ACCROPODE™ II for breakwaters has been created in 1999 by SOGREAH. The license is sold by CLI (Concrete Layer Innovations).

The design of this the ACCROPODE™ II is different than the ACCROPODE™:

ACCROPODE™

ACCROPODE™ II

There is no more anvils on the ACCROPODE™ II and no more sharp angles.
The mold is a bit harder and a little more expensive to make for ACCROPODE™ II than for ACCROPODE™.
Our company CLAS has tested ACCROPODE™ and ACCROPODE™ II on a lot of projects.

We consider ACCROPODE™ II as an improvement in the design for ACCROPODE™ used on one layer protection for breakwaters. ACCROPODE™ II offers an easier placement than ACCROPODE™. But it also cannot be used by "blind placement". The strong interlocking is the key to building a sustainable structure.

The advantages noted by the use of the ACCROPODE™ II in comparison with ACCROPODE™ are:

Less placing rules and more easy to build a strong armour protection if the interlocking is good, due to the fact that not exist anvil on the ACCROPODE™II.

PRIOR TO PLACE THE ACCROPODE™ II UNITS

The words "one layer concrete blocks" are not a reality. These words are used to make the difference between ACCROPODE™, ACCROPODE™ II, CORELOC™, ECOPODE™, X-BLOC® from the old concrete units used by placement on 2 layers like TETRAPODE.

The "one layer concrete blocks" are closely related to the underlayer. The rock size, the tolerances, the roughness of the underlayer are proportionate to the armour blocks and really we work with two layers, but one is rocks, one is concrete.

The construction of the underlayer is a sensible and difficult part of job as well. The quality of the interlocking and the ease of ACCROPODE™ II placement depends on the quality of the underlayer. Also the life time storm after storm depends on the quality of the underlayment and not only on the interlocking during the construction.
The excavator on the barge prepare the flat berm and the underlayer

Slope construction with an excavator from the shore

The slope is inspected and approved by several ways. Usually the profile every 10 meters is checked. It could be by excavator, by multibeam, by echo sounder. CLAS recommends and does a visual inspection of the surface of placement, even when the contractor use a multibeam. Because the ACCROPODE ™ II are not placed on a profile but on a surface. Because between the approval and the real placement it can happen a storm and damages. The visual inspection has to be done just before the placement and most of the time we found isolated
stone to remove, sometimes the surface is rejected even if it was approved before. Due to gaps, rocks producing or too rough surface.

When a producing rock is identified, the diver place a belt around the rock
The rock is removed easily and very fast

Using the same tools a diver can fill a hole in the underlayer. If we try to do it by excavator only, the slope is damaged and has to be profiled again. So for isolated gap to fill or rock to remove, it is better to do it by diver.

It happens that we saw a perfect profile on the multibeam survey

In the reality the profile and all the placement surface was terrible and it was not possible to place the ACCROPODE ™
The consequence of a rock protruding will be an ACCROPODE™ II out of profile.
A wrong grading could be a non-stable berm and non-stable first row of ACCROPODE™ II

Or ACCROPODE™ II collapsing in the small material
The placement of the ACCROPODE ™ II can start only when the surface for placement is properly built, in compliance with the tolerances.
PLACEMENT OF THE ACCROPODE™ II UNITS

PLACEMENT BY DIVERS

The use of divers underwater is just logic. Most of the time the placement area is not deep and most of the time never more than 11 meters. It is easy and safe to use divers under several conditions.

Diver is connected by underwater communication system

The main issue using the divers is the safety. But the placement of ACCROPODE™ and ACCROPODE™ II is not more dangerous than all other kind of underwater works. The problem is: not exist special diving school which teach the use of ACCROPODE™ and ACCROPODE™ II and the specific safety rules attached to this use.

All countries use their own regulation or sometimes no regulation at all.
Commercial diver in VIETNAM in 2008: no regulator, no communication except pulling the pipe and in the swell it doesn’t work well.

Diving equipment used in the UAE: the diver in charge of the placement use the standard IMCA rules and equipment. The CLAS inspector use a scuba to move fast from a diver to another one in the same area and because he doesn’t need to communicate with the operator.
An important tool for the divers and their safety is a steel hook. One of the main tasks is to adjust ACCROPODE™ or ACCROPODE™ II to fix a non-conformity during the construction, or to remove an ACCROPODE™ or ACCROPODE™ II. The sling has to be adjusted or replaced around the block. To not put the hands inside the concrete blocks, the divers have to use a steel hook.
The hook has to be long enough to catch the wire inside the ACCROPODE™ or ACCROPODE™ II without placing the hands between the blocks.

