities.

Saldanha Bay later became the centre for fishing and whaling along the productive west coast. The present harbour, developed for the export of iron ore, was constructed during the period 1973-76. Construction included an ore-loading jetty inside the bay protected from wave penetration from the open sea behind a sand breakwater linking an island (Marcus Island), with a headland (Hoedjies Punt). The entrance channel, located south of the island, can accommodate VLCs up to 250 000 tons although the jetties have been built to accommodate 350 000 ton vessels.

COASTAL ENGINEERING

Early harbour development in South Africa fell under the jurisdiction of the Colonial Office, with the result that the majority of the design and planning aspects were undertaken in England and local harbour engineers were responsible only for construction.

Coastal engineering is historically and essentially a branch of civil engineering and it was only following the creation, in 1919, of a department of civil engineering at the *University of Cape Town* that local expertise developed. An early staff member, Mr G Stewart in 1941 built what was probably the first coastal model in South Africa to study range action or harbour resonance in South Africa. Mr Basil Wilson continued the pioneering studies, and during the period 1941 to 1946 he extensively studied range action and the proposed harbour extension for Table Bay Harbour. The small 12 m by 15 m model built in the Cape Town docks was later replaced by a much larger model built by the South African Railways at Langlaagte (Johannesburg). Wilson also extended these studies to investigate mooring forces related to range action.

At the *University of Stellenbosch*, coastal engineering research was started in 1957 with a series of investigations on small-craft harbours and especially fishing harbours carried out in conjunction with the Fisheries Development Corporation of South Africa. Expansion of the hydraulic model facilities and in 1976 the formation of an Ocean Engineering Research Group has led to further work on armour units, breakwater stability, ocean dredging, devices for extraction of wave energy and the design of oil deflection booms.

Both the Universities of Stellenbosch and Cape Town offer study courses at postgraduate level towards a M.Eng. degree in Civil Engineering. The *University of Natal* (Durban) over the past few years has offered a specialist course in civil engineering as an honours thesis towards a B.Eng. degree.

The *Fisheries Development Corporation* is a State sponsored organisation responsible for the planning, construction and maintenance of fishing harbours. Model studies for proposed new fishing harbours or improvements to existing harbours are normally carried out in conjunction with the National Research Institute for Oceanology of the CSIR or with the University of Stellenbosch. Because of its requirements with regard to precise survey for demarcation of harbour boundaries, navigational aids, and hydrographic survey the Corporation's survey branch has developed expertise in seismic and side-scan surveys and aerial photography of the coastline.

The *Coastal Engineering and Hydraulics Division* of NRIO originated from a small Hydrodynamics Division established in 1956 as part of the National Mechanical Engineering Research Institute at Pretoria. The need for applied research in the field of coastal engineering increased rapidly, particularly because of the proposed construction of major harbours at Richards Bay and Saldanha Bay. The need for a suitable laboratory to house the usually large hydraulic models and the formation of a specialist group to undertake the studies became essential. These new buildings and facilities were created in Stellenbosch adjacent to the Faculty of Engineering to permit a close liaison with the University, and in 1969 the Hydraulic Research Unit was established.

The National Research Institute for Oceanology (NRIO) was formed in 1974 to take over and merge the ongoing CSIR activities in marine science and technology. The Institute now comprises four coastal engineering and hydraulic divisions, four marine science divisions, various service divisions, administrative back-up and the South African Data Centre for Oceanology. The staff numbers 165 (in 1982).

The Coastal Engineering and Hydraulics Divisions undertake basic and applied research (some 50 per cent of the projects are of an applied nature undertaken on a contract basis) required for the optimum design and operation of coastal works including major and 'small-craft' harbours, beach and estuary improvement and marine disposal works. A further objective is to develop and provide specialised expertise and consultancy services in coastal engineering with special reference to the needs in South Africa.

- Hydrodynamics Division
  - .. Numerical modelling of water flow and tidal circulation
  - .. Transport/dispersion of pollutants and water quality simulations
  - .. Harbour resonance
  - .. Wave data analysis (design wave condition)

. Sediment Dynamics	.. Coastal and estuarine sediment transport
	.. Estuary mouth dynamics
	.. Wave theory
. Ship Dynamics	.. Ship motions in entrance channels
	.. Moored ship dynamics
	.. Small craft harbours
. Structures	.. Breakwater design, dolos armour units
	.. Coastal structures, tidal swimming pools
	.. Ocean outfalls
	.. Laboratory facilities

SUMMARY

Despite a long history of shipping and considerable harbour construction along the coastline it was not until the early 1900s that "coastal engineering" emerged in South Africa. Prior to the Union of South Africa in 1910 all harbour development was under the jurisdiction of the Colonial Office and planning and design referred overseas. The establishment of a civil engineering department at the Univesity of Cape Town in 1919 provided a nucleus for gradual development of coastal engineering, which spread to the other universities with the formation of civil engineering faculties and particularly departments of hydraulic engineering. In the 1960s the proposed construction of major harbours at Richards Bay and Saldanha Bay dramatically emphasised the need for applied research in the field of coastal engineering and directly contributed to the development of the research facilities at the University of Stellenbosch and Coastal Engineering and Hydraulic Divisions of NRIO. The scope of work undertaken by the various organisations involved in coastal and ocean engineering research has expanded and now includes wave energy research, ocean outfalls and coastal management.