OTC-30582-MS

Innovative Use of a Rov to Control Underwater Coastal Protections

Thebaud Nicolas, VINCI Construction Terrassement; Macaigne Vincent and Le Bars Steven, ID OCEAN

This paper was prepared for presentation at the Offshore Technology Conference originally scheduled to be held in Houston, TX, USA, 4-7 May 2020. Due to COVID-19 the physical event was not held. The official proceedings were published online on 4 May 2020.

Abstract

The control of monolayer concrete armour units on coastal protection breakwaters can be time and cost consuming, especially underwater. It is even more the case when - for maintenance and control purpose - they are conducted long after the completion of the construction (positioning issues, number of units to control, etc). However, this occurs frequently on construction projects which last for several years, or during the operation and maintenance of such structures. On top of that, the complexity of this type of projects - usually coastal constructions such a dike easily exceeds 6000 units/km - requires precision and productivity for the control inspections.

As a result, specific control solutions have been developped on the NRL project to inspect and monitor the breakwater after its construction.

The NRL project lies in La Reunion (Indian Ocean). It is due to replace the current coastal road, which was built at the foot of a 100m height cliff. Indeed, after heavy rainfalls, rocks are falling from the cliff. The road is also usually closed during storms as the road is submerged by the sea on one side, and by rainfalls on the cliff side.

The objective of the project is to build a new road at sea to secure this vital economical axis between the cities of Saint-Denis - the island capital - and La Possession.

Objectives/scope

The control of monolayer concrete armour units on coastal protection breakwaters can be time and cost consuming, especially underwater. It is even more the case when - for maintenance and control purpose - they are conducted long after the completion of the construction (positioning issues, number of units to control, etc). However, this occurs frequently on construction projects which last for several years, or during the operation and maintenance of such structures. On top of that, the complexity of this type of projects - usually coastal constructions such a dike easily exceeds 6000 units/km - requires precision and productivity for the control inspections.

As a result, specific control solutions have been developped on the NRL project to inspect and monitor the breakwater after its construction.

Figure 1—Typical concrete armour units used on the project NRL

The NRL project lies in La Reunion (Indian Ocean). It is due to replace the current coastal road, which was built at the foot of a 100m height cliff. Indeed, after heavy rainfalls, rocks are falling from the cliff. The road is also usually closed during storms as the road is submerged by the sea on one side, and by rainfalls on the cliff side.

The objective of the project is to build a new road at sea to secure this vital economical axis between the cities of Saint-Denis - the island capital - and La Possession.

The road is positioned on several breakwaters built by GTOI (Bouygues), SBTPC and VCT (Vinci) with a total lenght of 6.7 km (Phase 1 + Phase 2). They are coupled with a 5.4km bridge at sea.

