Subsea Scour Protection

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ABSTRACT

Bridge scour is the removal of seabed or riverbed sand from around bridge and wharf abutments and piers. Scour is caused by fast moving water, thus compromising the integrity of a structure.

Commercial Marine Group has designed and installed custom scour mattresses for a range of Clients and will discuss the challenges presented by the Client and the solutions provided.

Recent projects that will be presented to delegates is the installation of the Callaghan Park Boat Ramp in the Fitzory River, Rockhampton, 80CBM of concrete in-situ installed into custom designed grout bags and the Kingsford Smith Drive Project in Brisbane, where the team assisted with the installation of 330 scour matts, weighing between 30 and 80 tonne each.

Secondly, you will be presented with the sewerage outflow solution on the Kingsford Smith Drive Upgrade Project, Brisbane.

Both projects presented unique challenges and learn how and why the final solutions were developed and installed in a subsea environment using commercial divers and specialized floating plant.

1 INTRODUCTION

CMG has been appointed as a subcontractor to several tier one projects that relate to provision of engineering design, fabrication and install of subsea scour protection, seabed stabilization and subsea structural solutions to support other structures.

The two projects that will be presented here are Kingsford Smith Drive (KSD) in Brisbane, Queensland and Callaghan Park Boat Ramp in Rockhampton, Queensland.

KSD Brisbane presented with a number of key challenges relating to structures (road and utilities) being installed in an environment with varying riverbed material, from rock to mud to hard clay, depth ranging from tidal to -10m, currents of up to 3 knots and challenging for divers with zero visibility. The Client required a solution to the Sewer Outflow Pipe and Rest Stop Piles.

Sewer Outflow is a treated sewer discharge that flows into the river. The pipe runs under the highway and into the river, connected to a junction under the highway. The pipe enters the river in the tidal zone and exits some -4m subsea. The pipe constructed out of a Glass Fibre Reinforced Polymer (GFRP) material was imbedded into a bed rock and required the capacity to withstand 1.5CBM per second of sewerage discharge. The solution presented by CMG was to breakout sufficient bed rock, install the pipe, the concrete around the pipe and key into the river bed. For obvious reasons you cannot just pump concrete underwater, you need some sort of formwork solution. So effectively the design is a subsea formwork solution.

The second part to the KSD challenge was a pile bag solution around the Rest Stop Piles. This solution is a bag that wraps around bridge piles and piers to stop scour. KSD design included 330 scour matts that were precast and placed using crane barge and divers. The piles remained exposed to the elements. The pile solution effectively wraps around the piles, fills the voids, keys into the precast scour matts and forms firmly against the piles.

Both solutions above conform to a 100 year design life.

At the Callaghan Park Boat Ramp in Rockhampton. The riverbed presented with over 6 metres deep of unstable mud and silt that could not be excavated. The ramp design included seabed stabilization using a variety of methods including 150mm steel piles at 1m intervals driven 10 metres deep. The sides and base of the ramp required a scour solution.

The scour mat (28m x 6m) was designed to protect the ramp shoulders and ramp toe. Divers installed the mat solution by rolling it onto the ramp and placing the boat ramp precast concrete planks over a flat section of the mat as the ballast. The toe mat was attached via eye bolts to the last row of boat ramp precast planks. All mats were filled using the specified concrete mix via a readymix truck delivered to a boom pump. Divers fed the boom pump hose into the bag compartments for filling.