The communication is a very important aspect of the equipment.

Communication pulling on the pipe in VIETNAM. Efficient for simple request with no swell
In the diving container the diving supervisor communicates with the diver, the operator and the riggers. He can see what the diver sees and what the operator sees.

One more diving equipment very important is the ladder. Most of the accident with divers happen during coming out of the water when they try to walk on the slope. In case of swell it is very dangerous. CLAS requests to all contractors using divers to provide a good ladder. This ladder has to be long enough to go inside the water. It’s a strong safety requirement.
In case of emergency, all tools able to take the diver out of the water are acceptable. To use the basket of the excavator is spectacular but really safe and comfortable for the diver.

To use divers the training and teaching about the use of the ACCROPODE™ and ACCROPODE™ II is an essential part of the work. Specially the safety rules.

The training done by CLAS is in 3 steps.
Step 1 Theoretical training.

CLAS inspectors are commercial diver with more than 20 years of experience. They explain the special safety rules in the use of the blocks.

CLAS inspectors train the staff from the management to the labor forces regarding the safety, the placement rules and the general management of the working area regarding the safety and the efficiency to give the highest production.
Step 2 Practical training on the training slope

CLAS trains the staff in the use of the ACCROPODE ™ II for construction

CLAS trains the staff also for dismantling and all kind of situation that can happen in the reality.
Step 3 Underwater training

A well trained diver understands when and how to check the ACCROPODE™ II

A trained diver knows how to adjust the hook to change the attitude of the ACCROPODE™ II
The training never stops due to the turnover of the staff onsite.

CLAS inspector in addition to insure the quality of the placement, explains the non-conformities and constantly reminds the security rules in the use of ACCROPODE™ and ACCROPODE™ II.
To be efficient the training has to be done non-stop due to the turnover of the labor forces.

All tasks regarding the placement and the inspection of the ACCROPODE™ and ACCROPODE™ II can be done without any risk if the safety rules are understood and applied. This is the basic task of a commercial diver and for all the staff in charge of the placement.

To build a strong breakwater using ACCROPODE™ and ACCROPODE™ II several inspections have to be done.

At first during the placement.

The diver checks the contact with the ACCROPODE™ on both side on the row below, and the contact with the underlayer. The integrity of the blocks is controlled to avoid cracking in the concrete due to impact.
The diver can release the sling when all placement rules are in place.

These placement rules and the acceptance criterion are definite in the TID given by Concrete Layer Innovation with the contract of license. The placement rules have to be applied strictly to reach the acceptance criterions. These acceptance criterions are not so strict than the placement rules, but if we are too lax about enforcing construction rules, non-conformities giving a risk for the structure can exist.

Good interlocking, no gaps, density 101,5 %
ACCROPODE™ II not interlocked at the water level. For sure it will be extracted and damages will exist soon.

Contact missed: it leads to settlements and breakages.
ACCROPODE™ II broken out of the water due to settlements underwater. In this area starts the mechanic of slow destruction.

Contractors afraid by the use of divers prefer to use placing tools. These placing tools are sold as “diverless” placing tools. The reality is different.

The ECHOSCOPE® is an acoustic tool used in a lot of projects. When it is implemented with divers it could be a very good solution. In case of poor visibility the operator places the ACCROPODE™ II and the diver only checks the unit before to release the sling. The picture on the screen of the operator give a good view of the gap where the ACCROPODE™ II has to be placed. But when the ACCROPODE™ II is in contact with row below, the operator cannot see if the ACCROPODE™ II touches the underlayer, gives good contacts with the row below and if the interlocking is strong enough to avoid future settlements.
In case of poor visibility, the use of the ECHOSCOPE® increases the safety and the production. Using divers to check the block increases the quality. It was the way of work in RAS LAFFAN for example and CLASS still like a lot to work using in the same time ECHOSCOPE® and divers.

The use of the ECHOSCOPE® without divers did a technical failure in DAS ISLAND and we did the repairs on 5 km of breakwater build with X-bloc®. The X-bloc® was not the problem, the problem was the wrong use of the ECHOSCOPE® for placement and use for approval.