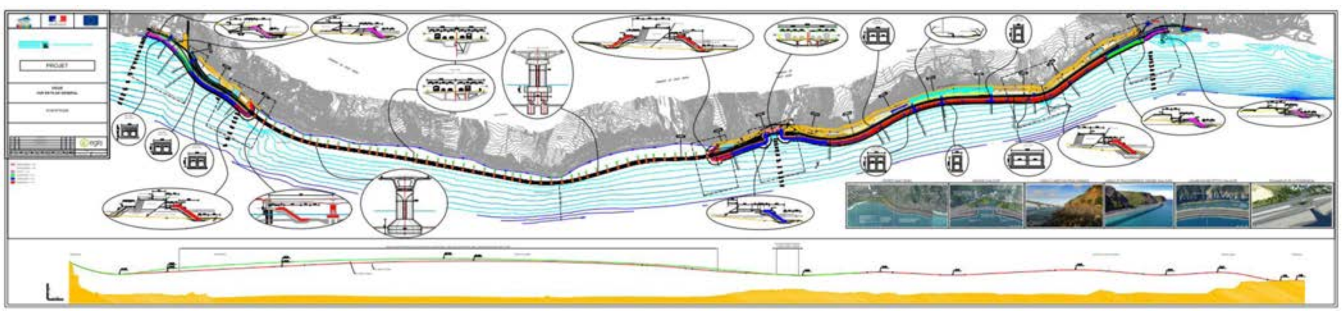

Figure 2—General overview project NRL

Figure 3—NRL dike D1

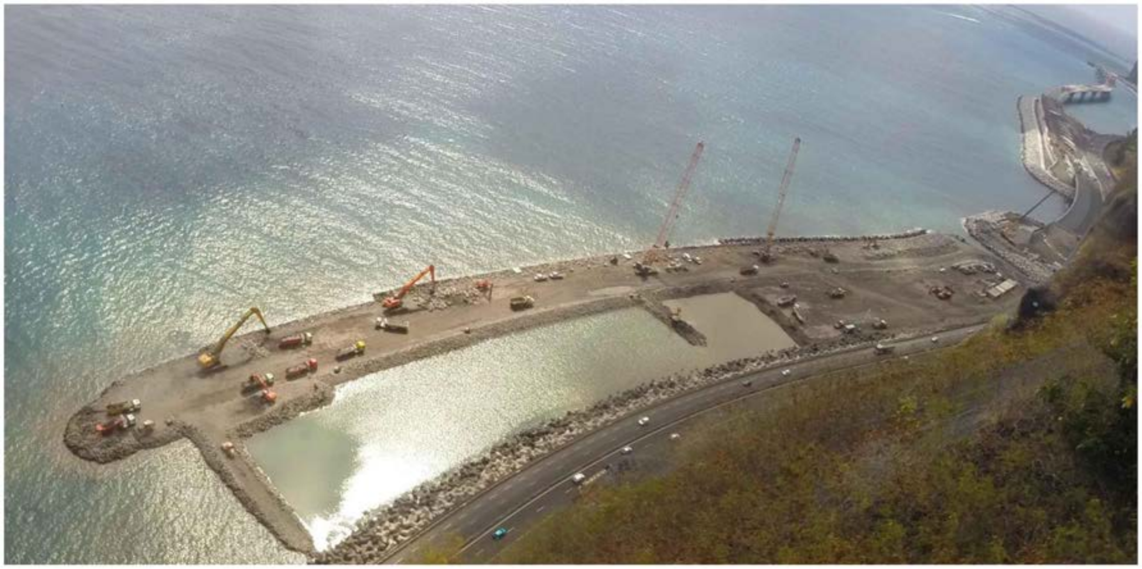

Figure 4—Dike D3 under construction

For such projects, subsea controls after the completion of the breakwater are usually relying on inspections by diver which are :

- Difficult to analyze and not accurate – indeed, divers do not have any subsea positionning system so the inspection needs to have a starting point marked on a subsea tablet and a pre-planned inspection path couting the number of blocks. This method requires a lot of post-processing video analysis by the offline surveyor in charge of identifying the blocks and evaluate their conformity. He needs to manually correlate the high resolution bathymetry with the video to identify the blocks being observed at any time of the video.
- Cost consuming – the observed mean productivity of a seawall diving inspection is of 110ml per day with a team of 3 commercial divers from diving vessel with a cost of 2 500€ per day.
- Potential risky activities

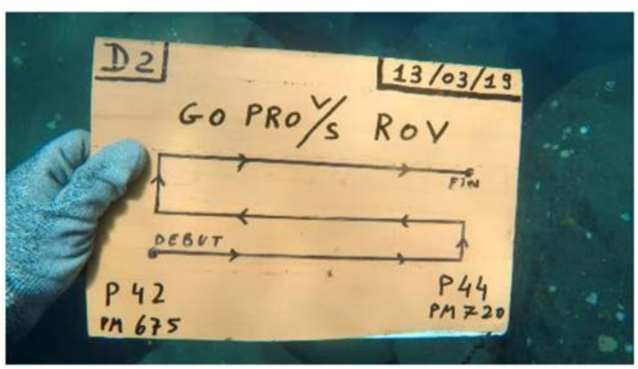

Figure 5—Georeferencing slate – diver seawall inspection

As a result, an innovative robotized method has been developped on the NRL breakwaters to develop a more economical, more accurate and safer way to inspect coastal protections made with concrete armour units. This was developed in a partnership between NRL consortium - GTOI, SBTPC and VCT - and ID OCEAN, a local subsea engineering and ROV survey service provider.

