proserve
MARINE CONSTRUCTION ENGINEERS

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Berth Scour Protection - Using Concrete Mattress

Berth Scour Aprons

These provide protection to quay structures against:

- Propeller Scour
- Ro Ro Fast Ferry Jet Scour
- Bow Thrusters
- Wave and Current Action

The Concrete Mattress System

Mattress fabric is pump filled insitu with micro concrete:

- Creates robust interlocking concrete slabs underwater and is often used for berth protection
- Unlike rock armour, it does not suffer from rolling or sliding displacement
- Much lower mattress thickness saves dredging and importantly reduces wall span height

The system is lightweight (0.7 kg/m²) for handling and transportation and can be used by contractors and divers worldwide. Proserve undertake scour apron design using appropriate design guides and proven performance. We engineer and fabricate mattress systems to suit site conditions and provide engineering support for installation worldwide .

Berth Scour Actions

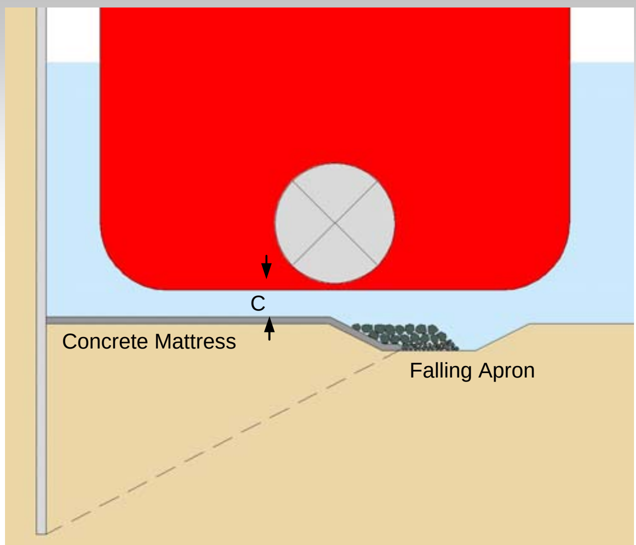
Propeller Scour

Concrete mattress aprons are typically designed to resist propeller suction as they readily resist propeller flow. Design guides are used to estimate suction uplift forces on the bed. The principal parameters affecting suction and thus mattress thickness are:

- Propeller tip clearance to bed (C)
- Propeller diameter
- Engine power used on berth

Mattress edges often have a stone falling apron to protect against underscour.

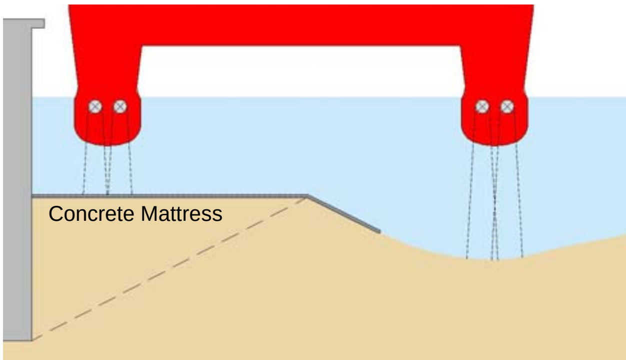
Case Histories: Cotonou; Belfast VT4 Ferry Berth
Technical Note: Berth Protection Using Concrete Mattress



Jet Scour

Large Ro Ro Fast Ferry vessels have jet velocities of up to 23m/s. Jet deflection during mooring creates high speed jet impact onto berth beds. Where berths are unprotected, very significant scour holes up to 9m deep have been created in soft deposits.
Mattress is designed to resist suction uplift based on CFD modelling and comparison with proven usage. Concrete mattress has performed well for this extreme action where many other protection types have failed.

