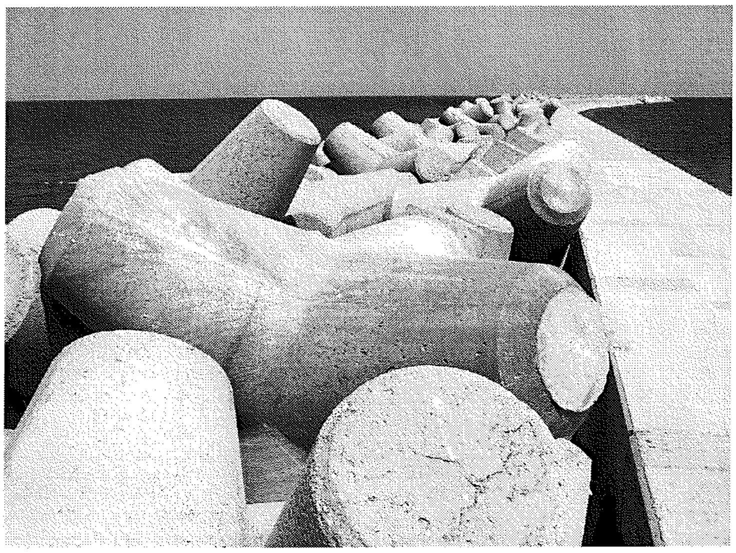
Breakwaters
Capability statement



24 November 2008
Version 2.1

ROYAL HASKONING

HASKONING NEDERLAND B.V.
MARITIME

George Hintzenweg 85
P.O. Box 8520
Rotterdam 3009 AM
The Netherlands
+31 (0)10 443 36 66 Telephone
+31 (0)10 443 36 88 Fax
info@rotterdam.royalhaskoning.com E-mail
www.royalhaskoning.com Internet
Arnhem 09122561 CoC

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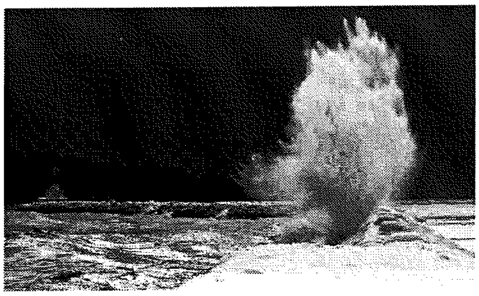
CONTENTS

1 INTRODUCTION

As its name explains, the main purpose of a breakwater is to break-the-water. Either by breaking the waves or by "breaking" the currents. Both functions aiming at creating calm and quiet water to support navigation or to facilitate coastline development and coastal protection. Many types of breakwaters exist, from rigid vertical structures to dynamic berm breakwaters. All these types of breakwaters have their advantages and disadvantages to be studied and evaluated within the boundary conditions of a site and application. However, generally speaking, all breakwaters have one common aspect: the cost for construction in general is high. Construction costs for a breakwater typically range between €10,000 and € 100,000 per running meter (largely depending on water depth) and lengths may vary between a few tens of metres (groynes) to a few tens of kilometres (port breakwaters, coastal protection). Therewith the design and construction of breakwaters often runs into millions of Euros/Dollars and in some exceptional cases even beyond.


Breaking the waves


Groynes

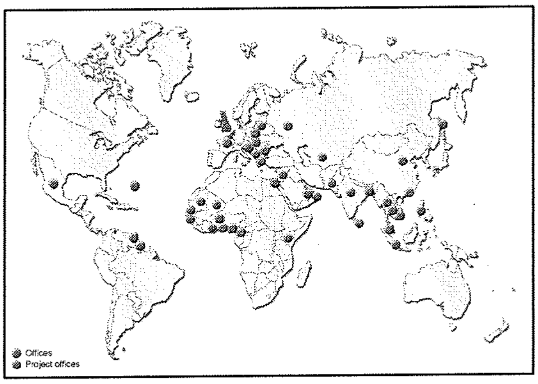
Optimisation of the breakwater design aims to reduce the construction costs of breakwaters. A thorough understanding of the design factors and the design process forms the basis of such optimisation process. Through knowledge and experience, Royal Haskoning has built this understanding. By designing breakwaters in many places in the world under varying conditions. This breakwater capability statement envisages to illustrate this knowledge and experience. Firstly by providing Royal Haskoning's project experience in designing breakwaters and secondly by providing a method statement for the design of breakwaters. Finally, an overview of key staff is presented with summarised CV, with ample experience in breakwater design, construction and inspection.

2 BREAKWATER PROJECTS EXPERIENCE

Royal Haskoning's experience in breakwater design results from a long track record of projects. A track record which developed during the nearly 125 year long history of the firm.

2.1 History

Founded in The Netherlands in 1881 as Haskoning B.V., Royal Haskoning is an independent, multi-disciplinary consultancy with its head office based in the historical town of Nijmegen. Today Royal Haskoning offers the combined expertise and long term track record of two of its founding companies, Posford Duvivier Ltd. (of the United Kingdom) and Haskoning B.V., as well as the wider experience of other affiliated organisations. The company combines a wide range of knowledge and experience with 3,000 professionals and has an extremely strong worldwide presence. In addition to our nearly 30 European offices, the group has around 50 permanent offices globally spread across, including the Middle East, the Indian Subcontinent, South East Asia, Central Asia, Africa, Eastern Europe and FSU and South America.



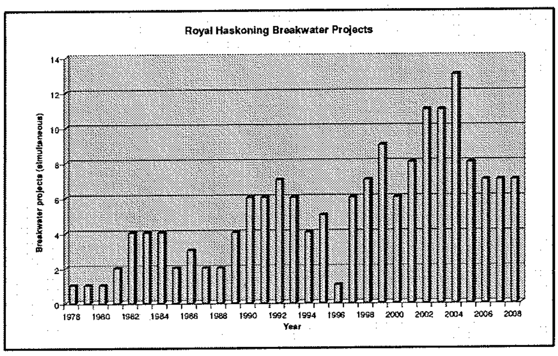
Royal Haskoning offices world wide

Royal Haskoning is a member of the Association of Consulting Engineers in The Netherlands (ONRI) which organisation is affiliated to the Fédération Internationale des Ingénieurs Conseils (FIDIC) and is a member of NEDECO, Netherlands Engineering Consultants. Royal Haskoning is accredited by Lloyd's Register Quality Assurance Limited as operating a Quality Management System conformable to NEN-ISO 9001. Royal Haskoning was awarded with the honorary title 'Royal' in 1981 for it's outstanding achievements in the field of maritime and civil engineering.

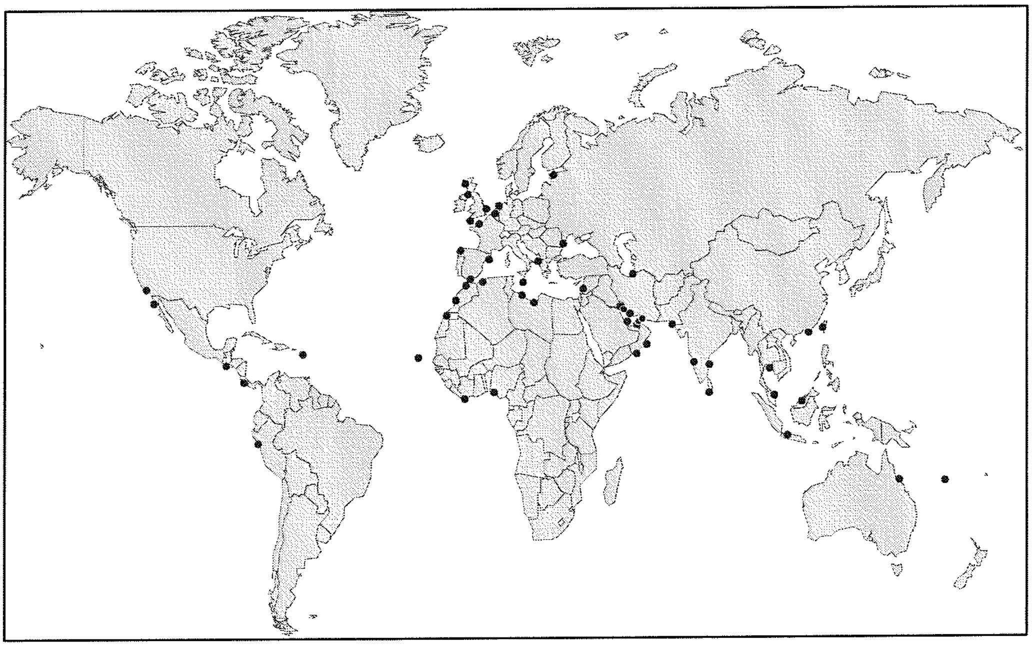
Royal Haskoning has a particularly strong track record in countries with emerging economies and projects in these countries account for some 25% of the company's workload. Our experience in these countries allows Royal Haskoning to bring to individual projects a valuable combination of international expertise and a working knowledge of local conditions.

2.2 Projects track record

During the long history of Royal Haskoning a large number of breakwater projects have been executed. Much of Royal Haskoning's breakwater experience has been gained under different circumstances in different projects around the world.



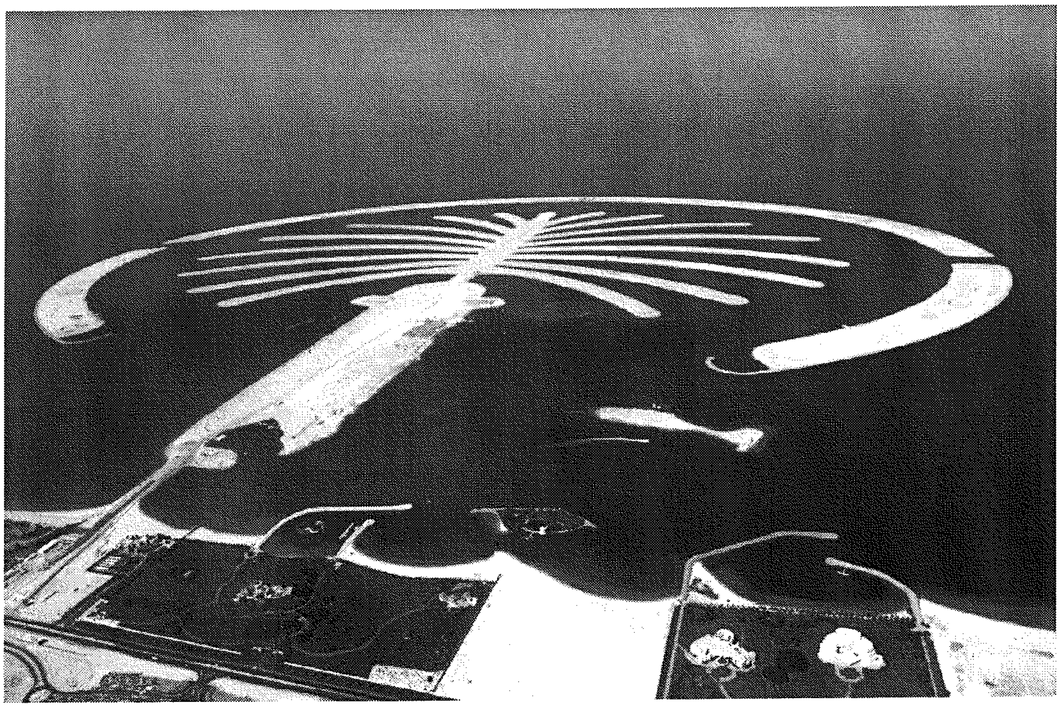
Breakwater projects carried out



Royal Haskoning breakwater projects world wide

This is illustrated by the list of breakwater projects included in Appendix A of this breakwater statement, together with a short description of each project. From this long list some recent breakwater projects are presented below in more detail. This short list of breakwater projects in particular have been selected to demonstrate Royal Haskoning's experience in designing breakwaters of different types.