2 SCOUR AND SUBSEA ENGINEERING

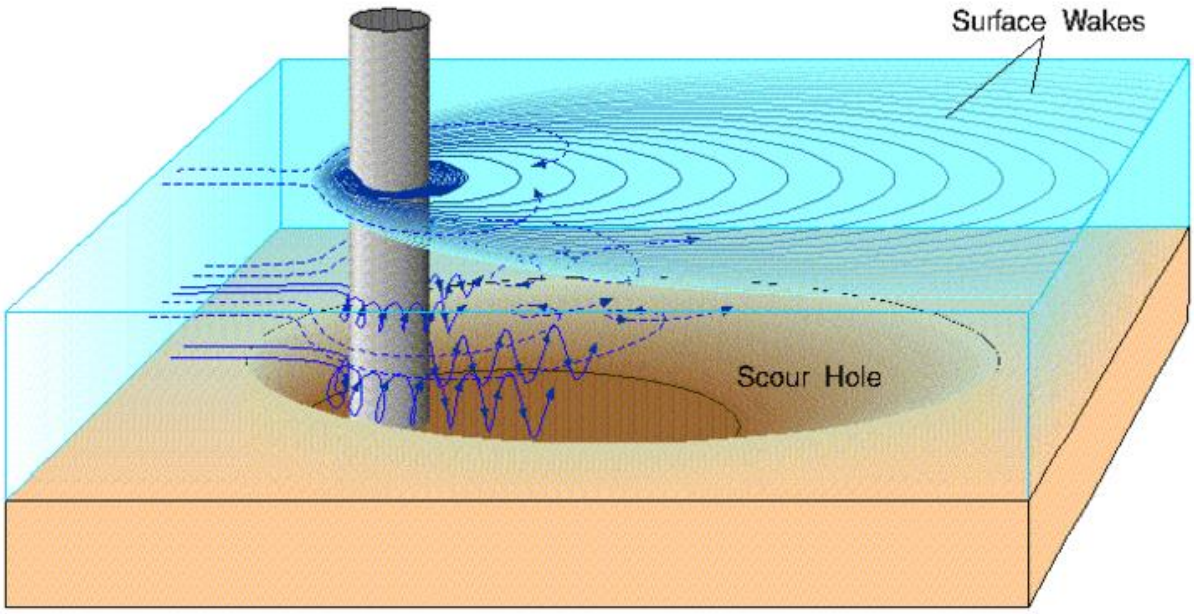
What is Scour?

Bridge scour is the removal of sediment such as sand and gravel from around bridge abutments or piers. Scour, caused by swiftly moving water, can scoop out scour holes, compromising the integrity of a structure.

Bridge scour is prolific in Australian waters, predominantly in rivers and creeks affected by tidal flow.

There are a number of online resources and studies completed that explain and provide formulas for calculating the potential scour on a bridge pile. The main reference documents with the technical calculations are:

- Supplement to Austroads Guide to Bridge Technology Part 8, Chapter 5: Bridge Scour (2018)
- Countermeasure and Prevention - Hydraulic Engineering Circular No. 23 Manual (HEC-23)
- Estimating Scour Depth - Hydraulic Engineering Circular No. 18 Manual (HEC-18)
- Bridge Scour Countermeasure Assessments at Select Bridges in the United States, 2014–16
- Countermeasure Design for Bridge Scour & Stream Instability



Reference: http://mo.water.usgs.gov/current_studies/Scour/images/LocalScour

What is subsea engineering?

Generally subsea engineering relates to the design and engineering of underwater structural solutions, typically in the oil and gas space, however onshore civil subsea engineering relates to design of scour solutions, pile remediation solutions, seabed stabilization, artificial reefs and subsea pipelines and related structures.

What are subsea grout bags?

Subsea grout bags are geofabric or synthetic custom designed bags and mats. Bags and mats are designed in any shape and size with the ability to withstand up to 8 bar of pressure. Typical designs include scour pile bags, cavity bags and scour mattresses.

Types of suitable concrete/grouts

Traditionally, a non-washout solution is specified to reduce the risk of concrete/grout wash out into a waterway. It is not unreasonable to use a standard readymix 50mpa solution with a 20mm aggregate. A slurry mix works best for efficient flow into the bags and mats. The stickier the product, the more difficult to install.

CMG have used a bag mix when filling bags that are up to 2CBM using a Putzmeister SP11. It can be done, but complex and slow.

Typical Design Scour Mat

CMG scour mats are designed and certified for quality. Certification of specified design by others. The mats are seam tested and are accompanied by a manufacturer's warranty. CMG warranty workmanship of installation.