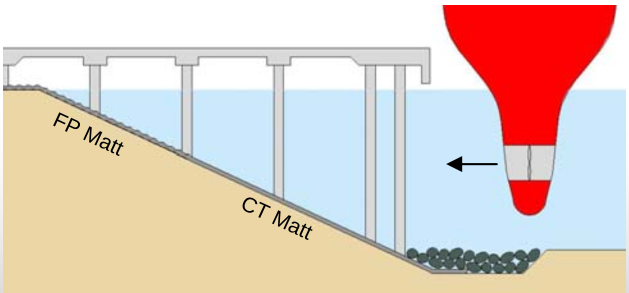
Case Histories: Belfast VT4 HSS Berth; Portsmouth
2013 Paper: Berth Scour Protection for Fast Ferries



Bow Thrusters, Wave and Current Action

Bow thruster jets acting against jetty slopes are readily protected by concrete mattress cast around the jetty piles. A porous filter point (FP) mattress is generally used in the tidal/wave zone and a constant thickness (CT) mattress used to the lower slopes. Filter point mattress is designed for wave action using established guidance based upon relative mattress and soil permeability. Design against currents is not usually critical for mattress in ports. Concrete mattress has 50 years of proven usage.

Case Histories: Shell Jetty, London Gateway; Belawan
1984 Paper: Revetment Construction at Port of Belawan, Indonesia, Sir William Halcrow and Partners, ICE London

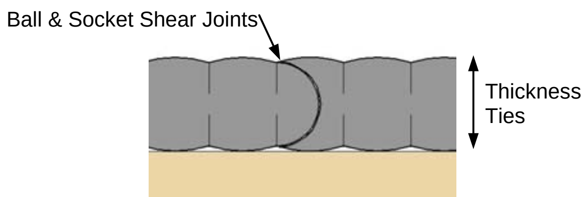


Concrete Mattress System

Fabriform

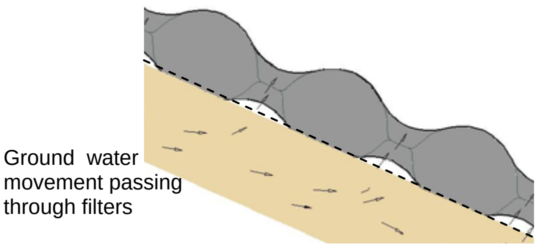
Concrete mattress aprons are formed by divers rolling out mattress fabric underwater which is pump filled with highly fluid small aggregate concrete. The fluid concrete is protected against wash out by the mattress fabric.

Joints between mattress panels are formed using zipped or sewn ‘ball and socket’ shear joints, this produces an apron of interlocked good quality concrete slabs underwater. Where ground settlement is expected movement joints can be engineered. Mattress is typically pump filled with a 2:1 sand:cement micro concrete mix of 35 N/mm² strength which has proven durable over the past 50 years.



Constant Thickness Mattress CT

This is normally used on harbour beds and permanently submerged slopes. Mattress aprons readily cope with high propeller and jet velocities with relatively low thickness when compared with rock protection. Thicknesses of 100 to 600 mm are available with a 200 mm minimum thickness recommended for controlled maintenance dredging to beds of large berths. Weep holes can be incorporated to cope with any residual ground water tidal movement.



FP and CT Matt

Filter Point Mattress FP

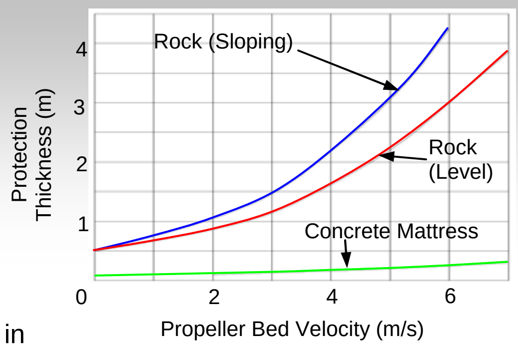
The porosity of the woven in filters allows this mattress to be used to slopes in tidal ranges for wave heights (Hs) up to 1 to 1.5m. Typical FP matts, FP150 and FP225 have overall thickness of 150 and 225mm, with an average thickness of 100 and 150 mm respectively. A geotextile fabric is required under the mattress for longer term protection.

Engineering Control

Proserve’s engineers undertake design, mattress fabrication and installation support; using risk management and quality control systems suitable for submerged maritime works. Engineering experience is used to tailor mattress systems to suit berth working conditions.