2.3 Palm Island Jumeirah and Palm Island Jebel Ali (2001-2005)

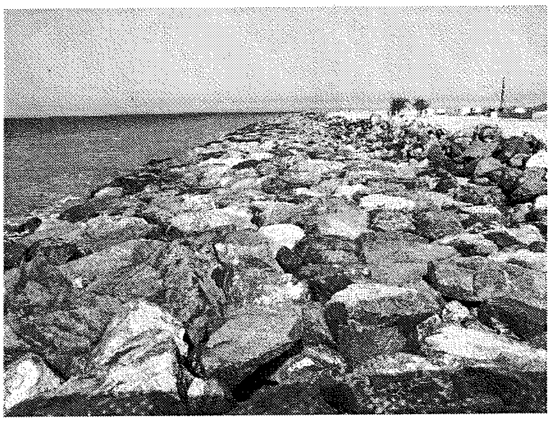


Palm Jumeirah

When Royal Haskoning in 2001 was awarded the design of the outer face of the crescent island for Palm Island Jumeirah, the basic design of the project already had been established. The project consisted of a land reclamation offshore Dubai, United Arab Emirates, in the shape of a date palm tree. To protect the sand beaches of the fronts of the palm against wave action, a crescent shaped island was wrapped around the crown of the palm. The crescent island covers an area of 4 by 5 km and by itself is about 200 m wide. The crescent island will accommodate transport infrastructure, tourist facilities (hotels, restaurants) and private residences.

Palm Jumeirah, outer face of crescent breakwater

This directly set distinctive requirements to the design of the outer sea defence. One of the most important ones being the limitation of wave run-up and overtopping and thus the volume of water potentially reaching the infrastructure and real estate to be constructed on the island. Apart from this, a requirement had been set that the outer face of the crescent island had to be constructed of natural materials like sand and rock.

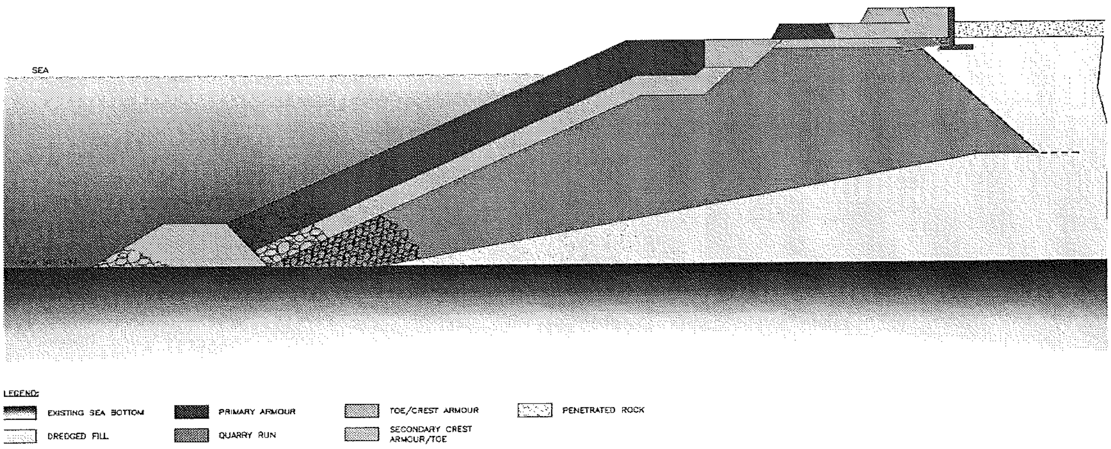


Crescent breakwater 20 m rock crest width

To meet these requirements, Royal Haskoning designed the outer face of the crescent island as a rock protected breakwater. Primary armour of the breakwater was selected at 3-6 tonne rock being available in the area. To meet the stability requirements of the breakwater the slope gradient of the breakwater was set at 1:2. Since the crest of the island already had been set at +4.00 m CD, model tests were carried out to investigate the wave run-up and overtopping. To limit the overtopping volume to a pre-set quantity, the width of the rubble mound crest had to be set at 20 m.

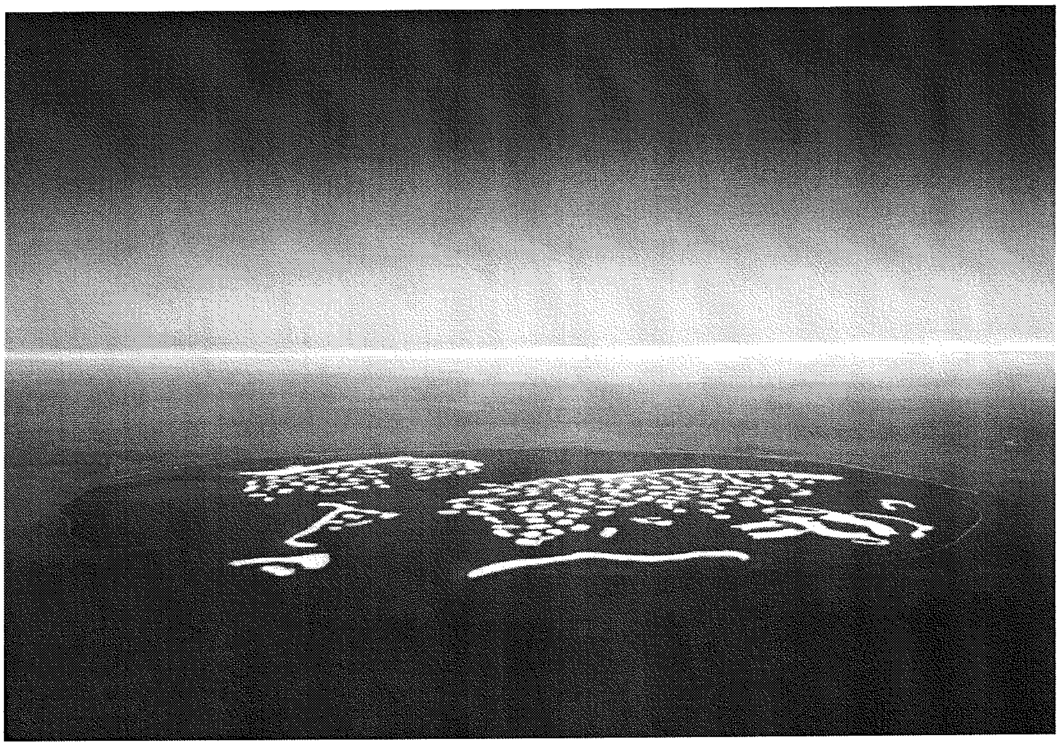
Following the design of the crescent breakwater of Palm Island Jumeirah, Royal Haskoning was also awarded the design of the crescent break-water of Palm Island Jebel Ali. The design of this crescent breakwater was made along similar principles as for Palm Island Jumeirah, albeit that Palm Jebel Ali is slightly larger (6 by 7 km).

Palm Jebel Ali



Typical cross section of the outer face of the crescent breakwater

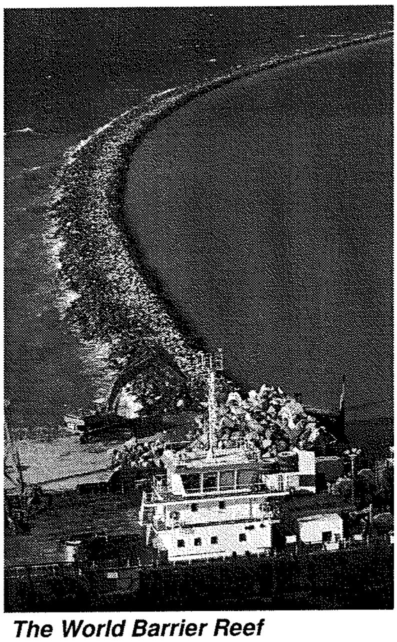
2.4 The World Barrier Reef (2003-2005)



The World (picture by courtesy of Nakheel)

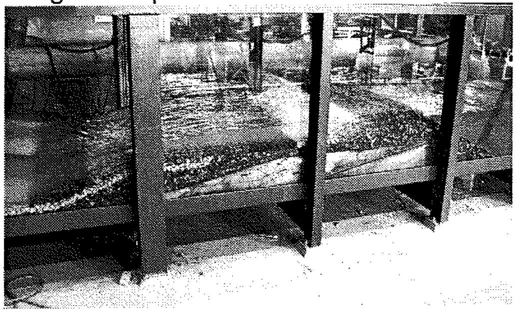
In this project Royal Haskoning was challenged to provide the protection for a group of over 200 artificial islands to be reclaimed offshore the coast of Dubai, United Arab Emirates. The islands together were to be grouped to resemble the continents of the world and cover an area of 7 by 9 km. As one of the objectives of The World project, the result should have the "natural look and feel" of islands as found in the Maldives.

After establishing the design conditions, basic designs were prepared of different concepts to protect the islands. Apart from a conventional rubble mound breakwater, a reef breakwater was developed. The reef breakwater was provided with a wide submerged berm. The width of this berm had been selected such that waves would break first before reaching the rear of the structure. At the rear a small water emerging crest was designed to reduce the waves transmitted to the rear of the reef. Apart from this reef breakwater also a series of bay-beaches with offshore breakwaters were investigated. A cost comparison revealed the latter not feasible, but that the conventional breakwater and the reef breakwater were comparable. Subsequently both concepts were subject to physical model tests.



