FACTS ABOUT

An Information Update from the IADC

UNDERWATER DRILLING & BLASTING

WHAT IS UNDERWATER DRILLING & BLASTING?

Rock is often encountered in rivers, estuaries, coastal and open waters and can pose an obstruction to various works. Dredging can be done to remove the rock but sometimes the rocks that are too hard to be dredged directly have to be removed with explosives. Underwater drilling and blasting can sufficiently fragment the rock to allow for it to be dredged.

Underwater blasting or submarine blasting as it is otherwise known is done for a range of projects. These include deepening of harbours and channels, excavation of trenches for installing oil and gas pipelines and communication cables, demolition work and excavation for foundations (civil engineering).

Underwater drilling is the first part of the process during which drilling is done to make bore holes in the rock to place charges or explosives for blasting. The drilling (and blasting) can be done from the surface via floating pontoons and self-elevating, spudded platforms. The process also often includes overburden drilling (OD) – overburden is the softer materials overlaying the rock. This is done with a casing tube which is drilled through the overburden into the top of the rock. In this way a firm connection is made between the pontoon and the rock on the sea bottom. Within this casing the drilling of the deeper borehole is done and the explosives are lowered.

Underwater drilling and blasting is no easy feat and there are various factors that can make it very challenging. Water is often moving and this movement can create an additional burden. The water also makes it difficult for blasting as the explosives need to be water-resistant. In addition, underwater blasting can pose various impacts such as ground vibrations and underwater shock waves and steps need to be taken to mitigate these impacts.

Furthermore, before any underwater drilling and blasting operation can be undertaken, a thorough site investigation must be conducted. The information often includes the depth of overburden and type of material, level of rockhead (the surface between overlying unconsolidated material and solid bedrock below) and the type of rock. Also, an inspection of nearby buildings and harbour structures is often done to calculate the impacts of the drilling and blasting operations on them.

WHAT ARE THE DIFFERENT DRILLING PONTOONS?

Floating pontoons such as flat top barges or hoppers can be adapted for mounting drilling equipment. A floating pontoon for drilling consists of: drill towers; anchor winches; compressors; generator; accommodation such as office, mess, workshop, storage; explosives storage including separate storage for detonators and boosters.

The floating pontoon is anchored in position and anchor adjustments are made for each drill hole or line of holes. The drill towers are moved over rails on one side of the pontoon or over a hopper (well) so as to drill several holes from one pontoon position. When a row of holes has been drilled, the pontoon is winched to the next position. Coupling and uncoupling the casing and drill rods is usually automated on small rigs and manual on large rigs (the rig refers to the entire drilling machinery and the accompanying equipment).

Also, as the height, pressure of waves and swells can have an impact on work, rigs are often fitted with a wave compensator.

A drilling pontoon on spuds, otherwise referred as self-elevating platform is also used for drilling operations. At each corner of the pontoon is a spud, which is lowered into the sea bed. The pontoon is then partially or entirely lifted out of the water on the spuds and used to position the self-elevating platform and for winching in order to blast.

Above: An underwater blasting operation being undertaken in Porto Sudeste, Brazil. The white foam indicates the area where the blasting occurred underwater

A floating pontoon with drill towers moved over rails on the side

A drilling pontoon with a self-elevating platform

A self-elevating platform is placed in the right position utilising either anchor wires or a tug boat. The platform ends up in an “approximate position”, after which the correct position of the drill towers is obtained by measuring the location of the platform and then moving the drill towers onto the platform into the correct position.

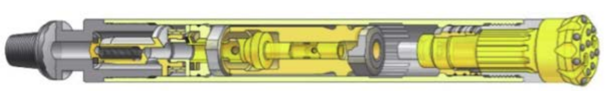
Thus, the drilling and blasting cycle of pontoon with a self-elevating platform is longer than with a floating pontoon as positioning, raising and lowering the platform takes up significant time.

WHAT ARE THE VARIOUS DRILLING SYSTEMS?

Before blasting operations can be conducted, the rock needs to be initially drilled in a pre-determined pattern to place the explosives. The pattern of drilling depends on various factors such as the type of rock , size of charges, fragmentation and the depth of the bench height. The bench height is the depth of the rock from rockhead to the required excavated bed level.

There are several drilling systems used for underwater drilling. The first is the top hammer drilling system, the second is the down-the-hole (DTH) hammer system and the third is rotary drilling system.

A traditional top hammer drill



Down-the-hole (DTH) hammer

In the top hammer drilling system, the stroke is applied on top of the drill rods. The impact energy is transported through the drill rods to the drill bit. There are major energy losses at significant depths in a drilling process. This is because the shockwave of the hammer is attenuated (reduced in strength) travelling down the length of drilling rod due to buckling and the rod’s finite stiffness.