Advantages of Concrete Mattress

Lower Thickness - Higher Performance

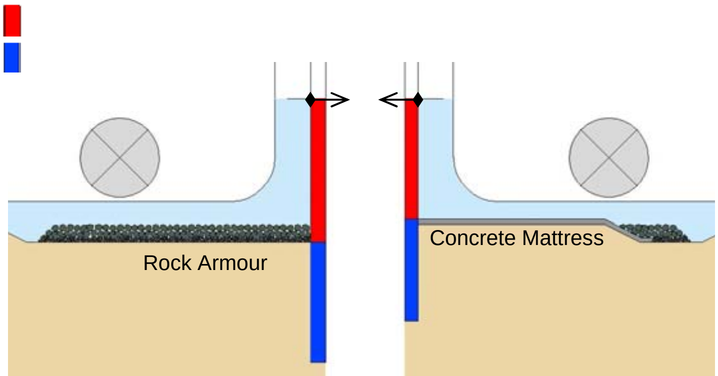


Concrete mattress has a low relative thickness compared to other protection systems because it creates reliable interlocked concrete slabs on the seabed or submerged slopes. The concrete is highly durable and gives high performance up to 12.5 m/s in jet flow (Stranraer).

Quay Wall Design - Cost Savings

The reduction in protection layer thickness creates significant savings in the design of quay wall structures from :-

- Reduced pile clear span or structure height
- Reduced pile or structure embedment
- Reduced dredging volumes



Sloping Construction - Toe Protection

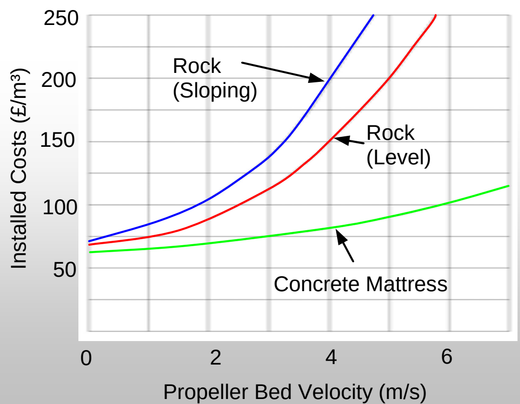
Uniquely, it is the only insitu system that can be used on slopes, allowing sloping toe trench edge details with stone falling apron edges which are good practice. Other systems with open insitu joints can't create these important toe details.

Constructability - Avoids Wash Out

Expensive marine plant is usually not needed as concrete mattress is normally installed by divers working from the quay wall or top of revetment slopes. Typical installation rates per dive team are 125 m²/ day (Belfast) to 300 m²/ day (Cotonou) depending upon working conditions. The system can be used on undulating beds and slopes and does not require expensive bed levelling preparation. Diver time can be reduced and output increased by using pre installed layflat hoses for automated filling.

Washout from currents or vessel actions is prevented whilst setting. This creates reliable protection in comparison to grouted rock or tremi concrete.

Health & Safety - Environment



The mattress system is lightweight fabric, which makes it much safer for divers to install relative to heavy preformed systems which risk diver entrapment. Environmentally it reduces dredging and material quantities and avoids wash out of cement.

Lower Installed Costs

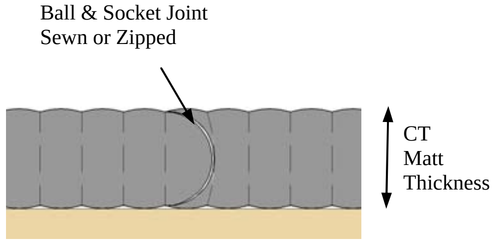
Concrete mattress has a lower cost than typical rock armour
(Example based upon: Rock £60/ m³, Geotextile £ 8/ m², Dredging £24/ m³, 0.45 m maintenance dredging depth)

Cotonou; Benin

Case Study: Propeller Scour

Contractor: Bachy Soletanche   Designer: Proserve   Clients Engineer: Royal Haskoning   2011