CMG scour matts are configured as either:

1. "Slab Mattresses" in other words a concrete slab poured underwater contained within a fabric formwork structure. They are fabricated in composite units up to 28mx6m, and thickness ranging from 200 to 750mm (most common 300-350mm), though unit final dimensions are usually determined by the on-site logistics available for inflation or
2. "Pile/Pier Units" oval, round, filleted square construction either
    a. Forming a cone around a pile or pier, replacing rock baskets and other forms of independent scour protection or
    b. Filling the gap between a pile and
        i. Surrounding precast block form scour protection or
        ii. Integrating into adjacent CMG slab mattress structures

The construction/configuration of our products is unique in that we use integrated baffles to allow the units to inflate to the optimum thickness, the baffles being strategically located to ensure that a robust form is created

CMG mattresses are superior to conventional grout mattress as the point sewn products provide a uniform coverage with optimum hydrodynamic surfaces

Unit Fabrication

1. Materials
    a. Form Fabrics
        i. Fabrics are according to the application using specific characteristics, eg elongation to peak strength, to complement finished the product. Most commonly use heavy weight non-wovens, for example, Texcel R Series; where elongation optimises gap/cavity, irregular surface conformance. The R series fabrics are frequently recommended for soft rock geotextile sand containers
        ii. Other fabrics may be specified dependent upon the application
        iii. Fabrics are used to hold the form during concrete curing unlike, for example, soft rock where fabric durability is critical to the life of the structure
    b. Belting
        i. Polyester lashing, lifting and seatbelt style webbings with Breaking Load ranging from 3000kg to 10000kg

2. Fabrication
    a. All bag construction is configured using heavy duty chain stitch
    b. Why Chain stitch
        i. More thread in the stitch as material stretches laterally (usual testing comparison) it is 15 to 20% stronger than an equivalent conventional stitch
        ii. Reduced potential to cut the material under load

c. Type of thread used: all subject to application
   i. High strength soft bonded polyesters/nylons and polypropylene
   ii. Kevlar threads similar to kite boarding lines
   iii. Advance polymers not unlike braided fishing lines

2.1 Scope 1: Sewer Outflow Pipe

Installation of a 1,200OD GFRP Sewer Outflow Pipe into a subsea bed rock location, tied into existing sewer (20mm tolerance) with capacity to withstand a 1.5 CBM per second flow. This volume of water is not unusual in creeks and estuaries.

The scope of works included breakaway of bedrock to RL -6m. The sloping ground rock profile made a cofferdam solution impractical and not viable.

Divers and an excavator were used to achieve depth and cavity for headwall key into bed rock.

The subsea environment, rock ground conditions, fragile pipe material, and sloping geometry of the pipe influenced the methodology. It was very important to ensure the bedding, support and backfill to the pipe did not damage the pipe and would securely support the pipe and not be scoured away in the future.

The solution was to design a system that would protect, encapsulate and support the pipe and secure it in position within the hard rock profile. Some of the initial designs were invert culverts with lids. The invert culverts could be drilled into the bed rock using the divers. The culverts would then perform as the formwork solution. The solution presented with a number of challenges.

1. A smooth culvert surface would not key into the bed rock
2. The rock anchors would not provide sufficient structural support to meet the 1.5 CBM volume of treated sewer
3. The rock anchors were made out of steel and corrosion therefore became an issue
4. Duration of installation
5. Precast elements needed to be sealed
6. The precast elements require backfilling

Pumping any concrete and grout underwater needs containment. Usually this is a formwork or sand bag solution. Due to the sloping ground, the need to ensure seal against the pipe, the number of sand bags required to withstand the possible pressures and the 100-year design life sandbags, this solution was not considered further. Sand bags were used as temporary support to position the pipe prior to grouting.

A solution to build timber or steel formwork around the structure was considered. The challenge would be installation of timber formwork underwater, and both solutions would require a level surface to place a lid and close the formwork off so that grout did not spill into the river.