In DTH hammer systems, the hammer is behind the drill bit. The impact of the hammer is applied directly to the drill bit. This results in significantly less energy loss. In addition, DTH drilling makes less noise and is a more accurate drilling method.

Rotary drilling system involves a sharp drill bit that exerts downward pressure that drills rotationally into the rock. However, this drilling technique is not often used in underwater drilling compared to the top hammer and DTH hammer systems. This is because rotary drilling requires a large force to be exerted on the drill bit, thus making it a requirement for the drill unit to be much stronger and larger in capacity. This in turn requires a more robust and larger stable platform, for an example, the jackup barge, all of which adds to the initial capital cost.

WHAT ARE THE DIFFERENT TYPES OF BLASTING WORKS?

Blasting is done for various works and the techniques differ for each type of blasting.

Trench blasting

Trench blasting is a common method – trenches are excavated for installing oil, gas, water, sewage pipelines and cables. The (blasting) rounds are only a few metres wide; the drilling is done up to 1-3m depth and large lengths of up to 300-500m in the rock, depending on the rock profile.

Foundation preparation blasting

Blasting for foundation preparation requires a different technique; this type of blasting is also not as commonly used as trench blasting. However, this technique is used when it is a requirement for minimum fracturing of the surface at out-falls and intake systems to dams and preparations for placing sheet piles – a temporary supportive wall structure that been driven into a slope or excavation to support soft soils collapsing from higher ground to lower ground – which then would be pinned and or grouted in place. This technique is also used when preparing work on caissons – a watertight retaining structure used, for example for the construction of quay walls. The drill holes on the rock require closer spacing and consideration to adjusting explosives charges to avoid overbreak when blasting is done. Overbreak is defined as the removal of rock beyond the required lines and levels.

Line drilling and blasting
The line drilling technique involves drilling a series of holes that are spaced only several inches apart on the desired line of breakage. Reduced charges or explosives are utilised on the row leading into the line drill. Once the rock has been blasted, the body of rock is blasted and dredged. This technique is used, for an instance, to protect and prevent damage to the rock mass behind the (excavation) line which may be supporting a quay wall. It also creates a line of discontinuity which helps reduce the transmission of vibration that helps protect any structures behind the (excavation) line when the bulk blasting is being carried out.

WHAT TYPES OF EXPLOSIVES ARE USED IN BLASTING?

Explosives are essential in underwater blasting and a few factors need to be considered before choosing the right ones. These factors include the velocity of detonation, density, detonation stability, water-resistance and shelf life. The velocity of detonation is the speed at which the detonation travels through the explosive and is higher when the explosive is confined (in a borehole) than unconfined (on the surface of the rock). The density of an explosive is important when designing the charges as it determines the drilling pattern that will be used. It is especially essential to check the explosives for their resistance to deterioration in water; this is seen as the time a charge can remain in water while detonating reliably.

Two types of explosives are mainly used in underwater drilling and blasting operations – nitroglycerine-based explosives (NG) and ammonium nitrate-based explosives (AN).

Nitroglycerine is fluid and highly unstable so a small shock can trigger a reaction that could lead to detonation. The explosives are waterproof but the period they are allowed underwater should be kept to a minimum.

AN explosives are tri-nitro-toluene or watergel based and are sensitized with fuel, thickened and crosslinked to a glutinous consistency. These types of explosives are softer, cheaper and safer to handle compared to nitroglycerine-based ones. However, AN explosives need a contact primer for firing which is expensive. These explosives can be used underwater and are packaged in cartridges or are in bulk form.

Besides explosives, other equipment is also essential for detonating the explosives. These include the detonating cord, detonator, primer, booster, lead-line and ignition device.

WHAT IS A DETONATING CORD?

A detonating cord is a strong, flexible cord with an explosive core, often Pentaerythritol tetranitrate (PETN) or commonly known as penthrite, a highly explosive chemical akin to nitroglycerine. The core is protected from moisture and wear and tear by a number of synthetic layers. The cord is used as a means of initiating a blast or as an explosive charge by itself. The PETN is hygroscopic and can only remain in the water for a short time. The cord can be utilised to synchronise multiple charges to detonate simultaneously. Cordtex and Primacord are two commercial products commonly utilised.

WHAT ARE DETONATORS?

