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.
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.

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.

Down-the-hole (DTH) hammer
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. Cordtexit 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