The World Barrier Reef (picture by courtesy of Van Oord)

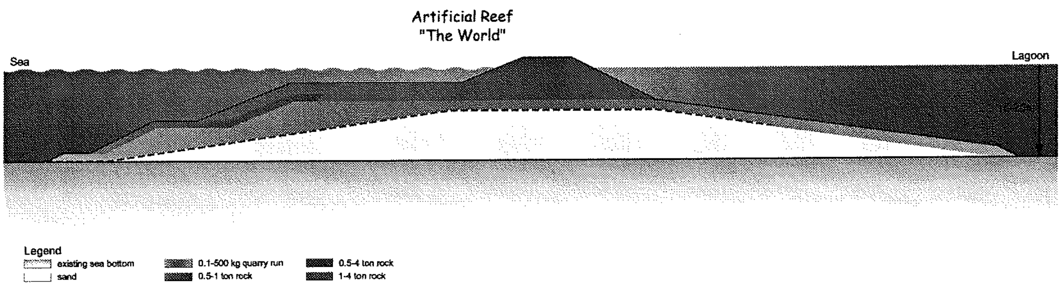
These model tests revealed that the conventional breakwater needed 3-6 tonne rock to withstand the design waves and yet still showed considerable damage on the crest and the rear of the breakwater. This would require regular inspection and maintenance. The model tests on the reef breakwater demonstrated the feasibility of the concept. Large waves break on the shallow berm before reaching the crest at the rear of the breakwater and damage to the breakwater remained well within acceptable limits. Importantly model tests revealed that the initially adopted width of the berm could be substantially reduced, leading to large cost savings for the concept.



Model testing the reef breakwater

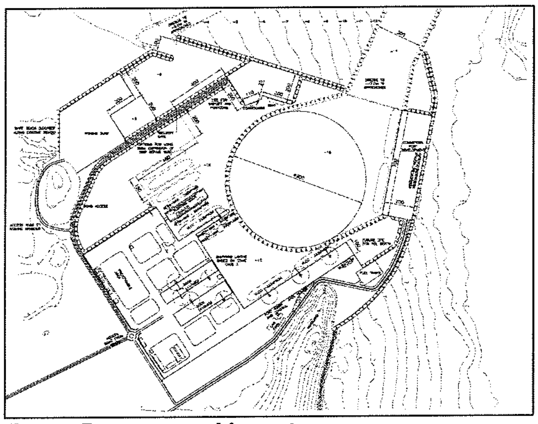
Following the model testing the design of both breakwaters was modified to include for the results of the tests. Subsequently comparing the construction cost of both breakwaters, it was found that the construction costs were more or less equal. Since the designs also met all the design requirements, the selection of the preferred concepts was based on the argument that the reef breakwater provides for a more natural look and feel than the conventional breakwater. The crest of the reef breakwater is only 2 m above mean sea level and 1.5 m above high water. Further the width of the reef breakwater above water is about 11.25 m less wide than the conventional breakwater. Under water the reef breakwater is much wider, but this area is always under water and thus forms a perfect ground for marine growth. Therewith the shallow foreshore is likely to provide a large environmental advantage. In view of the water depth over the shallow foreshore (about 1.5 to 2.5 m) with calm weather the area may develop into an area suitable and interesting for diving and snorkelling.

The World Barrier Reef
(Crest of the Shamal reef)



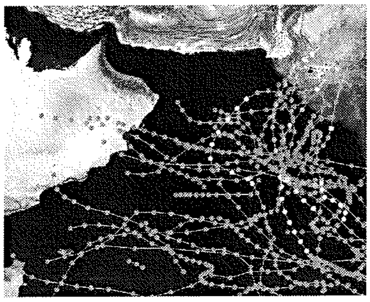
Typical cross section of The World Barrier Reef

2.5 Duqm Port Breakwaters (2001 – 2008)



Duqm Port, general layout

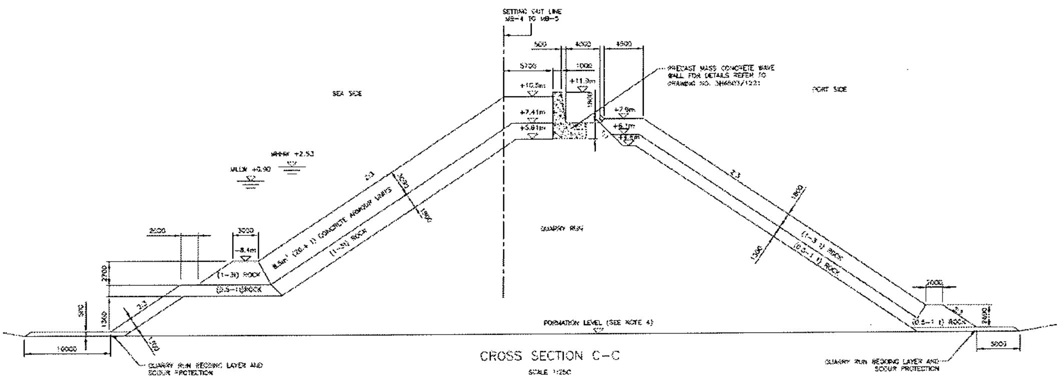
Duqm is situated midway between Muscat and Salalah in the Al Wusta Region of Oman. At this location a new port will be constructed including a fisheries harbour, a ship repair yard for vessels up to 100,000 tonnes, a commercial port and government berths. The port infrastructure will include two breakwaters and a dredged harbour basin constructed on an undeveloped site. The fisheries harbour will be for trawlers, dhows and skiffs and will become the main centre for the export of fish from the region. The ship repair yard will include dry docks and alongside quays for maintenance of vessels. The commercial port will be used for the import of construction materials and general goods for the region and for the export of locally available materials such as limestone.



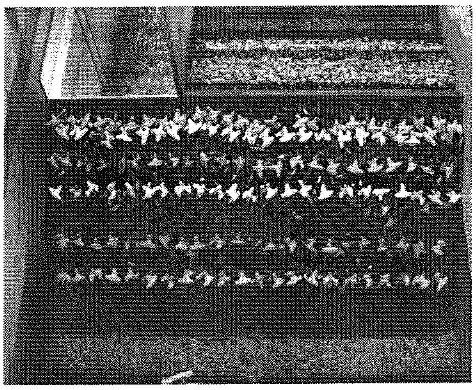
Cyclone tracks (1980-2005) relative to the Duqm site

The wave climate at the location is determined by a combination of "normal" wind generated waves and cyclone generated waves. Of these waves, the cyclone waves show to be the highest with significant wave heights of 5.8 m in front of the main (east) breakwater.

The largest water depth in front of this breakwater is about CD -14 m. The root of the main breakwater and the lee breakwater are located in much shallower water. In view of this limited water depth and realising that caisson breakwaters are only cost effective in deep water, it was selected to design the breakwaters as rubble mound breakwater. However, site investigations indicated that the largest rock pieces to be provided in substantial quantities from local quarries do not exceed about 4 tonnes. This showed to be insufficient to be used as main armour for the main and lee breakwater. Hence it was decided to design the rubble mound breakwater with a concrete armour units. In view of the familiarity in Oman with the Core-loc^{TM}, it was selected to prepare that design of the rubble mound breakwaters on this armour unit.



Typical cross section of main breakwater



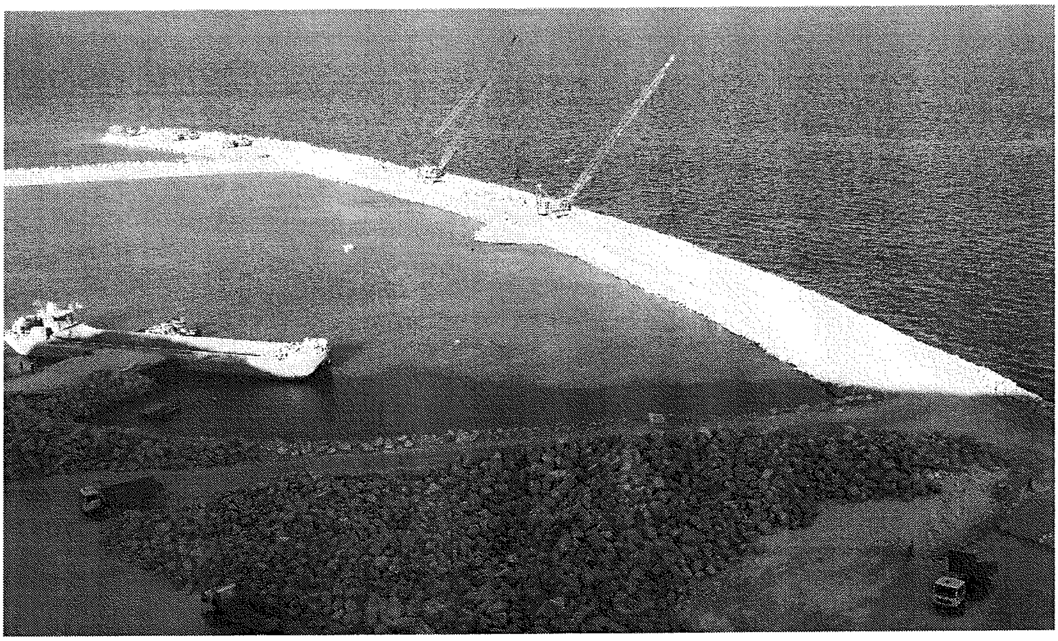
Set-up of 2D model test and damage after cyclone test

Following the initial design (resulting in 8.5 m^3 or an equivalent 20.4 tonne Core-loc^{TM}), 2D model tests has been carried out at Delft Hydraulics. Apart from investigating the stability of the armour units, the model tests were also used to confirm the assessed overtopping and crest elevation at the relevant main breakwater cross section. To be able to design the wave wall at this cross section also wave pressures acting on this wave wall were measured by means of pressure transducers. The 2D model test results confirmed the prepared breakwater design without the major modifications.

Upon the completion of the 2D flume test the final design of the breakwaters was prepared, including the design of the breakwater heads. These breakwater heads were subsequently investigated by Delft Hydraulics in a 3D physical model test. To account for proper wave transformations in the model, in this test the entire harbour entrance layout was modelled, including the (deeper) approach channel. Thus the shielding of the lee breakwater by the main breakwater and the refraction/ diffraction effects on the slopes of the approach channel are accounted for. The 3D model test results confirmed the prepared breakwater design without the major modifications.

Layout of 3D physical model test

Upon completion of the breakwater (and port) design, the dredging for this new port started in November 2007 and construction in February 2008. Royal Haskoning is taking part in the construction supervision of this project.



Duqm: start of breakwater construction in 2008

3 BREAKWATER DESIGN METHOD STATEMENT

Based on it's long project track record, Royal Haskoning has built an extensive expertise in the design of breakwaters. This expertise is reflected by the method statement for the design of breakwaters presented below. Through this breakwater design method statement Royal Haskoning would not only like to demonstrate it's knowledge of the design of breakwater but also that, apart from the physical model testing requiring extensive laboratory facilities, all breakwater design work can be carried out in-house.

Within Royal Haskoning, the design of a new breakwater or the rehabilitation of an existing breakwater is broadly executed in three phases:

1. Basic design
2. Physical Model testing
3. Detailed Design

After these three phases, depending on project requirements, additional steps may include:

4. Preparation of technical specifications
5. Construction supervision

This approach will be highlighted more extensively in the paragraphs below.