The ECHOSCOPE® didn’t identify broken units (broken X-bloc®)
The ECHOSCOPE ® didn’t identify out of profile (Out of profile not identified on X-bloc ®)

The ECHOSCOPE ® didn’t identify gaps or shows non-existing gaps. (Gap not identified on X-bloc ®)

Making diving inspection CLAS did several comparisons between the placement approved by the ECHOSCOPE ® and the reality. We noted on the placing drawing the not acceptable non-conformities giving a real risk for the stability of the armour layer by non-identified gaps, broken units, blocks not interlocked and ready to be extracted by the swell, important contacts missed ready to generate settlements:

- Placement approved.
- Contact missed sometimes without overlapping and risk of settlement.
- Risk for the stability due to extraction possible.
This is a limit of the acoustic tools. But properly used, knowing the limits of the tool, we still recommend it in addition of divers to increase the safety and the production when the visibility is poor.

**By experience on several projects our position is: the ECHOSCOPE ® cannot be used for the approval of the placement.**
Some other contractors prefer to use the POSIBLOC™ system. POSIBLOC™ is a tool based on measurements. The accuracy is + or – 0.15 meter.

In 2009 the picture was different from the reality with “floating” units.

In 2017 still existed important differences between the virtual image created by POSIBLOC™ and the VISIBLOC™ software and the reality and “floating units”. The operator cannot know if the block underwater is acceptable or not.
Block well placed on the virtual picture, not interlocked in the reality

In addition the system cannot identify the broken units as well and cannot identify properly the out of profile units.

To identify out of profile units, the contractor has to use the software VISIBLOC PROCESSING to check after the placement if exist out of profile units. It already a serious problem: in case of out of profile identified, the contractor will be obliged to remove all the blocks placed above the out of profile units.

In 2017 we placed a block out of profile on a trial section to understand how the software VISIBLOC PROCESSING will show it. On the following picture one unit is out of profile, the units in the pink color are the out of profile units identified by the POSIBLOC ™ system, using the VISIBLOC PROCESSING software:

The VISIBLOC ™ picture cannot be used for the approval of the placement
Another strategy is to place the blocks and to check using multibeam sonar.

Multibeam used on ACCROPODE ™ or ACCROPODE ™ II we cannot be sure that the interlocking is strong enough to avoid underwater settlements and future breakages.

The picture from a multibeam cannot provide enough reliable information about the quality of placement, CLAS recommend to not use it for approval.