The Brisbane river has up to 3 knots of current. The sewer outflow pipe is situated in a high flow section.

Both the formwork and precast solutions required significant dive time.

The solution that presented as structural, non-corrosive and flexible to key into the bed rock and a closed formwork solution that would not spill grout was effectively the grout bag. The bags are impermeable and therefore also meet the strict environmental and safety regime of the project.

Custom made grout bags were designed and trialed in surface locations to determine grout bags durability, strength and ability to secure the pipe.

Trials started at a site in Brisbane, all stakeholders (SMEC, Jacobs, Brisbane City Council, Lendlease Engineering, Boral and CMG Management) were all involved to inspect and provide feedback about the solution.

The pipe was loaded onto a barge and sand bags used to establish base support. The 12m long pipe was delicately positioned in the trench using crane and barge. The grout bags could be preinstalled on the pipe reducing hours on site. Once in position and checked the grout bags were positioned at 2m

centres. Grout was pumped from shore at a rate of 60 litres per 5 minutes, very slow, however the process and positioning of the bags was delicate to conform to a 20mm tolerance. The grout mix was a Parchem Combextra UW Cementitious Grout 50MPA rating at 28 days.

The grout bag presented with the following key advantages:

1. Custom design
2. Fabrication lead time – one week
3. Material that would not corrode
4. 100 year design life,
5. Flexible enough to key into the bed rock
6. Bag filling pressure of 4 bar, tested to 8 bar
7. Certified and engineered
8. Health, safety and environment risks were eliminated by the use of the bags

All of these factors resulted in the grout bag solution being the most efficient.

The solution worked well and conformed to the specification. Further solutions have been developed since then.


LC=3000KG

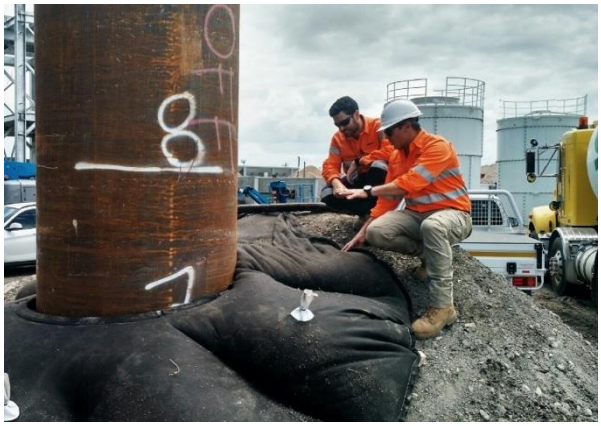
2.2 Scope 2: Rest Stop Pile

The concept of designing a scour protection solution for the Rest Stop Piles was then developed using the same principle of grout bag.

The subsea scour mats were installed prior to the piles being driven, gaps were left in the scour mats to allow for the piles. The gaps remaining between the scour mats and piles required some sort of filling to manage future scour.

The location of the pile was also on a 25 degree gradient, so an aggregate or rocks placed over geofabric would not be appropriate.

The pile grout bag was developed and tested in another simulated environment to ensure that the grout bag would not burst or become overloaded when installed on a slope.



2.3 Scope 3: Callaghan Park Boat Ramp

The Callaghan Park Boat Ramp is located on the Fitzroy River in Rockhampton, Queensland.

TMR introduced a new design based on further investigations into the frequest scouring at boat ramps due to power loading of boats or floor erosion. The design now includes installation of a scour matt at the base of the boat ramps to prevent scour.

The Client on the project approached CMG to propose a solution. CMG presented the subsea scour mat solution, based on previous design outcomes with KSD sewer and pile bag designs.

The scour mat design follows the same principles as previous designs. Geofabric material, designed to suit a 28 metre length, by 6 metre width with a 200mm cover over the seabed.