3.1 Phase 1: Basic Design

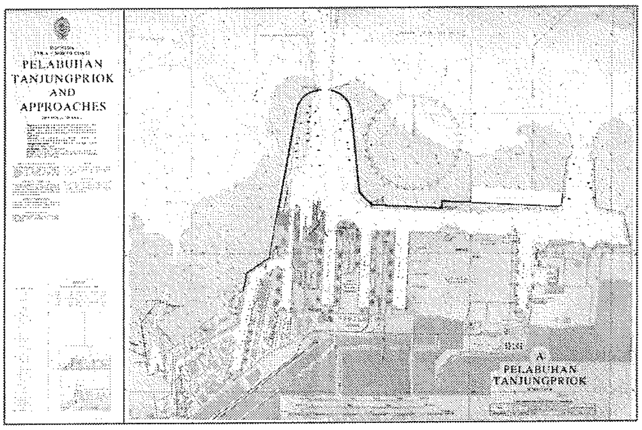
In this phase all activities are carried out for the purpose of defining a basic design of the preferred breakwater including:

- Initial data gathering
- Additional data collection
- Compilation of design criteria
- Basic design of breakwater

3.1.1 Initial Data Gathering

The objective of the initial data gathering is to build up an overall appreciation of the extent of existing data available. Typically, during the initial data gathering the following data is being looked for:

- Admiralty maps
- Detailed bathymetry
- water levels
- waves
- currents
- sedimentation rate
- winds
- geotechnical data
- earthquake conditions
- construction materials



Following the initial data gathering, the data will be screened for completeness. In case considered incomplete, additional data gathering will be proposed to be carried out.

3.1.2 Additional data collection

Additional data collection may include (but not be limited to): bathymetrical, topographical, quarry, soils and seabed investigations. In addition, data may need to be collected on coastal processes including tidal observations, current measurements and sediment sampling.

Retrieving Acoustic Doppler Current Profiler

If required, Royal Haskoning will draft Terms of References for additional survey campaigns and assist in letting the same works. Royal Haskoning will supervise the execution of the survey campaigns (of crucial importance for any sub-soil investigations) and incorporate the findings of the campaigns in the following steps of the design exercise.

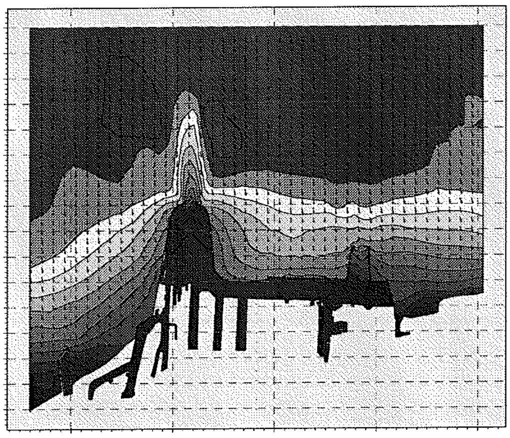
3.1.3 Compilation of design criteria

Following the collection of all data, the data will be analysed and processed to compile all required design criteria. The studies will determine the key parameters for the design of the breakwater. Amongst other this will cover the assessment of wave and tidal conditions at the site and will include the following:

- Assessment of water levels (tide, surge, sea level rise)
- Assessment of waves (offshore and nearshore)
- Assessment of tidal currents
- Assessment of geotechnical design parameters

To be able to compile all relevant design criteria, the following mathematical modelling may be required to carry out:

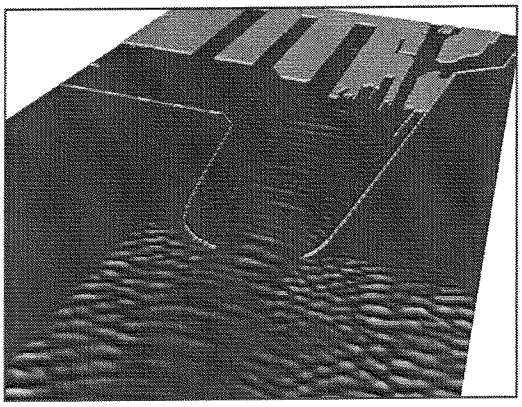
- Wind/wave hindcast analysis to predict offshore wave conditions
- Offshore to nearshore wave transformations to assess wave conditions at the location of the breakwater
- Current modelling to assess current patterns around the breakwater



Offshore to nearshore wave transformation (Mike 21)

- Wave penetration to assess wave conditions behind the breakwater
- Sediment transport modelling to assess sedimentation and erosion around the breakwater

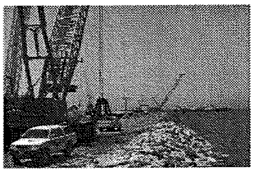
The mathematical modelling exercises can be carried out in house by Royal Haskoning using Mike 21 software from the Danish Hydraulics Institute. Alternatively, it may also be subcontracted to specialised institutes.



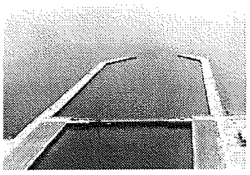
Wave penetration modelling (Mike 21)

3.1.4 Basic design of breakwater

When contemplating the basic design of a breakwater, a range of breakwater types may be considered. These include:

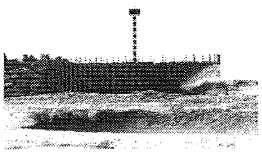


Rubble mound breakwaters (composed of rock and/or concrete armour units), either statically or dynamically stable, submerged or emerged (with or without overtopping)



Monolithic breakwaters (like a caisson, block wall or masonry structure), generally emerged and with limited overtopping

Composite breakwaters (combining a monolithic element with a rubble mound berm or base), generally emerged and with limited overtopping



Special breakwaters (floating breakwaters, pneumatic breakwaters, hydraulic break-waters, pile breakwaters, horizontal plate breakwaters)

The optimum choice of breakwaters will be governed by a number of factors which include:

- Availability of construction materials (and costs)
- Site conditions (soil and water)
- Methods of construction
- Future maintenance of the structures

- Wave penetration to assess wave conditions behind the breakwater

- Sediment transport modelling to assess sedimentation and erosion around the breakwater

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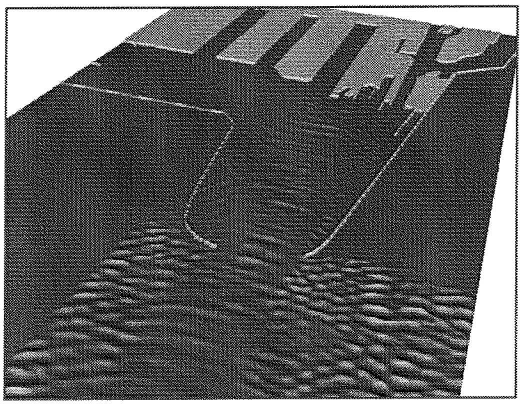

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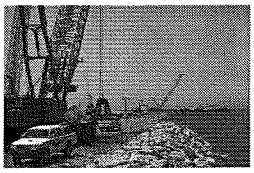

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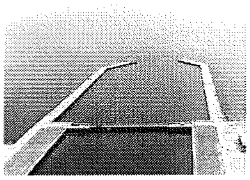

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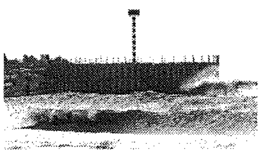

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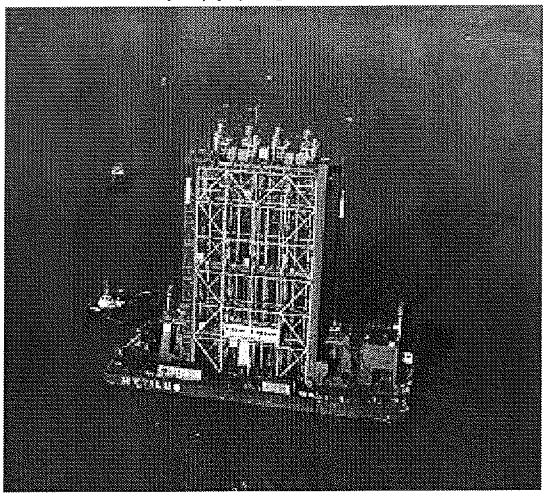
The optimum choice of breakwaters will be governed by a number of factors which include:

- Availability of construction materials (and costs)
- Site conditions (soil and water)
- Methods of construction
- Future maintenance of the structures

In all cases methods of dealing with the foundation problems of the breakwater posed by foundation layers may involve the application of:

- Complete removal of the soft layers and replacement by granular fill
- Partial removal of the soft layers and replacement by granular fill, granular columns, lime columns, or jet grouting
- Improvement of the soft layers by consolidation or chemical stabilization
- Utilization of the soft layers as a foundation by applying minimal stresses
- Bypassing the soft layers by structural load carrying elements such as piles or deep caissons
- Modification of the breakwater geometry to ensure stability (having potential implications on the hydraulic stability of the breakwater as well).
- Vacuum consolidation
- Thermal improvement
- Lightweight fill
- Electro-osmosis
- Dynamic compaction
- Piled embankments



Offshore dynamic compaction

Depending the boundary conditions for the design and based on its long time experience and engineering judgement, Royal Haskoning generally selects 1 to 3 most promising concepts to be worked out in a basic design. In general the concept of the rubble mound breakwater is preferred in situations of relatively small water depths and sufficient availability of rock. In very large water depths or if short of rock the use of a monolithic breakwater or composite breakwater might be more cost effective.

The design of a breakwater on soft foundation is an interaction between hydraulic stability of the breakwater and the geotechnical stability of the breakwater. Most often the first step is to draft a breakwater cross section design which meets the hydraulic criteria (generally with respect to stability and transmission or overtopping). Next step is to verify whether the developed cross section meets the geotechnical criteria with respect to stability, settlement and liquefaction.

Stability of Accropode against wave attack		
INPUT:		
Significant wave height:	$H_s := 4.9 \cdot m$	
Density (sea) water:	$\rho_w := 1025 \cdot \frac{kg}{m^3}$	
Density concrete:	$\rho_c := 2350 \cdot \frac{kg}{m^3}$	
Safety coefficient:	$\gamma_s := 1.4842$	
FORMULAE:		
relative density:	$\Delta := \frac{\rho_c - \rho_w}{\rho_w}$	$\Delta = 1.292683$
nominal diameter:	$D_n := \frac{\gamma_s \cdot H_s}{\Delta \cdot 3.74}$	
Accropode weight:	$W := \rho_c \cdot D_n^3$	
Hudson:	$K_D := \left(\frac{H_s}{\Delta \cdot D_n}\right)^3 \cdot \frac{3}{4}$	
Accropode volume:	$V := D_n^3$	$V = 3.404\,m^3$
unit height:	$H := \left(\frac{V}{0.34}\right)^{\frac{1}{3}}$	$H = 2.155\,m$
layer thickness:	$t := 0.9 \cdot H$	$density := \frac{1.35}{H^2} \cdot 100 \cdot m^2$
OUTPUT:		
Accropode weight:	$W = 7.999\,tonne$	$K_D = 12$
Layer thickness:	$t = 1.94m$	
Placing density:	$density = 29.063$	Expressed in number of Accropodes per 100 m^2.