CLAS did experiences with the acoustic cameras from SOUNDMETRICS. The result was better, but not enough to make an approval with the guaranty that is will not exist settlements and breakages:

```markdown
Acoustic camera on ACCROPODE ™
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The acoustic camera is, according to CLAS, the best tool to make a survey of the general structure. It is not enough to certify the quality of the construction or to identify all local non-conformities.

A breakwater is a work that must last for decades.

The investment is always very important.
The means and price to achieve this goal are nothing compared to the total investment.

However, the lack of knowledge of the limits of placing and survey tools or human resources leads to a risk-taking that led CLAS to establish this classification A, B and C.

In addition to this classification CLAS has established a list of knowledge and qualifications that an inspector responsible for approving an ACCROPODE ™, ACCROPODE ™ II or any other kind of breakwater armour, X-bloc ®, CORELOC ™ or other concrete blocks, needs to assemble. This list of skills and quality was then followed by a very strict selection of its inspectors, then at the expense of a mark and a label: CLAS TECHNOLOGY COMPLIANT recognizable by this logo:
No breakwater using CLAS inspectors and process, for pedagogy, construction, monitoring and approval have been damaged. Our inspectors are not associated to any failing project.

The production for placement of ACCROPODE™ and ACCROPODE™ II depends strongly on the tools used and the management of the project.

We did real time comparisons between different tools. Except using POSIBLOC™ the production regards approved placement, after repairs included in the calculation.

The results are reported on the following boards:

**Underwater placement by wire crane and trained divers – Result 1**

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<thead>
<tr>
<th></th>
<th>ACCROPODE™</th>
<th>ACCROPODE™ II</th>
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<tbody>
<tr>
<td><strong>Good visibility</strong></td>
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<tr>
<td>Average production/hour</td>
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<tr>
<td>Average production/hour</td>
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<td>Maximum</td>
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**Underwater placement by excavator and trained divers – Result 2**

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### Underwater placement by wire crane using ECHOSCOPE® and divers – Result 3

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<tr>
<td>Maximum</td>
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### Underwater placement by wire crane using POSIBLOC™ – Result 4

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The calculation using POSIBLOC™ not includes the repairs after monitoring.

We can see on these boards that the production is the same with ACCROPODE™ and ACCROPODE™ II using placing tools. When the sea conditions are too rough or no visibility at all, the contractors, the engineers and the clients must accept a large part of unknown risk. Repairs will be very difficult. Maybe it is the limit in the use of one layer concrete blocks?
Example of result of the blind placement:

![Image of underwater construction]

The quality of the placement and the interlocking is a strong requirement to build a breakwater safe and strong in compliance with the 3D model test.

**Example of a visible result of a bad interlocking underwater:** Sliding movement due to a settlement underwater and broken units out of water
Usual non-conformities in the use of ACCROPODE™ and ACCROPODE™ II making risk of breakages, settlements and extraction of blocks

ACCROPODE™ placement in column

ACCROPODE™ contact missing

ACCROPODE™ II out of profile
ACCROPODE™ Lozenge mesh not respected

ACCROPODE™ nose on the slope

Gap in the ACCROPODE™ II
Non-conformities and bad interlocking can generate damages after the construction.

**We identified on real site construction 4 level of risk:**

**Level 0:** No risk. It could be similar attitudes with strong interlocking for example.

**Level 1:** Minor risk. Needs to check sometimes how it evaluates. Better to fix it during the construction.

**Level 2:** A real risk is identified. It could be bad interlocking with risk of settlement for example. Better to fix it during the construction.

**Level 3:** The risk is high and the area has to be rebuilt. It could be out of profile blocks, bad interlocking on several blocks etc.

Due to the way to place the ACCROPODE ™ and ACCROPODE ™ II we identified 3 different levels of quality in the construction and we classified the armour layer using these 3 classes:

**CLASS A:** the quality is at the better level and confirmed by diving inspection done by accredited inspectors under the trademark **CLAS TECHNOLOGY COMPLIANT**. The project is in compliance with the acceptance criterions. The level of risk is 0 on a scale of 4. The placement has to be approved. Until now, it is possible only by the use of divers well trained with an accreditation from CLAS confirming their experience and knowledge and not submitted to any conflict of interest, to make the inspections and the approval for CLASS A projects.
CLASS B: the quality cannot be confirmed due to the use of acoustic tools or virtual pictures for the inspections and the approval or due to so bad visibility that the diver cannot check any think and cannot confirm that the interlocking is good. The placement has been done using not trained divers without a real knowledge, the approval has been done by divers not accredited by CLAS. We don’t have all information about the compliance with the design or some “strange” thinks exists in the design. The risk regarding the quality is not well managed.

Example: placement using placing tools and approval by multibeam

The construction done by placing tools, inspected by divers submitted to conflict of interest or by multibeam has to be class B or C. The use of the process under the The project longevity may not be consistent with the expectations of the client.

CLASS B projects have to be monitored more often and preventive repairs should be necessary. CLASS B projects may have premature obsolescence.
CLASS C: the quality is bad and we know it. The placement has to be rejected.

Example: First and second row of ACCROPODE ™ II not stable, the berm is not flat and makes a slope, the berm and underlayer is not the good grading of rocks but very small material.

The ACCROPODE ™ II are not well interlocked, one of them is quite on second layer.
ACCROPODE ™ II placed on sand

The CLASS C is the consequence during the placement of the ACCROPODE ™ and ACCROPODE ™ II of a non-respect of the placing rules, the wrong understanding of the principle of interlocking, wrong information given to the contractor about the interlocking, bad or insufficient training given to the contractor, use of acoustic tools for approval. This lack of knowledge and training of the contractor is associated with the same deficiency on the part of the inspection company in charge of approving, or this company is submitted to conflict of interest.

The classification A, B and C can be seen:

Example of breakwater class A:

Example of breakwater class B after several years:

Disconnections, breakages and holes are visible
Example of breakwater class C:

CLAS inspector identifies movements on a very bad construction, using a drone