Detonators are small, sensitive charges that set off an explosion. They consist of a thin-walled aluminium or copper sleeve filled with a small amount of sensitive primary explosive and an amount of secondary explosive. The major advantage for using detonators for detonating a blast is the possibility of delayed blasting – blasting using delays to detonate blast holes at separate time intervals. Delayed blasting can provide better fragmentation of rock and better control over ground vibration and pressure wave.

There are several types of detonators – ordinary detonators that are not used for underwater blasting, electrical detonators, NONEL (non-electric) detonators, and electronic detonators.

In electrical detonators, the basic charge is initiated by an electrical charge from a blasting machine or battery source. These detonators are not often used in underwater blasting due to various issues with the electrical firing – lack of electrical continuity and premature detonation due to external stray currents such as lightning, radio waves and power lines.

NONEL detonators are initiated by a shock that comes from a shock tube, which is a small plastic laminate tube coated with a thin layer of reactive material. These detonators are most often used for underwater blasting for several reasons: they are relatively insensitive to impact, they are insensitive to stray electric currents and they are reliable in water and easy to use.

Electronic detonators include their own time interval chips in them. The charge is initiated when a signal is emitted by the chip to the electrical bridge. This type of detonator is also rarely used in underwater blasting.

Detonators can also have timing properties – instantaneous detonators, millisecond detonators and half-second detonators. Millisecond delay detonators are important in blasting works as their built-in millisecond delay element can delay the detonation at a predetermined time. These are often used in bench and trench blasting.

WHAT IS A PRIMER?

A primer is a unit, package or cartridge of explosives used to initiate other explosives or blasting agents and includes a detonator or a detonating cord that is attached to a detonator designed to initiate the detonating cord.

WHAT IS A BOOSTER?

A booster is an explosive charge, usually of high strength and high detonation velocity, used to improve the initiation of less sensitive explosive materials. A booster usually comprises of TNT with a specific amount of PETN.

WHAT IS A LEAD-IN LINE AND IGNITION DEVICE?

A lead-in line is a shock tube (a plastic laminate tube coated with a thin layer of reactive material used to deliver a shock to initiate explosives) with a connector with a delay (delay time is the time between initiation and detonation of a detonator) of zero milliseconds. The connector is connected to an ignition device, a device that can cause a severe shock that can cause the lead-in line to ignite. The shock moves at 2000 m/s through the line and causes the detonator to go off that initiates the blast.

WHAT ARE THE IMPACTS?

Though special care is taken to keep surrounding structures and the environment safe from underwater blasting, there are impacts from this activity. Ground vibration and underwater shockwaves are two of the major impacts from underwater blasting.

Underwater blasting is often conducted close to different types of structures such as quay walls, breakwaters and harbour buildings. Ground vibration, which is the energy from the blast transmitted through the rock or ground, can occur from the blasting. These vibrations are determined by various factors such as quantity of charges, characteristics of the rock and distance from the blast.

There is a risk of propagation between (blast) holes in underwater blasting. This could cause larger total charges to be detonated at the same time as well as stronger ground vibrations. The energy from the blast can be transmitted in various directions in the water and at different frequencies – these frequencies are high at short distances but are reduced further from the blast.

Underwater shock waves are another impact from blasting that can cause damage to nearby structures, aquatic fauna and even vessels and people in the water. In water, the explosive energy is transmitted with great efficiency, which means that the shock wave has high destructive power even over large distances. Moreover, the pressure of the shock waves is higher if the explosive is detonated freely in the water – the maximum pressure is 10 times higher if the explosive is detonated on a rock surface instead of a blast hole drilled into the rock.

HOW ARE IMPACTS MITIGATED?

There are various methods to mitigate impacts. One technique is to determine the size of charges that can be fired without causing excessive ground vibrations. Ground vibrations can be controlled by determining the right size of charges in relation to the drilling patterns and the firing sequence.

Just like mitigating ground vibrations, the most effective way to reduce both the pressure and impulse of a shock wave is to reduce the charges through reduction of spacing between blast holes and charging fewer explosives in the rock.

Another method to mitigate the pressure of underwater shock waves is to use an air bubble curtain around the blasting zone. The air bubble curtain is produced by using perforated steel pipes, through which air is pumped and bubbles up to the surface. The shock waves in the water are partly absorbed in the bubbles – the air bubble curtain reduces the peak pressure of the shock but not the impulse of the wave.

The air bubble curtain is one method but other methods such as acoustic deterrent devices are also utilised. The acoustic deterrent devices can emit specialised acoustic signals to safely and temporarily deter various marine fauna species from marine construction sites.

Furthermore, dredging organisations working on marine infrastructure works in general, and those that require underwater drilling and blasting are constantly seeking innovative ways to ensure that environmental impacts from their projects are mitigated.

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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