Once having developed a number of alternatives, quantities and cost estimates will be determined to support the selection of a preferred alternative. The results of the basic design are generally reported in a basic design report, including but not limited to the following documents:

- Design brief
- Calculation notes
- Drawings
- Bill of Quantities
- Costs

3.2 Phase 2: Physical model testing

Albeit that much knowledge has been gained in the design of breakwaters, based on its experience Royal Haskoning in principal recommends the use of physical model tests for the design of breakwaters. In general the costs for the model tests are negligible to the costs of the construction of a breakwater and construction cost savings resulting from model testing therefore easily pays for the costs of such test. Depending the type of breakwater selected for the testing, the testing is recommended to be carried out to investigate:

For a rubble mound breakwater:

- stability of armour. Although often considered a confirmation of the applied design formulae, model testing is particularly useful in cases of high overtopping (stability of rear armour)
- overtopping and transmission
- stability of rock aprons at the toe of the structure

Failure of crest due to overtopping (filter layer visible)

For a monolithic breakwater

- (impacting) wave pressures on the structure. The measured pressures to be used in a calculation of the total (geotechnical and hydraulic) stability of the structure.
- overtopping and transmission
- stability of rock aprons at the toe of the structure

For a composite breakwater:

- stability of armour.
- (impacting) wave pressures on the structure. The measured pressures to be used in a calculation of the total (geotechnical and hydraulic) stability of the structure.
- overtopping and transmission
- stability of rock aprons at the toe of the structure

When the breakwater is subject to predominantly normal incident waves a 2D test (flume) may be sufficient. However, in case of oblique incident waves the use of a 3D test (basin) is to be preferred. The latter test facility is also required to test section of a breakwater with strong 3D effects, like at breakwater heads, Y-forks etc.
When physical model test are to be carried out, Royal Haskoning generally drafts Terms of References for the tests. Royal Haskoning will supervises the execution of the tests and incorporate the findings of the campaigns in the design exercise. Either by including the results in the basic design or by including the results in the final design, depending on the timing of the physical model tests and the requirements of the project.

3.3 Phase 3: Final design of breakwater

The design process will confirm and refine the preliminary cross-section selected earlier on in the design process and will cover:

- Final design of the breakwater cross section, including the results of model tests
- Final design of filter layers, including either granular filters of geotextiles
- Final design of monolith elements (reinforcement, connections, floating and sinking facilities)
- Final design of transitions in breakwater cross sections
- Preparation of design drawings
- Preparation of bills of quantities
- Cost estimates

A Final Design Report will be prepared to draw together all the detailed design information for the development and will include but not be limited to the following:

- Design brief
- Calculation notes
- Drawings
- Bill of Quantities
- Costs

3.4 Phase 4: Preparation of Technical Specifications (optional)

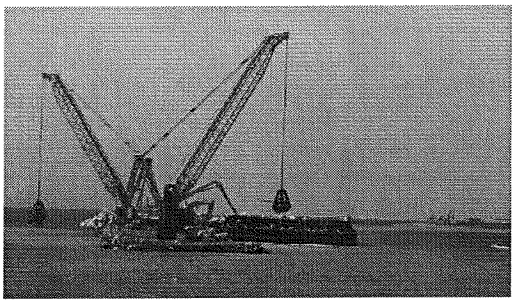
If required, Royal Haskoning may draft Technical Specifications for the construction of the breakwater. These specifications may include, but not be limited to:

- Materials specification
- Construction specifications
- Quality control procedure
- Operational and maintenance manuals

3.5 Phase 5: Construction supervision (optional)

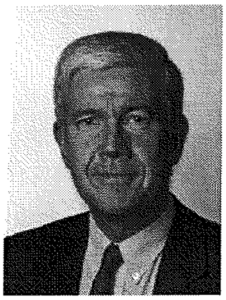
If required, Royal Haskoning may provide construction supervision for the construction of the breakwater. These may include, but not be limited to:

- Materials specification
- Construction specifications
- Quality control procedure
- Operational and maintenance manuals

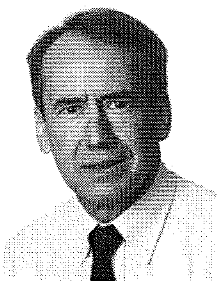


4 KEY STAFF

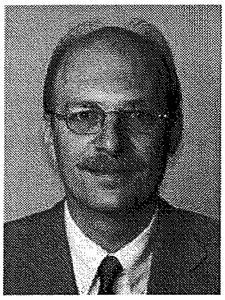
As key staff involved in the design and project management of breakwaters and coastal protections related projects, Royal Haskoning would like to introduce:



Prof. Han Ligteringen
With more than 30 years of experience, Prof. Ligteringen acts as the Maecenas of the staff executing the breakwater design work. As Professor Port and Waterways at Delft University, he is well introduced subject of ports, port planning, breakwaters and other port related structures. Prof. Ligteringen is author of more than 50 papers on subjects related to the above areas of expertise. One of the major projects Prof. Ligteringen was involved in was the rehabilitation of the Sines West Breakwater after its collapse in 1978.



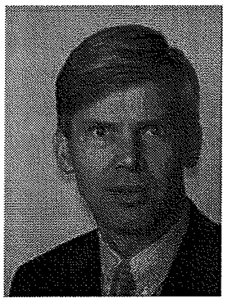
Mr. Tony Neal
Mr. Neal has over 35 years professional experience. He has extensive UK and international experience in planning, design and management of marine works, particularly container and Ro-Ro terminals. He also has wide experience in breakwaters, dredging and reclamation projects.



Mr. Ronald Stive
With more than 25 years of experience Mr. Stive is the director of the Maritime Advisory Group in Rotterdam and moreover was the design team leader for the breakwater reefs protecting the manmade islands Palm Island Jumeirah, Palm Island Jebel Ali and The World off the coast of Dubai. Lately he is involved as Project Director in the design of all waterfront structures for the Palm Deira and Dubai Waterfronts development scheme in front of the city of Dubai.

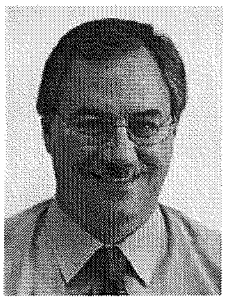
Mr. Alec Sleigh
Alec Sleigh over 25 years professional experience in coastal engineering projects or on the maritime aspects of large civil engineering projects. His expertise includes coastal engineering, wave, tidal and sediment modelling studies, breakwater design; appraisal of flood defences and coastal protection

Mr. Stephen Pearson
Mr Pearson has gained over 25 years of international experience in the design and project management in the areas of dredging, reclamation, river training, inland waterways, ports and sea defences, which is backed-up by some 10 years of construction experience working for both contractors and consultants on-site.
He spent some 4 years on the Ennore Coal Port Project in India as a Designer for the dredging works and associated coastal defences and later as Chief Supervisor (including financial and contractual administration) for the construction of 4km of rubble mound breakwaters.



Mr. Cor van der Lem
Mr. van der Lem has over 20 years professional experience in ports and harbours. He participated in major port expansion and masterplan studies, dredging and reclamation schemes and coastal protection developments in countries all over the world. Project tasks included studies with respect to waves, currents, water levels, tides and storm surges and their impact on harbour lay-out design, coastal morphology, breakwater and slope protection, harbour and channel sedimentation.

Mr. Nabil Abdul-Rahim
Mr Abdul-Rahim has over 20 years professional experience, including a total of 13 years internationally, in the study, planning, design, project control, site supervision and management of a variety of projects, as well as business development. His experience embraces transportation, container, Ro-Ro, general cargo wharves and jetties, together with breakwater design.



Mr. Ian Cooke
Ian Cooke has over 20 years of internal experience. As a Senior Project Manager Mr. Cooke is responsible for managing the larger coastal and maritime projects. He specialises in coastal processes and in the design and appraisal of breakwaters, although his experience extends across a broad range of civil engineering design, including earth retaining structures, coastal defences, harbour walls, dry docks and outfalls.

Mr. Dirk Heijboer
Mr. Heijboer has 20 years of professional experience in the design and installation of hydraulic structures in inland, estuary, port, coastal and offshore environments. Main part of Mr. Heijboer's professionalism is related to the design and installation of breakwaters and dams, erosion control and scour protection schemes, shoreline stabilisation measures, soft soil engineering and landfall / offshore pipeline and cable protection.

As key staff involved in the inspection and construction supervision of breakwaters and coastal protections related projects, Royal Haskoning would like to introduce:

Mr. Stephen Pearson

Mr Pearson has gained over 25 years of international experience in the design and project management in the areas of dredging, reclamation, river training, inland waterways, ports and sea defences, which is backed-up by some 10 years of construction experience working for both contractors and consultants on-site.

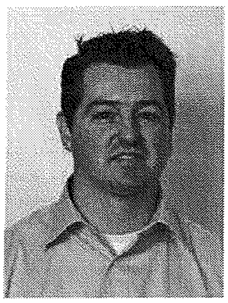
He spent some 4 years on the Ennore Coal Port Project in India as a Designer for the dredging works and associated coastal defences and later as Chief Supervisor (including financial and contractual administration) for the construction of 4km of rubble mound breakwaters.

Mr. Paul Zwetsloot

With more than 25 years of experience, Mr. Zwetsloot has worked as Resident Engineer and Resident Advisor for marine construction projects, Specialist Advisor in the field of breakwater construction and repair, Senior Project Engineer for planning, feasibility, and design studies. Specialist hydraulic studies, including mathematical modelling of wave, current and morphological processes, and supervision of hydraulic model testing.

Mr. Andrew Harvey

Andrew Harvey has over 10 year's professional experience within the river and maritime sector with a strong emphasis on contract preparation and administration, design work, multidisciplinary team management and site supervision. Mr Harvey has design and supervision experience of large scale land reclamation and breakwaters projects in both India and the Caribbean. Mr Harvey is also a qualified inshore commercial diver with experience of both technical supervision and a wide range of underwater structural inspections both in the UK and abroad.



Mr. Martijn Klabbers

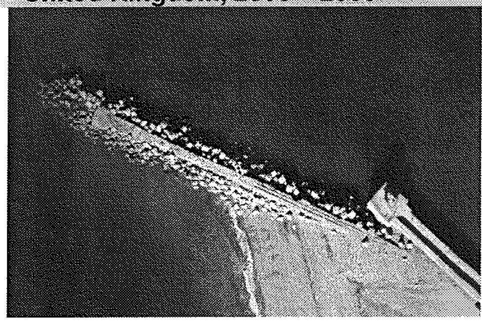
Mr. Klabbers has 10 years international experienced in the design and supervision of construction of shore protections, breakwaters, causeways, beach replenishments and scour protections. Furthermore he is experienced in supervision of hydraulic breakwater model testing and is specialised in concrete amour units. He is initiator and co-inventor of the X-bloc, and a recently developed concrete breakwater armour unit. He has been heavily involved in all stages of development of this unit.