Methods, Procedures, Process

The innovative solution implements a low-cost mini professional-grade ROV (Remote Operated underwater Vehicle) from BlueRobotics – the BlueRov II, to provide a HD 1080p video inspection of the dike. The presence of divers is not necessary at all for the inspection procedure. The ROV is fully vectorized with 8 thrusters to be compensated in depth, heave pitch and roll at all time in order to provide the most stable video possible even with a small swell. The ROV was successfully tested in open-seas conditions and very shallow water (0 to 10m water depth) with sea conditions up to 1 knot current and sea state 4.

Figure 6—ID OCEAN mini-ROV on NRL seawall inspection

To get the position of a ROV underwater, a USBL (Ultra Short BaseLine) positioning system composed of one surface transducer receiving the echo from an acoustic modem mounted on the ROV is used. Nonetheless, this traditional positioning method was tried and did not work efficiently in such a very shallow and highly reflective area. To cope with that, a low-cost SBL (Short BaseLine) system, the Waterlinked Underwater GPS, was used instead. It is composed of 4 receivers located 1m below water and spaced of 2m between each receiver that triangulate the signal received from the locator on the ROV base on amplitude difference. The SBL system is coupled with a SBG Ellipse IMU to get accurate heading of the vessel. The receivers are not equipped with internal AHRS, this limits the operation of the system to short distances and calm areas. The positioning accuracy in the current setup is estimated to be between 2 and 3% of range. The underwater position is coupled with a RTK GPS (accuracy to the cm) for accurate global positioning.

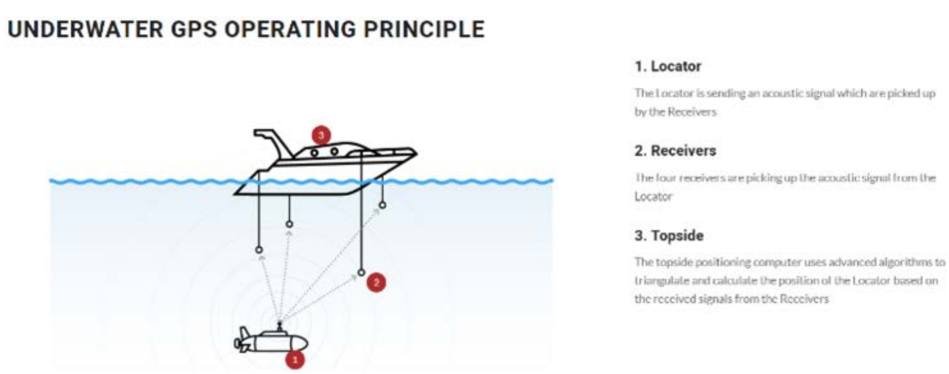

Figure 7—WaterLinked Underwater GPS principle

A specific setup was created by the survey company in order to integrate the receivers on rigid aluminium poles on the survey vessel with the correct spacing and immersion. The locator on the ROV was placed on the rear of the bottom skid so that the position is obtained even when the ROV is inspecting the waterline.

This does not create acoustic mask because the ROV always inspect the dike with the camera facing the wall and the thrusters pushing laterally.

