Marine Construction in Concrete

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Introduction

Concrete is widely used for maritime projects, with innovation in construction methods helping to overcome marine working conditions. Precast concrete construction is increasingly being developed to form marine structures, Figure 1. Methods to reliably form insitu concrete underwater have also advanced with innovation in the use of fabric formwork systems, as shown in Figures 2 and 3. Grout Bag systems are often used to form concrete foundations and joints to precast elements.

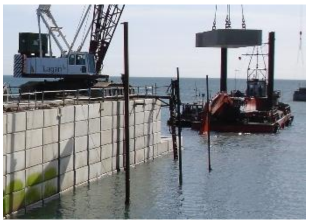

Figure 1: Precast Concrete

Figure 2: Grout Bag

Figure 3: Concrete Mattress

Insitu Concrete Mattress systems are often used for scour protection in conjunction with rock falling aprons to provide secure edge details. Recent research has shown that the basic performance of scour protection depends upon whether the protection is 'sealed' to flow entry[5] and this will be described with reference to present design methods[3,4,8].

Precast Concrete

Precast concrete construction is often used to form major marine structures such as breakwaters, bridges, barrages, quays, ITT's etc. The precast elements are usually a variety of caissons or solid blocks which are lifted or floated into place by marine plant. The use of precast construction offers greater reliability, efficiency and often rapid construction. It does however usually require the use of major marine plant and effective methods to form joints and foundations upon the seabed[1].

For construction of the New Coast Route bridge in La Reunion, precast bridge piers are being founded with insitu concrete using an automated foundation grout bag system as shown in Figure 4. The grout bag system is prefixed with cast-in grout hoses. Piers are accurately positioned on jack legs before the foundation is pump filled automatically from the surface. The contractor selected the system rather than accurate levelling of bedding stone layers.

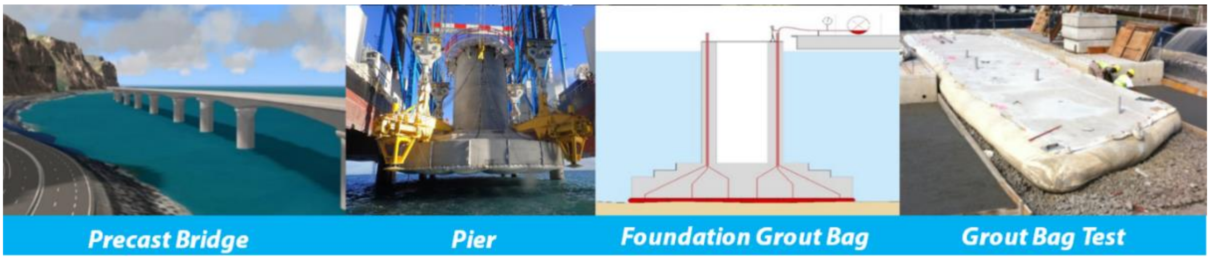

Figure 4: Case History, New Coastal Route, La Reunion - Sequence

For the Venice Barrage project, large caissons typically 60 x 48 m on plan and some 40,000 t, were founded using an automated foundation grout bag system, Figure 5. The system was chosen to give accurate placement of the caissons and limit settlement to ensure the operation of the flood gates.

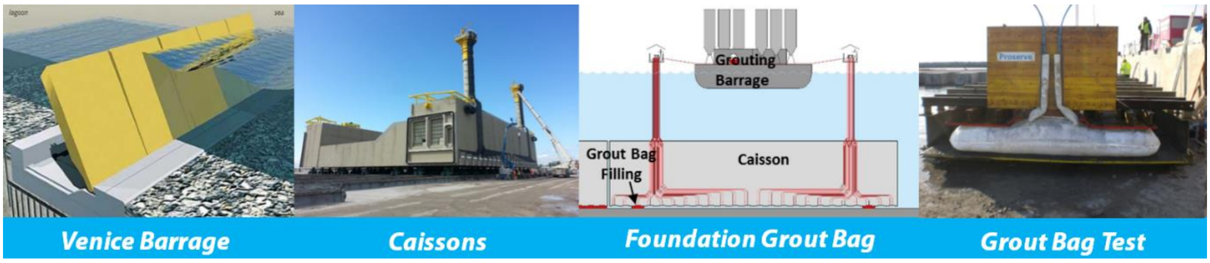

Figure 5: Case History, Sequence, Venice Barrage

Grout bags were prefixed to protective recesses on the underside of the caissons with hoses and grout sensors fixed to the sides to allow automated grouting. Once floated and lowered into place, the caissons were adjusted and held in place by jacks, before grouting of the foundations automatically from the surface. The automated system was needed due to high tidal flows in the inlets restricting diver access. Reliability of the system was aided by a risk management approach and reliability testing. The concrete grout bag foundation system avoids settlement and wash out issues associated with stone bedding layers[1]. The system has been used on many major marine projects over the last 30 years.