Appendix A
Shortlist of breakwater projects

Port of Palmeira,
Cape Verde, 2006 – 2008

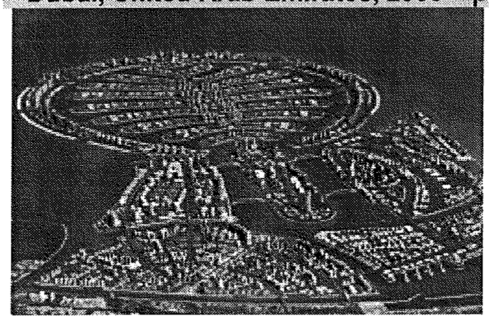
As part of a Master Plan study for the Port of Palmeira Royal Haskoning executed a traffic forecast, a location study, a conceptual design of the port (including **breakwaters**), and an economic feasibility analysis. In parallel, site investigations were performed, including hydrographic, magnetometer and sub-bottom survey, and geotechnical investigations. After completion of the Master Plan, the conceptual design was further detailed into a tender package for a design and build tender.

Port of Workington, South Breakwater Repairs
United Kingdom, 2006 – 2008



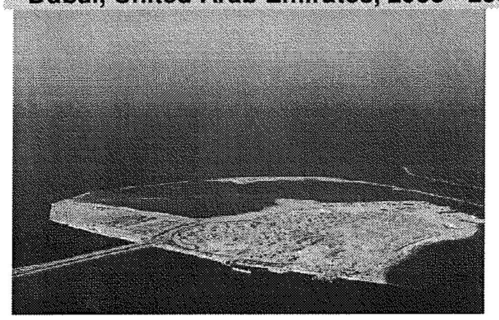
As a part of engineering refurbishment works at the Port of Workington we completed a review of the design and structural integrity of the existing **breakwater** to determine maintenance requirements. Royal Haskoning also completed the detailed design and tendering for the construction works.

Palm Deira and Deira Corniche
Dubai, United Arab Emirates, 2006 – present



Similar to Palm Jumeirah and Palm Jebel Ali, Palm Deira and Deira Corniche is a leisure, residential and tourist development under construction along the coast of Dubai. Our services include design of the 40 km-crescent **breakwater**, which protects Palm Deira and all **breakwaters** and revetments required for the construction of the islands of Deira Corniche

Dubai Waterfront Islands
Dubai, United Arab Emirates, 2006 - 2008



Similar to Palm Jumeirah, Palm Jebel Ali and The World, Dubai Waterfront Islands is a leisure, residential and tourist development under construction along the coast of Dubai. Similar to the named projects, our services include design of all **breakwaters** and revetments required for the construction of the islands of Dubai Waterfronts.

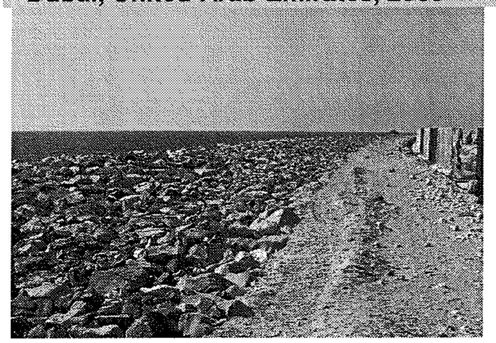
Ras Lanuf Breakwater Rehabilitation
Libya, 2006 - present

The **breakwaters** of Ras Lanuf Harbour in Libya required maintenance and repairs. Tetrapods had to be replaced following initial surveys and in accordance with quality plans. The site team comprised a three men team being a resident engineer, an inspector and an inspector-diver. The team fulfilled an extended assignment to inspect damages at the berths 3 A&B and to report on recommended repairs including cost estimates.

Champerico Fishery Port
Guatemala, 2004 - present

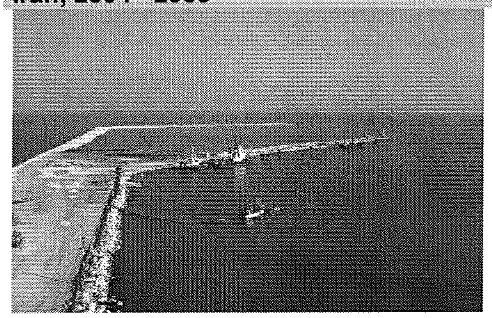
Following the masterplan study including feasibility analysis for the greenfield development of a fishery port, Royal Haskoning was awarded the detailed design and construction supervision of the project. The project is one of the 3 key projects of the National Government of Guatemala and comprises **breakwaters**, dredging works, an unloading quay and jetties and various onshore facilities. For the construction of the **breakwater** the newly developed X-bloc® has been selected.

Palm Island Jumeirah – Retaining Wall
Dubai, United Arab Emirates, 2006



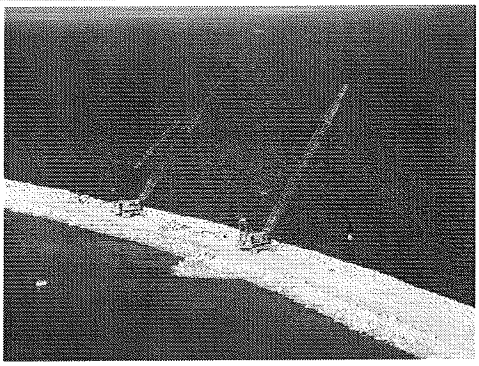
Final design of an (already installed) concrete retaining wall on the crest of the Palm Island Jumeirah crescent **breakwater** to reduce overtopping. Assessment of wave pressures against the wall by incorporating flow velocity observations from video recordings of physical model tests. Analysis of geotechnical stability. Overtopping and stability eventually maintained by adding rock in front of the wall, thus reducing wave forces acting on the wall.

Neka Port Project
Iran, 2004 - 2006



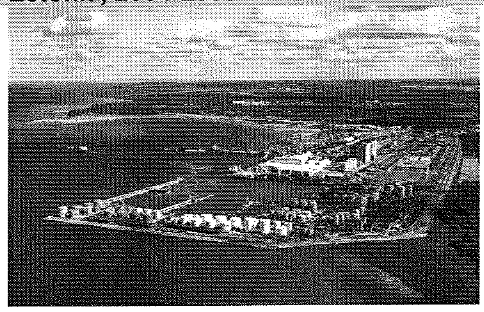
Neka Port is situated on the north east coast of Iran. The main users of the port agreed to expand the current port in view of the development of Iran's own oil and gas reservoirs in the Caspian. Royal Haskoning was retained by the users for undertaking full master planning and design services for the long-term port expansion, including two **breakwaters**.

Duqm Port and Shipyard
Oman, 2002-2006



Design of a new port including a ship repair yard for vessels up to 100,000 tonnes, a commercial port and government berths and a fisheries harbour,. The port infrastructure will include two **breakwaters** and a dredged harbour basin constructed on an undeveloped site. The **breakwaters** have been designed as rubble mound **breakwaters** provided with Core-loc® up to 10 tonne. Some sections of the **breakwaters** have been provided with a parapet wall to reduce overtopping while at the same time limiting the construction height.

Muuga Breakwater
Estonia, 2004-2005



Muuga port is not protected from waves from the north and the port has to stop operations in poor weather conditions. Royal Haskoning investigated the various options for the location and design of the **breakwaters**. An extremely thick layer of soft soil conditions led to the development of a piled **breakwater** concept.

Port of San Pedro, rehabilitation of breakwaters
Ivory Coast, 2004-2005

Already short after their construction in the late sixties of the last century, a storm caused severe damage to the 2 **breakwaters**. The process of degradation continued progressively, and repair works were only carried out ad-hoc. The existing **breakwater** system of the Port of San Pedro is therefore in a very poor structural state. Royal Haskoning, in co-operation with a local design institute, was retained for investigating the present state of the **breakwaters** and for designing a **breakwater** rehabilitation programme.

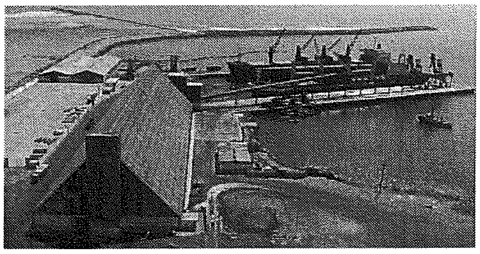
Tombak LNG Facility
Iran, 2004

The project included the design of a **breakwater** protected harbour for a new LNG jetty, a LPG jetty, a sulphur berth, a general cargo berth, a Ro-Ro berth and cooling water intake and outfall pipelines. Royal Haskoning provided engineering design input for the **breakwater** and the new facilities, together with advice on construction methods and construction planning and programming, and were responsible for the final preparation and compilation of the submitted tender document.

The World Barrier Reef
Dubai, United Arab Emirates, 2004

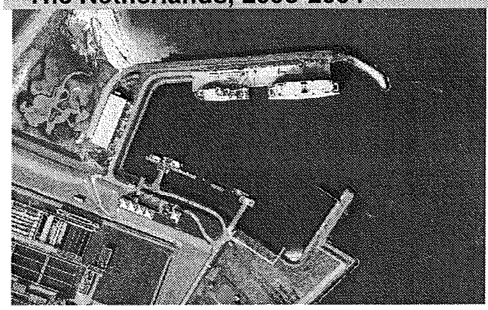
To protect a large number of artificial islands shaped according The World's continents, Royal Haskoning provided the design of an artificial protective reef **breakwater**. Because of aesthetic considerations the barrier reef was designed as a 16 km low-crested **breakwater**. Major part of the reef remains under water, reducing the visual impact of the **breakwater** without defying the protective capacity of the reef **breakwater**.

The Port of Salaverry
Peru, 2004



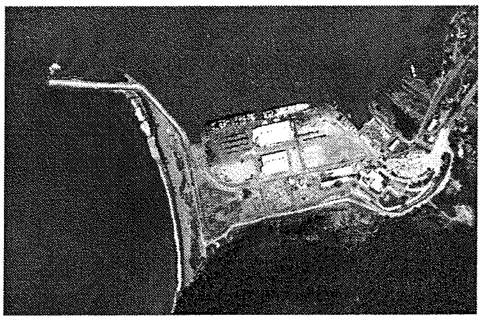
The Port of Salaverry suffers from severe sedimentation problems. The existing **breakwater** provides insufficient sedimentation protection for the available, local dredge plant to cope with. Royal Haskoning, in association with IHC, carried out a study into the optimum scheme of a **breakwater** extension cum dredge plant upgrading. Designs and technical specifications of **breakwater** extensions and new dredging plant were prepared. In addition, a groyne field was designed which served for protection of the coastline north of the port.