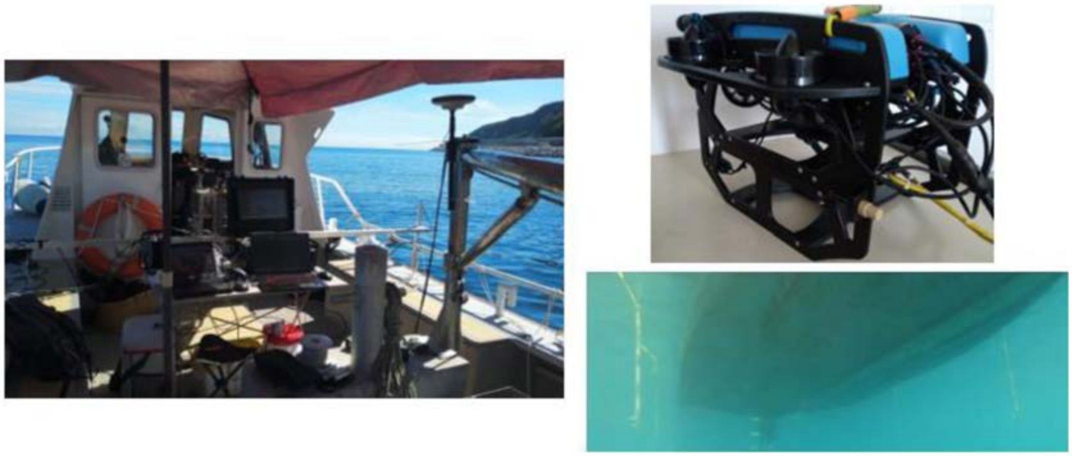

Figure 8—ID OCEAN ROV dyke inspection setup

A dedicated in-house Python code IHM has been developped by ID OCEAN to get the data from all sensors and transform it when necessary in NMEA standard sentences. This data is sent to a subsea inspection real-time overlay software (OV-REC from Delta ROV) and a 2D GIS navigation software on which the theoretical concrete armour unit laying drawing is displaid for real-time positionning and heading.

Figure 9—ROV video from overlay software

As the project already had all the theoretical 3D laying drawings and multibeam high definition survey of the area registred in QINSY Fledermaus, it was decided in accordance with the survey company to develop their system around this interface and integrate the 3D display of the ROV into it.

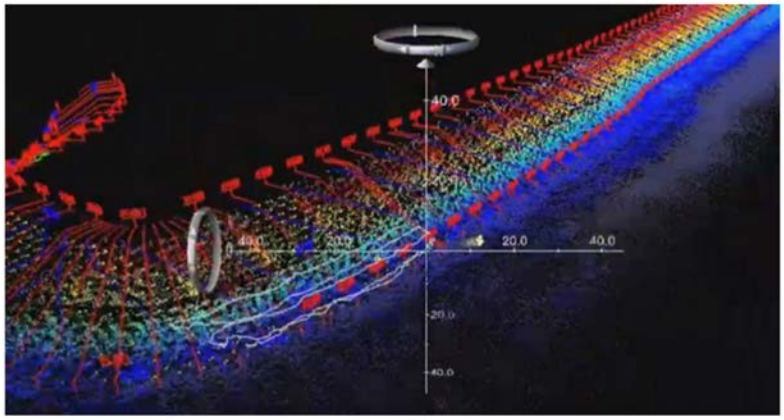

Figure 10—Seawall 3D model in Fledermaus

Once the inspection is completed, the navigation data from the ROV are extracted from the log file generated by the internal computer. The following data is retrieved for post-processing : ROV Roll, pitch, yaw // ROV depth and global position // ROV camera tilt.

A text file is then created with a Python code in the good format to be read by Fledermaus Vessel Manager module. The log file is time-tagged with the corresponding inspection video from GPS data so that the 3D scene exactly matches the video in time. The camera tilt and ROV pitch are combined in order to get a « true tilt » in the 3D viewer. The 3D model of the ROVwas integrated inside the software with an additional line on the front that helps to accurately get the concrete unit that is pointed in the center of the camera at each time.

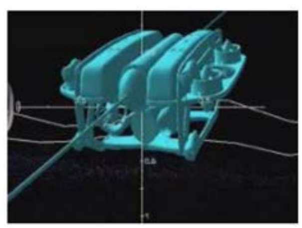

Figure 11—ROV 3D model in Fledermaus

Results, Observations, Conclusions

The first method is to run the video in parallel of the 3D scene and get the exact position of the center video at all time thanks to the created 3D scene then enables three different control methodology.

