FACTS ABOUT

An Information Update from the IADC

SUBSEA ROCK INSTALLATION

WHAT IS TYPICALLY MEANT BY ROCK INSTALLATION?

Rock has been used for ports and coastal protection purposes for millennia, for dikes and breakwaters, groins and scour protection. The Romans were the first to master the art of maritime rock works. During the past several decades the major dredging contractors have become increasingly involved in the development and execution of rock installation in marine environments. From the previously used term rock dumping, today the term Subsea Rock Installation is commonly used to reflect the advanced techniques that are being applied, in particular for the offshore oil and gas sector.

Two types of subsea rock installation must be distinguished: One is for shallow water till approximately 50 metres of water depths and is typically used for coastal and embankment protection works and for scour protection or stabilisation of subsea structures for the offshore oil and gas industry or for offshore wind farms. The other is rock installation at greater water depths, usually ranging from 15 meter as the minimum water depth up to 2000 metres, and is most frequently applied for the stabilisation and protection of pipelines of the offshore oil and gas industry.

HOW IS ROCK INSTALLATION IMPLEMENTED?

At first the installation of rock was done from ashore or by hand from a flat deck barge. In the last century the first mechanical rock dumping vessels were designed, built, tested and used for ever larger maritime works all over the world: port extensions as well as flood protection structures. These vessels were typically self-propelled vessels outfitted with a strengthened flat deck to load the rock, hydraulically or mechanically operated “shovels”, which were designed to gradually push the rock over the side of the vessel, and a series of anchors and winches for accurate positioning. They were designed to handle a large range of rock sizes, varying from gravel to large boulders weighing many tonnes.

Images used in this document are taken from the development of the Satah Al Razboot oil field in Abu Dhabi, two offshore artificial energy islands were constructed. This demanded multi-disciplinary activities such as engineering, dredging, reclamation, soil improvement by vibro-floatation and rock revetment. Whilst the location and weather conditions were challenging, these artificial islands provide a sustainable solution for offshore oil & gas winning

This technique is still used frequently and is referred to as side-stone dumping. Side-stone dumping is primarily used in water depths up to 30 metres. Alternatively we could use the “tremiepipe” to accurately install rock up to 50 meter close to structure or the fallpipe from 20 meter water depth because the accuracy of rock installation from the water surface is limited. The deeper the waters, the more currents will influence and disperse the rock, the more difficult it becomes to ensure accuracy. With the exploration and development of oil and gas fields in increasingly deeper waters, new rock installation technologies were needed to ensure accuracy whilst the workability in more remote offshore locations had to be secured.

HOW DID THE DREDGING INDUSTRY ADAPT TO WORKING AT GREATER DEPTHS?

To keep up with the pace of oil and gas field developments in deeper waters an entirely new solution was developed: A fallpipe, which could guide the rocks from the water surface subsea to much greater water depths. By the end of the 1970s a steel, telescopic fall pipe was developed for rock installation at water depths significantly exceeding 50 metres. The big diameter steel fall pipe is, however, sensitive to large drag and gravity forces.

In the mid-1980s an improved technique was developed based on a semi-open, flexible fall pipe consisting of a string of bottomless, heavy plastic buckets along two chains. At the lower end of the string a remotely operated, propelled vehicle (ROV) was attached. The ROV was equipped with a sophisticated range of technologies such as camera, survey and positioning equipment. This flexible fall pipe design, in combination with the ROV, installed on a Dynamic Positioned vessel, was able to achieve more accurate installation of the rock by correcting the off-setting caused by currents. The drag forces were lower and therefore the system was less sensitive to rupture, guaranteeing a higher workability as a result of the semi-open and flexible string of buckets able to adjust their shape along with the currents.

In the early 1990s DGPS (Differential Global Positioning System) was introduced in the offshore oil and gas and marine construction worlds: differential drift of the rock-laying fall-pipe vessel with respect to the subsea pipeline or cable could be achieved by dynamic positioning (DP). The success of this technique has proven invaluable as the dredging industry has become more and more involved with the offshore energy industry, working at ever greater depths.

WHAT TYPES OF SPECIALISED ROCK INSTALLATION TECHNOLOGIES ARE USED?

Specialised rock vessels have been developed and their sizes and the technologies that guide rock installation are constantly being improved. These heavy-duty vessels are able to load and transport very large quantities of rock and accurately install the rock at a precise predestined location. In recent years, for very deep rock installation, new technologies for controlling accurate rock installation have been developed, such as subsea acoustic positioning, discharge control, sensors, cameras, profiling scanners, streaming pre- and post-survey techniques and so on. These technologies are steadily growing in importance as the need for subsea rock installation for the offshore industry is expanding.