Jetty Design NIOZ harbour Texel
The Netherlands, 2003-2004



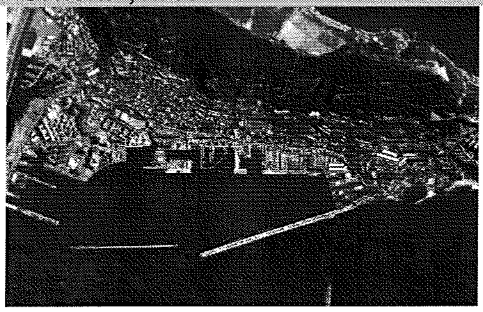
Apart from the design for a new fixed jetty in the NIOZ harbour on the isle of Texel, the project includes an alternative in the form of a floating jetty plus a comparative evaluation of the two. The design further includes a sheet pile **breakwater** next to the jetty.

Port of Caldera
Costa Rica, 2003-2004



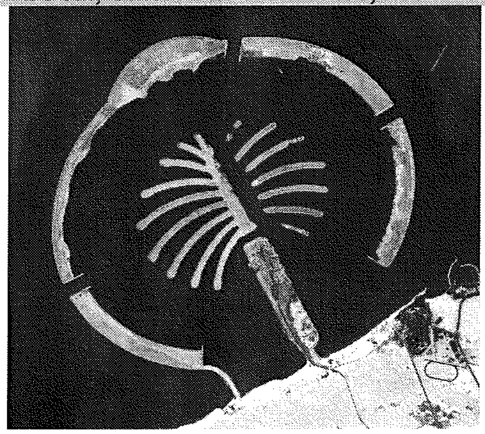
In May 2002, the recently finished **breakwater** of the Port of Caldera collapsed which resulted in the loss of the outer 75 meters of the **breakwater**. Royal Haskoning was retained for carrying out a study to revise the original design and construction method of the **breakwater** and to prepare a modified design. The services provided also included a study into the preferred layout of the **breakwater**, with the aim to reduce the existing wave disturbance and sedimentation phenomena in the port basin.

Professional Appraisal of Maritime Structures
Gibraltar, 2003



A detailed condition survey of the facilities at HM Naval Base, Gibraltar, was undertaken. A diving team, supervised by a Royal Haskoning diving engineer, was assessed the general condition of all submerged structures. The facilities inspected included **breakwaters**, quaywalls, a drydock and water intakes, and comprised many historical (19th Century) masonry structures. The appraisal also made recommendations for maintenance and repair of the facilities.

Palm Island Jebel Ali
Dubai, United Arab Emirates, 2002-2004

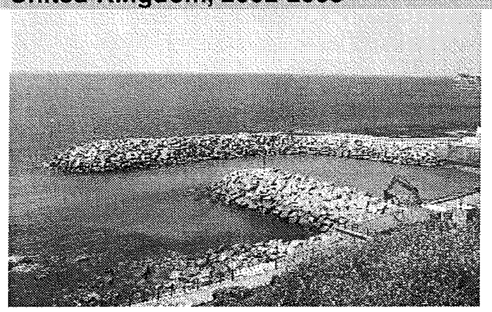


Palm Island Jebel Ali is a leisure, residential and tourist development under construction along the coast of Dubai. Our services include design of the 15.5 km-crescent **breakwater**, which protects the artificial island. It is designed as a rubble mound **breakwater** with three shipping entrance channels.

Fort Bay Harbour, Saba
Dutch West Indies, 2002 - 2003

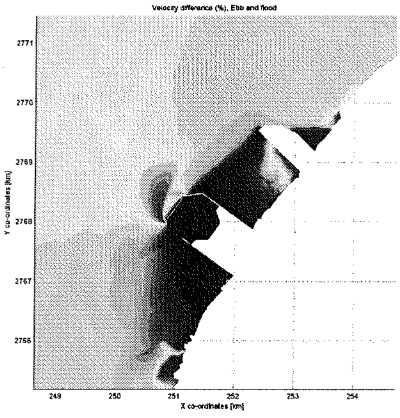
The project comprises the reconstruction of the Fort Bay harbour, which was severely damaged in the 1999 hurricane "Lenny", Reconstruction works comprise the main harbour quay, **breakwater** (top layer consisting of max 40 tonnes Accropodes), harbour basin dredging and navigation facilities. Royal Haskoning was responsible for the tender selection process of the Contractor, design review and total supervision of the project.

Ventnor Haven, Isle of Wight
United Kingdom, 2002-2003



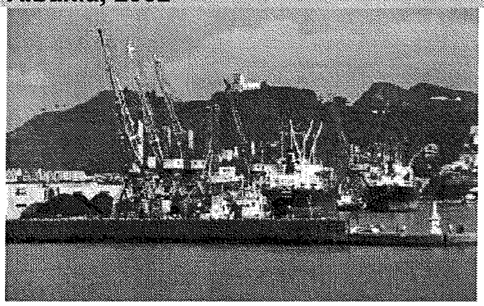
Design, contract management and construction supervision of a small haven for fishing boats and visiting yachts at Ventnor on the south coast of the Isle of Wight. For the construction of two rubble mound **breakwaters**, a total of 50,000 tons of imported rock was brought into the works. Other works includes the installation of entrance marker piles and buoys. A concrete walkway (including a viewing platform) was constructed on top of the western **breakwater**.

Taiwan LNG terminal
Taiwan, 2002 – 2003



The project started with an analysis and interpretation of the wave climate near the site, meteorological data and soil conditions. Downtime of the terminal, due to sea and swell conditions, was estimated with and without construction of a **breakwater**. The design included the optimisation of the port lay-out, **breakwater**, dredging and reclamation works, computer modelling of waves and current, site investigation, ship manoeuvring analysis, downtime assessment plus preparation of Material Take Off as input of detailed cost estimated.

Durres Breakwater
Albania, 2002



Verification of the design for the rehabilitation of the main **breakwater** for the Port of Durres in Albania. The original design had incorporated large mass concrete blocks at the crest of the **breakwater** to deflect waves. These blocks had, over time, been eroded by wave action.

Constantza Harbour Breakwater Extension
Romania, 2002-2003

The client intends to extend the unfinished **breakwater** system as part of the port expansion plan. In co-operation with Iptana consultants, Romania, Royal Haskoning was retained for carrying out the feasibility analysis of the **breakwater** extension. The activities carried out comprised a wave penetration analysis, downtime analysis and financial and economic evaluation of various **breakwater** schemes.

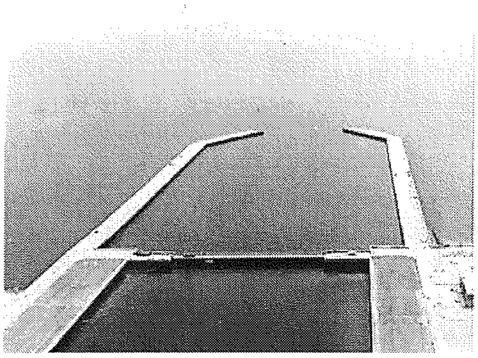
Icdas Port Study
Turkey, 2002

The client is developing a steel mill and power plant at a greenfield site, served by sea. An unprotected jetty has been built. The study involved assessing the future port requirements, including a review of cargo handling methods, and preparing options to meet these requirements. Downtime was a major concern, and therefore **breakwater** options were considered in detail.

Kharg Island Gas Gathering and NGL Project
Iran, 2002

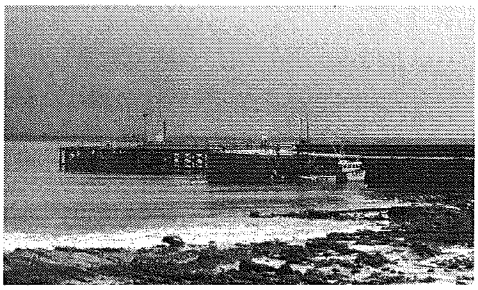
During the FEED preliminary designs were made of the marine works. This included the design of the main trestle, a LPG berth for 80,000 m3 vessels and a combined Condensate/Pentane berth for 10,000/30,000 dwt vessels respectively. Further a design has been made for a rubble mound **breakwater**.

Az Zour North Thermal Powerplant
Kuwait, 2001 - 2003



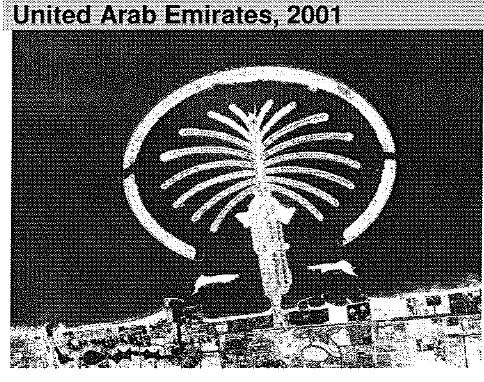
Planning and design of marine works associated with a new 2500 MW PowerStation. Services provided included design, specification, procurement and supervision of an offshore site investigation, procurement and suspension of data collection, hydraulic modelling studies and a marine EIA. Structures included twin **breakwaters** and coastal revetment.

Bruichladdich Pier Breakwater Extension
United Kingdom, 2001



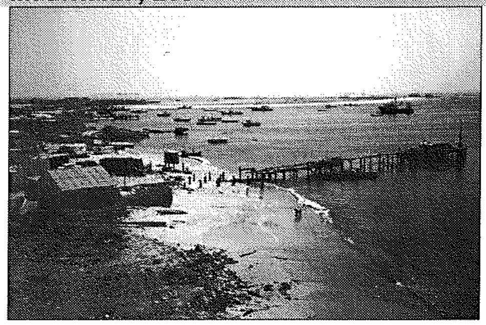
Appointed for preliminary and detailed design of an extension to the existing **breakwater** at Bruichladdich, Islay for fishing vessels. The facility is located in an exposed location. Surveys included hydrographic and current and sedimentation measurements, borehole and seismic. Wave and sedimentation modelling required in order maximise shelter while minimising silting of the harbour. Concrete quay extension rock armour **breakwater**.

Palm Island Jumeirah
United Arab Emirates, 2001



Palm Island Jumeirah is a leisure, residential and tourist development in the Arabian Gulf off the coast of Dubai. The island will measure approximately 6 km in diameter. It is designed in the shape of a palm tree consisting of 17 fronds and a trunk along with an 11 km-crescent shaped **breakwater** protecting the development. Royal Haskoning was responsible for the final design of the sea defence part of this crescent **breakwater**.

Nouadhibou Fishery Facilities
Mauritania, 2001

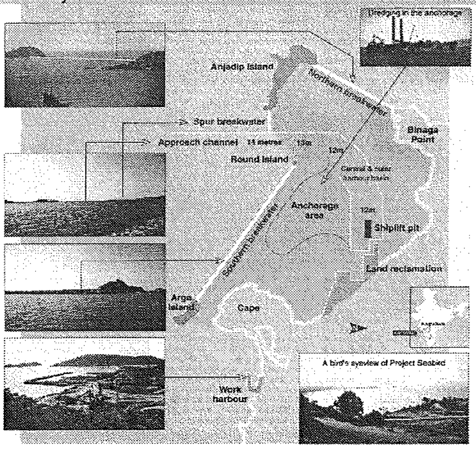


Tender design for a new fishing port at Nouadibou, Mauritania. The design consists of an offshore port area with storage facilities, connected to the mainland by a causeway. For the protection from incoming waves and current the causeway also functions as a **breakwater**.