- pointing line indicating which block and surroundings are being seen on the video. Validation tests were made by the project to confirm the accuracy of the pointing line to the correct block thank to the comparison of the bathymetry on the 3D model and the 3D shapes in the video. All validations trials were compliants.
- The second inspection method for anomaly identification consists in watching the video separately and going to the corresponding time in the 3D scene to check which block is concerned
- The last control possibility is when an anomaly such as an aeration between blocks or a lack of contact is suspected from the full high-resolution bathymetry in the viewer. In that case, the corresponding time in video can be identified from the ROV path time-tag and a subsea control is made directly on the video.

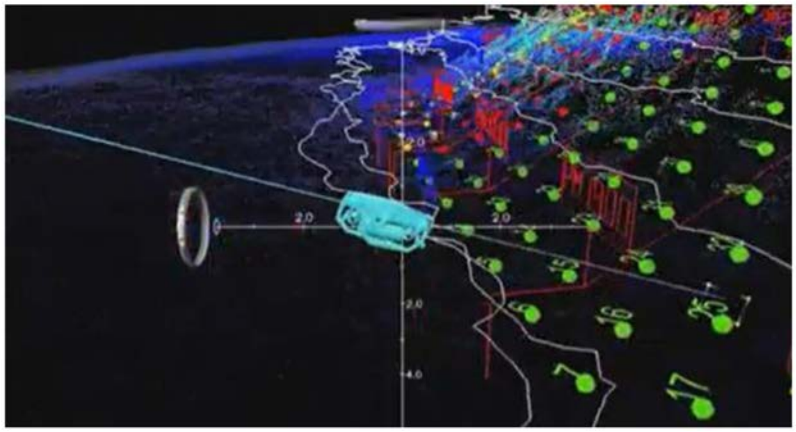

Figure 12—ROV pointing line on a block inside 3D model in Fledermaus

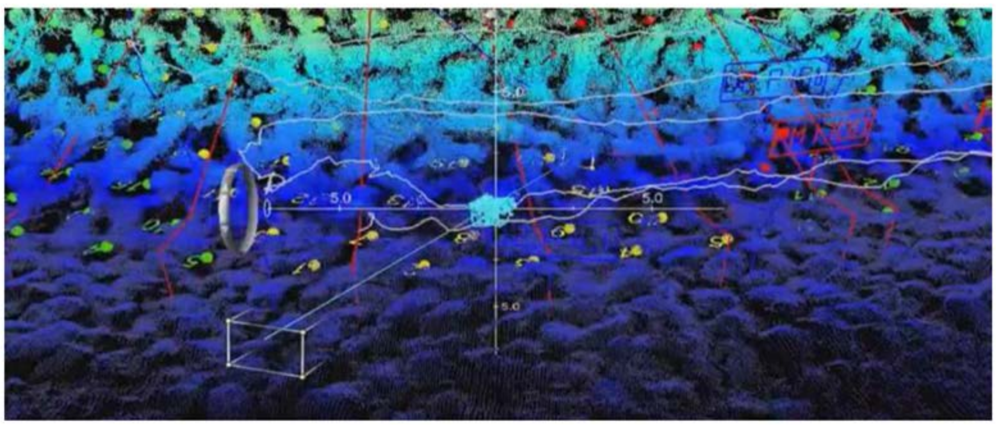

Figure 13—ROV track and full bathymetry display in Fledermaus

Compared to diver inspection, this new robotized methodology enables an accurate georeferencing of breakwater subsea videos. This new tool has enabled the internal control project team to save drastic time on subsea controls as and get a more accurate identification of laying anomalies for fast and efficient intervention, while presenting a user-friendly deliverable to the client.

Methodology improvements

Some improvements of the technology are being developed by the survey company to keep on improving the inspection procedure and deliverables. One project consists in integrating all the WaterLinked Underwater GPS system and required electronics in a stand-alone buoy that can be moored at any location and have a wireless communication to the vessel in order to reduce the required size of survey vessel and be able to survey at any location and water depth. Furthermore, an integration of velocity of sound correction and integration of AHRS inside the locators is expected from WaterLinked developers for the next generation hardware in order to improve accuracy and survey range.

ID OCEAN has also developed a numeric tool called SEABIM that enables to reconstruct a 3D digital twin of the Concrete Armour Units seawall from a high-resolution point cloud.