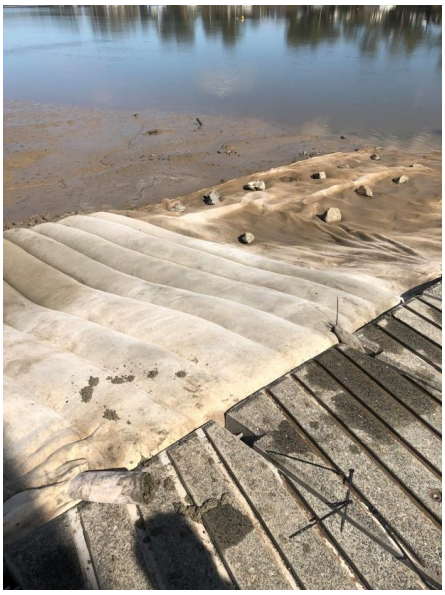
The mat design was presented to the Client who presented the design to the asset owner for approval and some modifications were made based on feedback received.

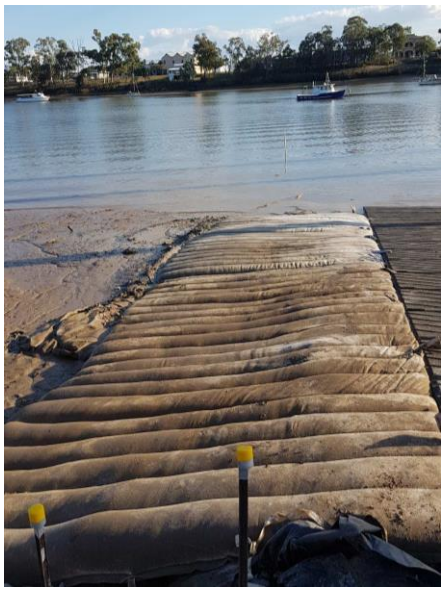
The initial shoulder design was grouted block paving to Mean Sea Level (MSL) for a grout pour into a 100mm aggregate placed. With the strong currents it was not possible to pour grout without a suitable formwork solution.

These customized mats were designed to:

1. Form a shoulder and anti-scour solution on the side of the ramp, and
2. Provide a no scour solution at the base of the ramp which presented with deep thick layers of silt and steep sloping riverbed.

Rockhampton's Fitzroy River is prone to flooding which presents with significant scour and erosion issues. The final benefit of this design was that it was not several precast planks, but rather one long 28m x 6m x 250mm concrete slab with a weight of approximately 110 tonnes. With this slab tied into the precast planks and the shoulder mats, it is unlikely to be moved by flood currents in the future.





3 CONCLUSION

Scour represents up to 80% of bridge failures around the world in water-based environments. Precast options require precast yards, molds, cranes, often barges, cranes, tugs and logistics which have significant impacts on project costs. Subsea scour mat designs can be very creative filling a void in almost any environment.

Engineered, certified and tested solutions designed to date include:

- Pile bags
- Grout bags for subsea pipes and drainage
- Scour mats
- Cavity bags
- Lifting bags to elevate structures

Grout bags can also be used in surface environments as a formwork solution.

4 REFERENCES

- Supplement to Austroads Guide to Bridge Technology Part 8, Chapter 5: Bridge Scour (2018)
- Countermeasure and Prevention - Hydraulic Engineering Circular No. 23 Manual (HEC-23)
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5 ACKNOWLEDGEMENTS

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Ray Crampton – Commercial Marine Group – Subsea Project Manager/Operations Director

6 AUTHOR BIOGRAPHY

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- 19 years' experience as an occupational diver
- Founder and director of Commercial Marine Group
- Designer of subsea grout bag solutions for several high-profile projects
    - Kingsford Smith Drive Upgrade in Brisbane
    - Eden Breakwater Extension
    - Callaghan Park Boat Ramp
    - Toll Berth 4 in Burnie Tasmania
- Qualified Hyperbaric Operations Project Manager
- Member of the Concrete Institution of Australia
- Committee Member of the Environmental and Sustainability Committee of the Civil Constructions Federation in Brisbane