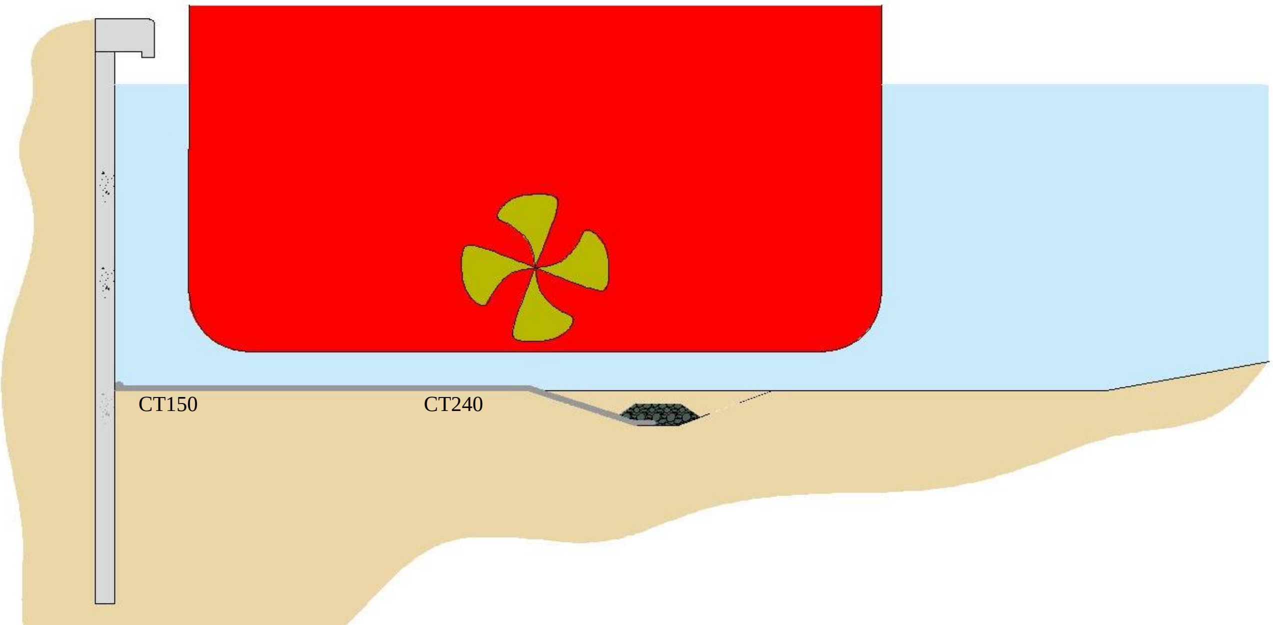
2 new container berths have been constructed at the port of Cotonou with a depth of 15m to accommodate larger container vessels. Proserve were engaged to design the scour protection apron and supply the required concrete mattress. The scour apron was designed to resist the suction forces due to container vessel propeller action, 240mm and 150mm thick CT Constant Thickness mattresses were used.



The lower construction thickness of concrete mattress provided a cost effective solution and importantly minimised the span height of the quay wall and maximised its protected embedment depth.

A local micro concrete mix was developed, initially with pumping and mattress filling trials. The mattress system was diver installed using the roll out technique and then pump filled automatically via pre installed lay flat hoses. 15,000m² of mattress was installed in some 6 weeks using 2 large dive teams.

A rip rap stone falling apron edge detail was provided to resist edge scour in the sand and clay bed.



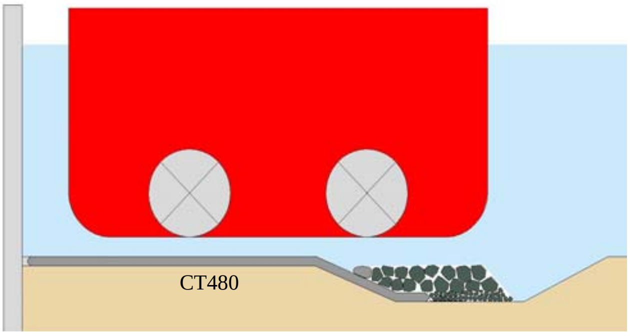
Section through berth after installation

Belfast VT4; Ferry Berth

Case Study: Propeller Scour and Wave Action

Contractor: McLaughlin and Harvey   Designer: Proserve   Checking Engineer: Royal Haskoning
Clients Engineer: Mouchel   2011

Belfast Harbour, Berth VT4



Typical Section Berth VT4

The Ro Ro berth at Belfast Harbour was extended to accommodate the new 'Superfast' 203 m long conventional type ferry vessels. A concrete mattress system was selected to maximise the increase in berth draught. Proserve provided a concrete mattress system including design and installation advice to the main contractor McLaughlin & Harvey for the berth scour protection works for Belfast Harbour Commissioners.