Figure 6: Joints

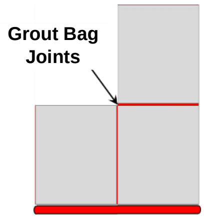

Figure 7: Precast Construction

Grout bag systems can be used to form both vertical and horizontal joints between precast elements as shown in Figure 6. This allows innovative construction underwater of precast elements both vertically and horizontally, Figure 7. Precasting is also used to form armour units, scour protection mattresses and other elements. Armour units of various shapes are commonly used to resist wave action in more exposed locations. For reinforced precast elements, improved guidance on durability[2] should now help avoid corrosion problems previously suffered above low water level.

Insitu Concrete

Insitu concrete may be formed in the dry in cofferdams or formed underwater using the tremie method. Nowadays, tremie concrete is usually pumped, with the hose end always submerged in fluid concrete to ensure the concrete mix does not separate. Fabric Formwork systems are usually easier to place than traditional shuttering, they also prevent washout and form compartments with interlocking joints. Micro concrete mixes of sand and cement or grout mixes are purpose developed using local materials. These are usually of high fluidity and self-compacting for ease of pumping and filling of compartments.

Insitu Concrete Mattress

Insitu concrete mattress systems comprise two layers of fabric with thickness ties that are zipped together by divers and pump filled to form plain concrete slabs with interlocking joints, Figure 8. The system gives high performance against flow actions when joints and edges are ‘sealed’ against underscour. Rock falling aprons provide a reliable and well accepted form of protection to edges as shown in Figure 9.

Figure 8: Interlocking Joints ‘Sealed’

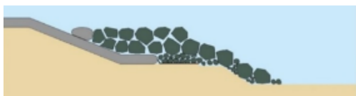

Figure 9: Rock Falling Apron Edges ‘Sealed’

Recent research has created a greater conceptual understanding of the performance of common scour protection types against flow and propeller jet flow. Fundamentally, performance depends upon whether the protection is 'sealed' or if it is 'open' where flow can enter under the scour protection.

Figure 10: 'Open' Joints

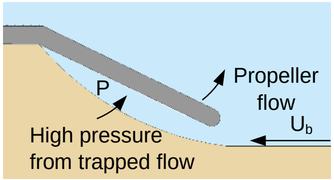

Figure 11: 'Open' Edges

'Open' protection types Figure 10 and 11, are subject to larger trapped flow pressures under the protection which causes failure (the range of trapped flow pressures can be estimated from Bernoulli's equation). Open flexible protection types can be designed to a method by Raes (1996) [3,4] shown in Figure 13. 'Sealed' protection types are much more effective as also outlined in Figure 13, but protections designed as 'Sealed' must be reliably constructed. This can be achieved using suitable experience, and an appropriate risk management approach during the design and constructability assessment stage plus a proven marine quality control system during construction.

Berth Scour Protection

The beneficial combination of insitu concrete mattress with rock edges is often used for berth scour protection. The lower mattress thickness in comparison to rock reduces span heights as shown in Figure 12, and this often significantly reduces quay wall costs. The system is similarly effective for berth deepening.