Lagos Breakwater Repairs Project
Nigeria, 1999 - 2003

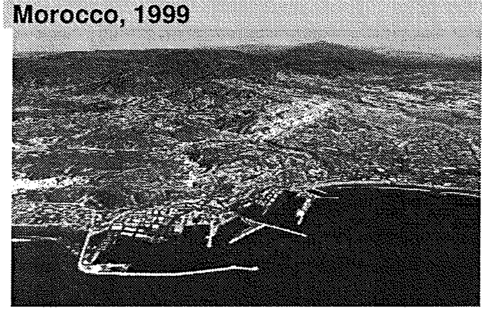
The Lagos Harbour **Breakwater** was constructed in the early 20th century and has suffered significant damage. 5A and Royal Haskoning were appointed to investigate their current state of the **breakwater** which involved mathematical wave modelling and physical modelling of repair works, to produce a detailed remedial design, prepare tender documents and award the repair works contract.

Karwar Naval Base (Seabird)
India, 1999 - 2005



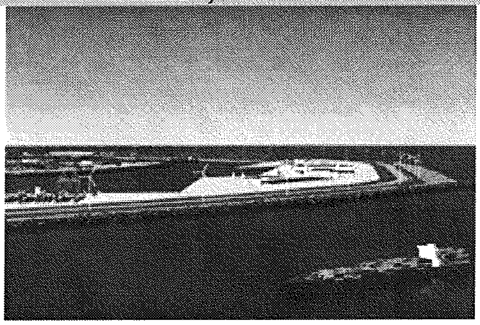
The design of a new naval facility at Karwar, involved the design of some 5 km of rubble mound **breakwater**, with rock sizes up to 20 tonne.

Agadir Port Breakwater Study
Morocco, 1999



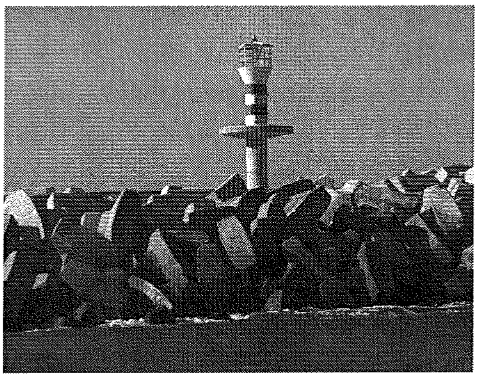
Objective of the assignment was to assist in finding a solution to execute the remedial works to the prolongation of a **breakwater** in Agadir Port. The armour layer consisted of 50 tonnes Accropodes, covering underlying rock material. Special attention was drawn to the placement of the Accropodes and the final slope of the **breakwater** trunk and the **breakwater** head.

Design alternatives 'Maasvlakte 2', Rotterdam
The Netherlands, 1998 - 1999



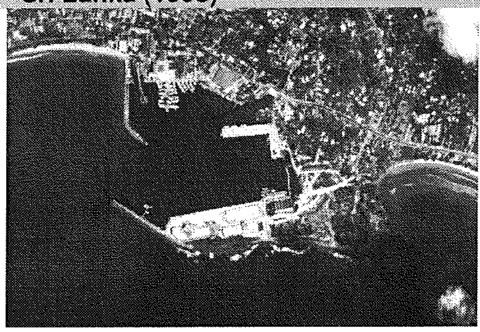
The development of the basic design took into account the mutual influence and affinity between the elements harbour entrance (navigation), sea defences (coastal hydraulics, morphology), port & industrial site layout, infrastructure (road, railway, inland navigation), nature & recreation. For 2 alternatives the method and construction was roughly analysed. Also screening took place of several cost estimates, a/o **breakwaters** and inland waterway connections.

Ennore coal port project
India, 1998



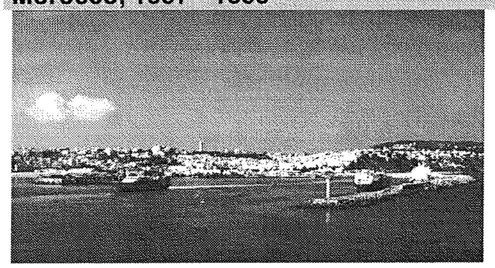
After the formulation of a masterplan of a new coal port near Chennai (formerly known at Madras), the construction design was worked out for rubble mound **breakwaters** (4 km), dredging works (13 million m^3), and reclamation (5 million m^3), a 600 m coal wharf for 65,000 DWT bulk carriers, 3 jetties for small craft, access via rail and road, as well as for other onshore port infrastructure. The design was based on the results of extensive field investigation programs, together with the outcome of wave hindcast studies, probabilistic and physical modelling of **breakwaters** and fast-time and real-time ship manoeuvring studies.

Port of Galle
Sri Lanka (1998)



Analysis of the relevant modes of failure and the risk of catastrophic failure of two **breakwaters** for the Port of Galle were undertaken. Special attention was given to overtopping and stability of the armour for the shore connected **breakwater** of the Port of Galle. A decision on the optimum height of the return wall of the **breakwater** was made based on these calculations. Both advanced first order reliability methods and simulation methods were used.

Tangier Atlantique
Morocco, 1997 - 1999

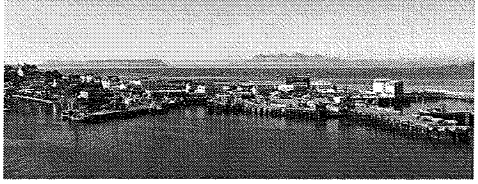


The company prepared tender designs for a major new container port on behalf of the client, who were bidding a BOT concession. The site was situated on the Atlantic coast and the works comprised **breakwaters**, dredging and reclamation, quay walls, pavements and equipment.

Tripoli harbour breakwater re-design
Libya, 1997 - 1999

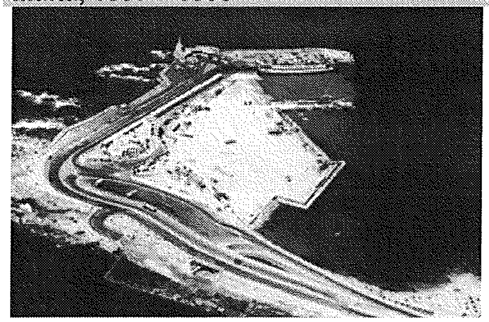
Detailed survey of **breakwater** and seabed situation, together with update of design (wave) data. After several possible design modifications it was chosen to adopt an Accropode primary armour layer combined with an extended underwater berm. Where a landfill is present, a stone filled canal was designed at harbour side in order to tackle venting and overtopping problems. The design modification was finally optimised using small-scale physical model tests. The project was concluded with the revision of the 1982 tender documents.

Mallaig Harbour Outer Breakwater
United Kingdom, 1997 - 1999



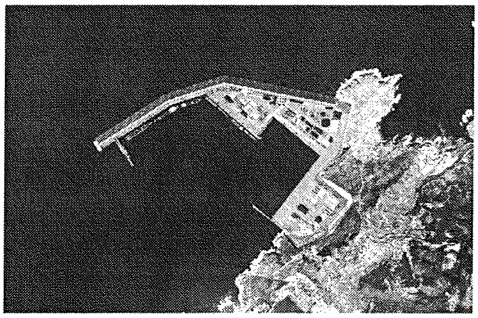
Alternative design of twin wall steel sheet pile rock filled **breakwater** of approx 300m total length forming a new harbour to support the town's fishing industry.

Cirkewwa / Mgarr Ferry Terminal
Malta, 1997 – 1998



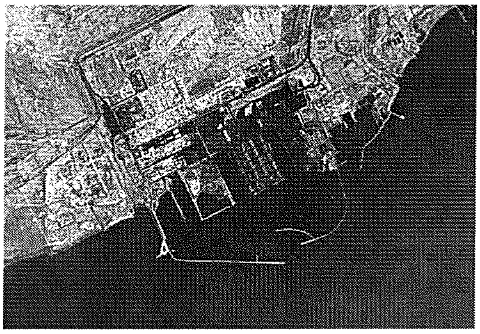
Upgrading of ferry terminal facilities at both sides of the ferry link Malta-Gozo, including construction of new berths and extension of the **breakwater** at Cirkewwa and the construction of terminal areas and buildings at both terminals. The extension of the **breakwater** included an protection on the outside with Accropodes.

Wave Modelling Study for the New Port of La Coruña
Spain, 1997



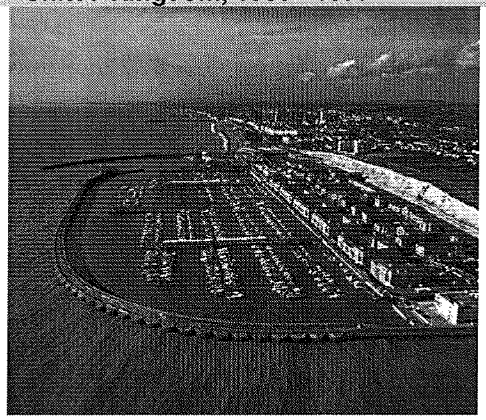
The construction of a new deep-sea port at La Coruña includes a large **breakwater**. The proposed structure will have a length of approximately 3 km and will be built in water up to 40 m depth. Facing the North Atlantic ocean, the **breakwater** will have to withstand very large waves. Royal Haskoning executed a detailed wave propagation study including: review of available information; setting up a MIKE21 NSW wave propagation model; establishing deep-water extreme wave conditions; determining design wave conditions for the **breakwater**.

Shahid Rajaee Port Complex, Bandar Abbas
Iran, 1976-1993



This project comprised the developed of a new 27 km^2 deep-sea port complex. The port included new harbour basins, 5 km of **breakwaters**, a 15 m deep access channel, general cargo, bulk and container handling berths and a number of transit sheds, warehouses and office/service buildings. Consultancy services for project included port planning and design of alternative layouts, review of contractor's designs, supervision of construction and providing expert advice on all technical and financial matters including planning and detailed progress monitoring.

Brighton Marina
United Kingdom, 1968 - 1977



The design of this marina included two **breakwaters**. A west **breakwater** of 630 m long and an East **breakwater** of 1220 m long. The **breakwaters** have been designed as caisson **breakwaters**, in total including 110 pre-cast concrete caissons weighing 600 ton each. Royal Haskoning commissioned the execution of initial surveys and investigations and prepared the basic and detailed design, supported with hydraulic model tests. Upon completion of the design Royal Haskoning prepared the contract and construction specifications and performed construction supervision.