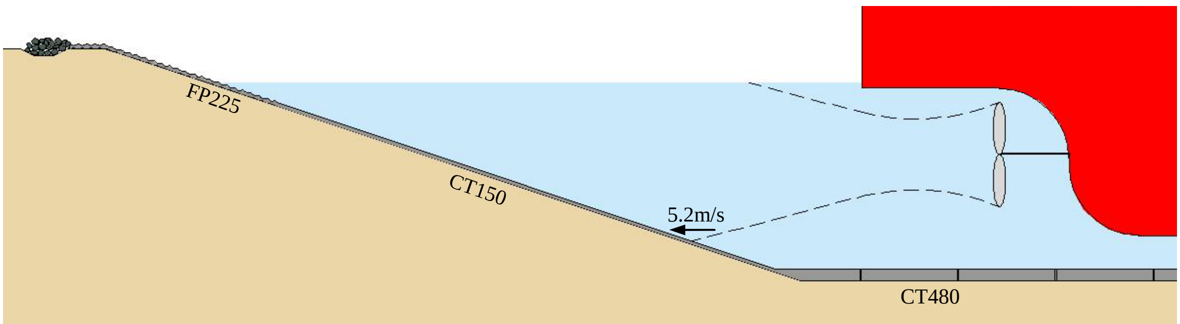
A greater draught was needed for the new superfast vessel but the capacity for increase in the existing quay wall height was limited. The concrete mattress system provided a 'solution of minimum thickness'. A 480mm thick CT concrete mattress was designed by Proserve's engineers to overcome propeller suction forces from the low clearance and high berthing power of the new vessel.

A 220mm thick CT mattress was used in areas of propeller action from smaller vessels. Proserve's design included the provision of a stone rip rap falling apron edge detail. This provides good resistance against edge underscour and allows suitable inspection and maintenance of this key detail.

Mattress installation used a semi automated filling system which increased output and allowed installation between ferry movements to each 10 hour working day period. The berth protection was laid in some 6 weeks.

At the end of the berth, a new turning head was dredged and the revetment slopes were protected by concrete mattress. A porous filter point FP225 mattress with a 150mm average thickness and a geotextile underlayer was used for a design wave height (Hs) of 1.0m. Lower slopes were protected against propeller wash using a 150mm thick CT mattress

FP to CT Joint



Turning Area Section

Belfast VT4; HSS Berth

Case Study: Jet Scour

Contractor: McLaughlin and Harvey   Mattress Designer: Proserve   Checking Engineer: Royal Haskoning
Clients Engineer: Mouchel   2011

Belfast Harbour, Berth VT4

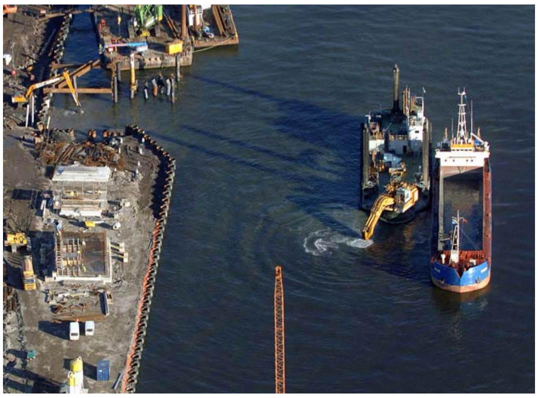
HSS Stena Voyager leaving Belfast Harbour

The HSS berth at Belfast Harbour was moved seaward to Victoria Terminal 4 in 2008 to accommodate large HSS vessels. Significant bed protection works were required to the berth to protect the piled combi wall span height and embedment depth.