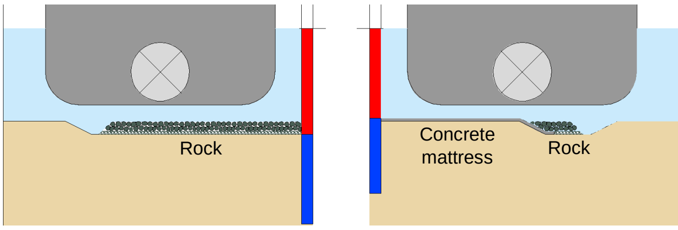

Figure 12: Quay Wall Comparison

Design can be based upon the worst case of propeller suction upon the bed[7], or for bed flow velocity as shown in Figure 13. Insitu concrete mattress is often used to slopes under piled quays, see Figure 14. Uniquely, it can be installed before or after deck construction. Suitable details can be used to reliably seal around piles. Recent research has provided guidance for rock stability subjected to flow deflected by the rudder.[5]

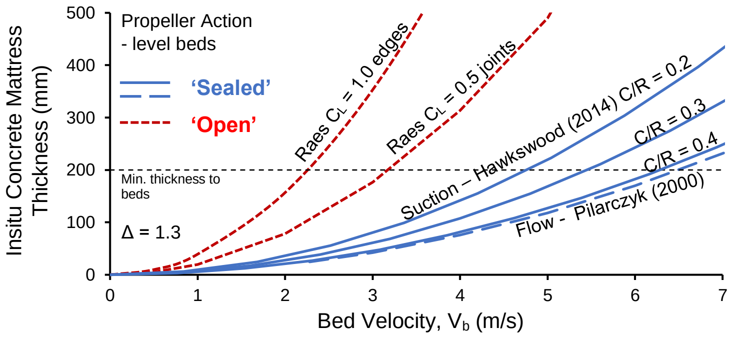

Figure 13: 'Sealed' and 'Open' Protection

Land Infill Method

This innovative construction method[6] has been recently developed to reduce time and cost, for the construction of open piled quays. 'Land Infill' of the quay area allows land based construction of piling and the deck, Figure 14. without the use of more expensive marine plant. This allows earlier installation of cranes and commissioning, etc. whilst dredging and scour protection installation. Insitu concrete mattress can be readily installed under the deck to the slope and around the piles[6].

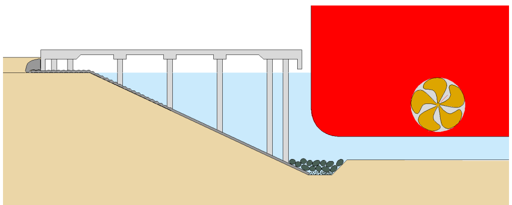

Figure 14: Piled Quay

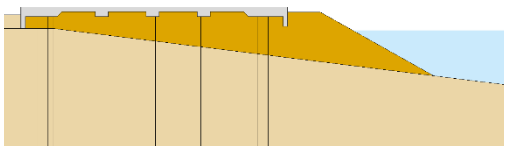

Figure 15: Land Infill Method

Channel & Bridge Scour Protection

Insitu concrete mattress has been used as scour protection to channels, rivers and revetments for over 50 years (Figure 16) demonstrating the durability of good quality plain concrete construction. The system is also used for the lining of irrigation channels particularly when the channel cannot be dewatered effectively. The fabric used for mattress can also be a biodegradable jute and is now being developed and trialled on major rivers. This innovation supports local industry and has environmental benefits. The combination of insitu concrete mattress and rock is also regularly used as scour protection aprons to bridges. The lower thickness of mattress in comparison to rock enables protection to bridges with shallower foundations and also reduces flow blockage and flooding levels at critical bridges.

Figure 16: River Arun

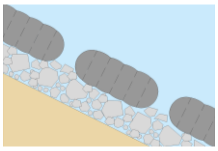

Figure 17: Open Hole Mattress

Wave Protection

Innovative developments are being made in wave protection using insitu concrete construction as outlined below. Presently Open Hole concrete mattress (Figure 17) has been developed to allow mattress use in 1-3 m wave heights. Gaps in precast armour units often occur after compaction from initial storms. These are often infilled with a grout bag repair as Figure 18. Repairs to higher wave zone areas are infilled at lower water states and vice versa. Insitu Concrete Armour units are being developed and tested using fabric formwork units.

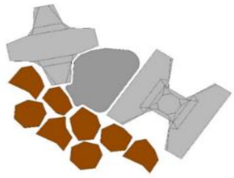

Figure 18: Insitu Armour Repair

Summary

Recent innovations for marine construction in concrete have been outlined as summarised below:-

- Precast concrete & grout bag systems with automation
- ‘Sealed’ and ‘Open’ scour protection
- Combination of insitu concrete mattress and rock
- Land infill method for open piled quays
- Insitu concrete armour

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