WHAT CRITERIA INFLUENCE THE CHOICE OF EQUIPMENT FOR ROCK INSTALLATION WORKS?

Factors to be considered include the location and accessibility of the site, the availability of the right quality and gradings of rock, of rock loading facilities, shipping traffic; the profile, length, width, grading, layer thickness and accuracy of rock to be installed and most importantly the water depth; the type of soil; the water movement such as currents, waves and swell; type of water, salt, fresh or brackish; the ecosystems.

WHAT IS A SIDE STONE DUMPING VESSEL (SSDV)?

The most commonly used vessel is known as Side Stone Dumping Vessel (SSDV). Usually stone is loaded onto the bays on the extremely strong, reinforced deck and the vessel sails to its destination, where dozer blades are used to push the rock over the side(s) of the vessel and deposit the stone accurately in the water with the aid of a positioning system.

The most modern SSDVs are sea going and self-propelled and may achieve sailing-speeds up to 10 knots, making it possible to load their cargo directly at the quarry and eliminating the need for offshore transshipment from supply barges. The SSDVs are used for marine engineering project all over the world and can handle many different rock types and sizes. From small diameter crushed rock or gravel to large boulders weighing several tonnes each. Even concrete blocks used in breakwater construction or coastal defence projects are being handled by SSDVs. The most modern vessels have dynamic positioning systems which allow safe operation at close proximity to offshore platforms and structures.

WHAT IS A DYNAMICALLY POSITIONED FLEXIBLE FALL PIPE VESSEL?

Another rock installation vessel is known as a fall pipe vessel. Dynamically Positioned (Flexible) Fall Pipe Vessels (DP FFPV) are typically used in water depths exceeding 20 metres. They are specially designed vessels or transformed bulk carriers which are designed to carry large amounts of rock in their holds. The loading capacities of these vessels vary greatly, from 1,400 tonnes to more than 33,500 tonnes.

Fall pipe vessels are primarily used for offshore projects, for covering offshore pipelines, cables or umbilicals, levelling the seabed, providing foundations for subsea infrastructure or applying scour protection. Rock material is loaded at a port or preferably at a seafront quarry into the holds of the vessel. Fully loaded, the self-propelled vessel travels to the area where the work needs to be performed. These highly computerised, automated and dynamically controlled vessels can achieve position-fixing within an accuracy of less than half a metre.

HOW IS ROCK DISCHARGED FROM A DP FFPV?

Discharging the rock can be done by transferring the rock by conveyor belts from the hull to the hopper on deck. Alternatively a large excavator can be used to feed the hopper on deck. From the hopper it goes through the feeder which controls the flow of rock into the flexible fall pipe. The ROV at the end of the fall pipe is used to manoeuvre the flexible fall pipe and carries all the survey and positioning equipment necessary to allow the crew to accurately install the rock at the pre-determined location. The newest generation of DP Fall Pipe Vessels can reach water depths of up to 2000 metres, six times the height of the Eiffel Tower, and can carry up to 33,500 tonnes of rock.

WHAT ARE SOME APPLICATIONS FOR SUBSEA ROCK INSTALLATION?

Some instances where Subsea Rock Installation is applied in the Offshore Industry include:

- In the preparation of the seabed prior to pipe laying or platform installation;
- To prevent scouring around maritime structures such as offshore platforms and rigs;
- To protect pipelines against damage from anchors, trawler boards, fishing nets and such;
- To mitigate free-span of pipelines in undulating terrain;
- For offshore ballasting works;
- To achieve axial locking and mitigate lateral or upheaval buckling of the pipeline, e.g., owing to temperature and pressure changes of the pipe; and
- For the physical separation and mutual protection of two or more pipelines in case of pipeline-crossings.

HOW IS ROCK INSTALLATION APPLIED IN THE OFFSHORE ENERGY INDUSTRY?

For several decades the dredging industry and the offshore energy industry have worked very closely together. The necessity to stabilise and protect offshore pipelines, cables and other installations such as Gravity-Based Structures (GBSs) for oil and gas or for offshore wind farm foundations is

obvious. The global dependence on offshore sources of oil and gas has increased, as has the proliferation of offshore wind farms. Consequently the necessity for dredging expertise in rock installation has also accelerated. Worldwide from Norway, The Netherlands and the UK to Sakhalin in Russia and Australia, Mediterranean Sea to Canada and Gulf of Mexican , the demand for pipe laying and stabilising the seabed and pipelines is on the rise.