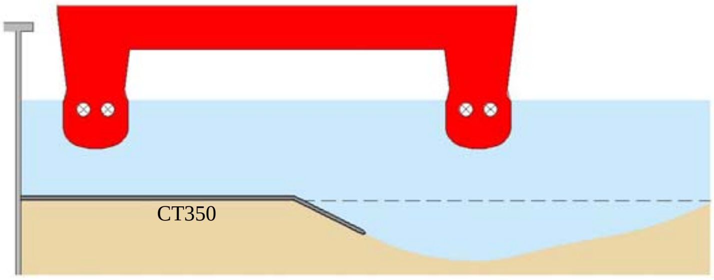
The large HSS had high velocity exit jets up to 23m/s. Mooring jetting action onto the bed created by deflection buckets during berthing at Stranraer had created a major scour hole into the soft deposit bed under the unprotected area of the outer hull, some 9m deep . The inner hull area had successfully been protected by concrete mattress.

A mattress design thickness of 350mm was installed to protect the passive support areas to the quay wall. The unprotected areas under the mooring jetting of the outer hull were eroded some 5m in 18 months into the soft deposits. A layer of very soft clay (sleech) at design formation level was removed to ensure necessary support to the concrete mattress apron to withstand the jetting contact pressures. Mattress panels were limited to 10m long as a precaution against any slight settlement.

Combined mattress panels typically 30m long were rolled out by divers and zip connected to form ‘ball and socket’ shear joints. A 35N/mm² micro concrete mix was used to pump fill the mattress using a long reach boom pump. Typical installation rates were 100-130m²/day per dive team. The scour apron comprised 4,700m² of mattress.



Berth VT4 During Construction



Scour Profile After 1 Years Service

London Gateway; Shell Jetty

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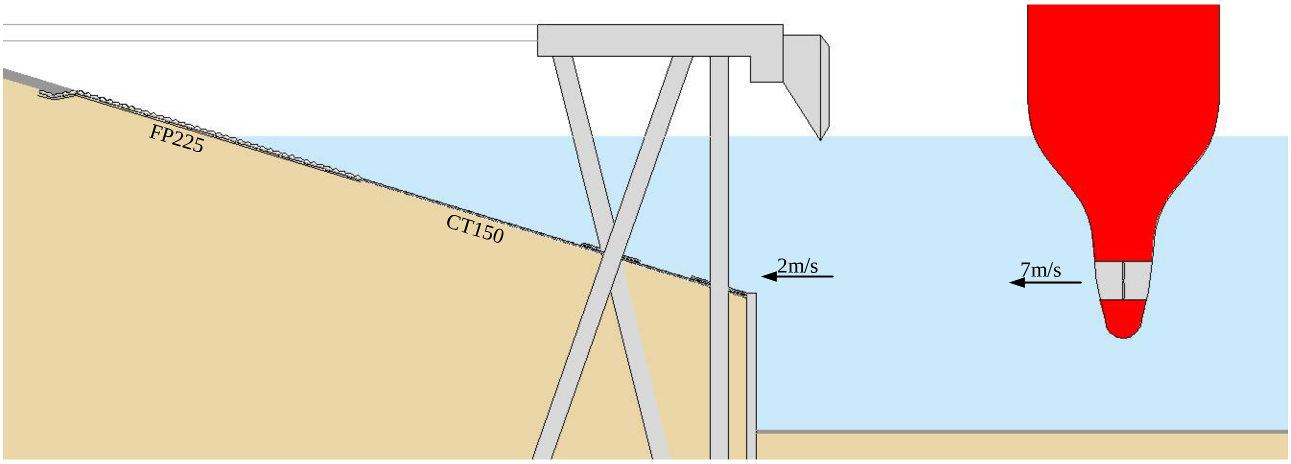
Case Study: Bow Thruster, Wave and Current Action

Engineer: U.R.S. Sub- Designer: Proserve Contractor: Laing O'Rouke/ D.I. Installation: Kaymac 2011

Shell Jetty

The existing Shell Jetty was deepened for larger vessels and the existing revetment slopes required protection from bow thruster erosion. The working conditions were difficult with tidal currents to 1.6m/s, a design wave height of 1.1m and soil investigation showed a layer of soft silt to slopes up to 1.5m thick with an estimated settlement of 70 -140mm.