WHAT ARE APPLICATIONS OF ROCK INSTALLATION FOR OFFSHORE WIND FARM FOUNDATIONS?

Basically, three types of foundations have been used so far for offshore wind turbine construction: the conventional monopile foundation, the jacket-type foundation and the gravity-based foundation (GBF). Dependent upon the site conditions, i.e., soil, hydro-dynamics, one type of foundation may be preferred over another. For instance, gravity-based foundations (GBFs) have been used for very large wind turbines, like the wind farm at Thornton bank off the coast of Belgium. These GBF's are pre-cast concrete structures which are constructed on shore on a quayside and then transported to the installation site by heavy-lift vessels. There they are lowered to the seabed into a prepared foundation pit. The engineered foundation pit is pre-dredged to its design shape and depth. A gravel layer is then accurately put in place with a DP fall pipe vessel as a foundation layer for the GBF. After positioning the foundation unit into the foundation pit the GBF is ballasted and the pre-dredged pit and surroundings is back-filled with sand and/or gravel.

Prior installing of monopiles or jackets and after installation of a GBF, these offshore structures need to be protected against erosion caused by the action of currents and waves. In most cases gravel and rock are being used to apply a solid and sustainable erosion protection layer. Specialised DP controlled gravel and rock installation and spreading tools are used to accurately position the gravel and rock layers next to the foundation. Special safety procedures are applied to allow vessel to operate in close proximity to these structures, sometimes in harsh environments.

HOW IS ROCK INSTALLED FOR PIPELINE SHORE APPROACHES?

In many cases offshore pipelines and cables need special protection in their shore-approach track. Typically the pipeline is installed in a pre-dredged trench and backfilled with previously excavated material or by means of natural backfill. Sometimes, when the excavated material does not meet the requirements to achieve safe cover of the pipeline, engineered backfill material is used. This may include the installation of rock on top of the installed pipeline. This will protect the pipeline against damage and guarantees that the pipeline is safely and firmly installed at its location , regardless of the natural coastal dynamics on the seabed, for instance, in the surf zone.

WHAT SPECIFIC CHALLENGES ARE ENCOUNTERED IN GREATER WATER DEPTHS WHEN INSTALLING ROCK ON SUBSEA PIPELINES?

The integrity of subsea pipelines can be endangered by large free-spans, lateral and upheaval buckling and physical impacts like fishing nets (trawl boards) and anchors or other falling objects. This can be avoided by installing pre-lay rock supports and post-lay rock covers. During rock installation a number of effects take place, such as surface erosion, rock penetration and settlement of the subsoil. These processes are called “immediate displacement” and can be accurately determined as long as sufficient geotechnical information on the seabed characteristics is available. Using flexible fall pipe techniques can offer the most successful outcomes. At the Aasta Hansteen project for Equinor the Subsea Rock Installation technics have been use up to 1300 meter water depth, other examples are Ormen Lange, Tyrihans and Penguin at water depths up to 1000 meter.

WHAT ARE THE ALTERNATIVES TO SUBSEA ROCK INSTALLATION?

Alternatives to subsea rock installation to protect offshore pipelines and to mitigate lateral and upheaval buckling do exist. A common method is to apply a thick armour layer or concrete shell around the pipe, to cover it with flexible concrete mattresses or to install the pipeline in an excavated trench. To mitigate free-spans, a pipeline can also be supported with concrete elements or steel frames. Another option is to dredge the high- spots by “pre-sweeping” to create a more even seabed. This reduces the length of the free-spans. Where a new pipeline crosses an existing pipeline, concrete mattresses may be used between the two pipes to avoid damage to either or both pipelines.

Good engineering practice used by the dredging community will consider the technical feasibility and cost aspects in order to select the most efficient and economical solution. Subsea rock installation is considered to be a competitive and reliable method to ensure a pipeline's integrity.

Flexible fall pipe vessels (FFPV) are primarily operated in very deep water up to 2,200 metres, when covering oil and gas pipelines, levelling the seabed or applying scour protection. An ROV is attached at the lower end of the fall pipe for better positioning.

FOR FURTHER READING AND INFORMATION

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Facts About is presented by the International Association of Dredging Companies whose members offer the highest quality and professionalism in dredging and maritime construction. The information presented here is part of an on-going effort to support clients and others in understanding the fundamental principles of dredging and maritime construction.

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