A 150mm thick cast insitu concrete mattress system was designed with crack and movement control joints at 2.2m and 3m centres to accommodate settlement. An FP225 porous filter point mattress was used in the tidal range with a geotextile under layer pre-sewn to the mattresses. Lower slopes subject to bow thrusters wash were protected by CT150 mattress. Toe trenches were provided to mattress edges to protect against underscour.



Typical Section London Gateway

Mattress Filling FP

A site specific mattress installation system was developed by Proserve and Kaymac, with mattress panels custom designed and fabricated to aid rapid panel installation, in diver working periods limited typically to some 1.5 hours. Internal filler sleeves within the mattress allowed rapid filling by pumping a 35N/mm² sand:cement micro concrete mix to form the insitu protection. The mattress was fabricated for installation around existing piles, with a sliding steel and mattress collar formed to cope with expected settlement. Working between vessel movements, Kaymac overcame the working conditions to complete the scour protection.

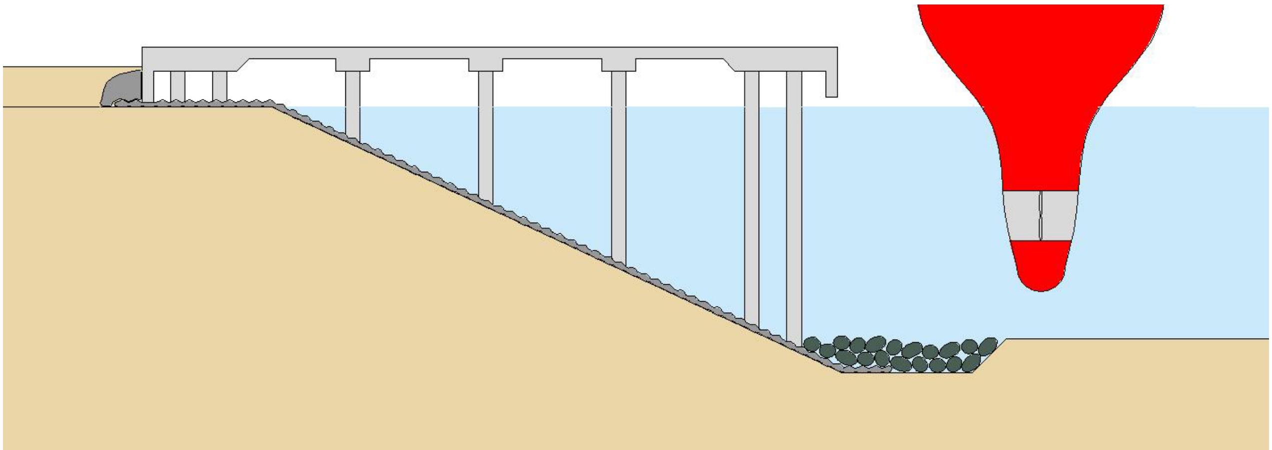
Case Study: Bow Thruster, Propeller, Wave and Current Action

Engineer: Halcrow   Mattress Designer: Proserve   Contractor: Dharsamin   1983

The port was expanded in the early 1980's by using a fine sand hydraulic fill. Piled jetty structures were used with a range of ground improvement methods to limit fill settlement. Following a cost appraisal, a concrete mattress system was selected in preference to the initial design in rock rip rap. Revetment slopes were protected by a porous Filter Point mattress FP150 with an average thickness of 100mm which a geotextile under layer. The protection was to resist bow thrusters action, manoeuvring propeller wash, wave action to 0.5m and tidal currents to 1m/s.

Pile Collar

To cater for overall slope settlement up to 0.5 m and localised settlement, movement and crack joints were provided at 1m centres. Around piles a sliding collar movement joint was formed using a steel and mattress collar with a local flexible fabric seal.



Typical Section

The mattress was laid by divers, sometimes working under the jetties and without the use of costly marine plant. A falling apron stone toe detail was used to protect the bottom of the mattress against underscour.

Pile Collar

The paper 'Revetment Construction at Port of Belawan, Indonesia' gives a detailed account of the works. The project is also given as an example in the PIANC 'Guidelines for the Design of Armoured Slopes Under Open Piled Quay Walls' Fig 3.10 by WG 22. The port advised in 2013 the protection continues to perform well after 30 years of service