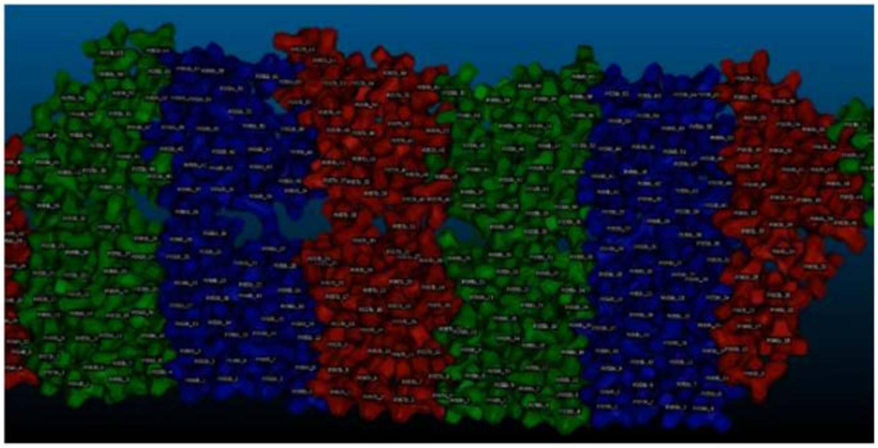

Figure 14—3D model of a dyke portion

The next step is now to integrate this model in the navigation and 3D viewer software instead of bathymetry to get the as-built model in real time during survey instead of theoretical positons. To do so, the EIVA Mobula software for BlueRov2 steering is being tested by the company for its high capacities in 3D real time display and navigation. Indeed, some integration limitations by bugs in timetagging and data importation have been observed in Fledermaus and the Vessel Manager module will not be renewed in the new Fledermaus 8 version.

Another tool developed by ID OCEAN is the waterline reconstruction by photogrammetry from ROV video. Indeed, as there is hardly any tide (50cm average) in Reunion Island, the waterline area can be acquired in point cloud neither by bathymetry nor by UAV photogrammetry. From this photogrammetry, a point cloud is generated and assembled to the bathymetry from recognized shapes on both point clouds. This enables to recognize the 3D shapes in this area to feed in the digital twin.

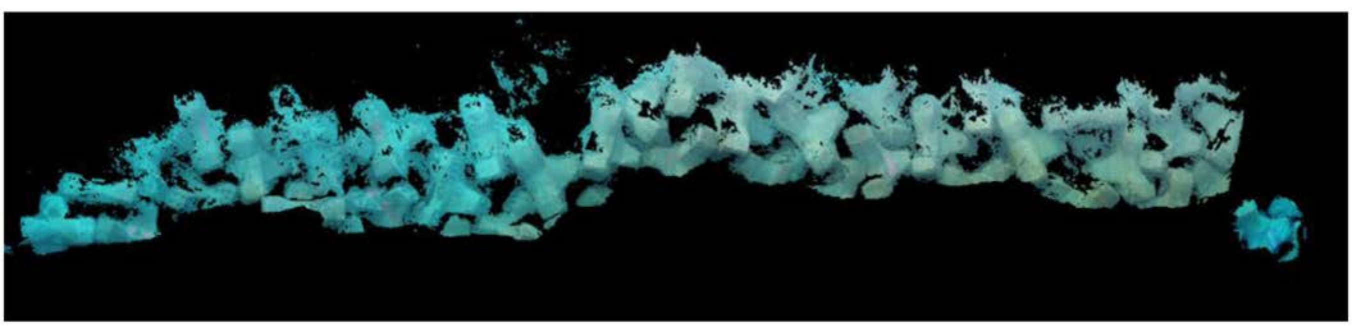

Figure 15—Dyke waterline photogrammetry

Last but not least, the objective of the consortium was to improve even more the inspection process by getting directly the laying number of the concrete armour unit overlaid in the ROV inspection video. In order to do so, ID OCEAN has developed a tool that enables the georeferencing of the inspection camera in post-processing based on the optical sensor instead of acoustic sensor. Once the camera is georeferenced relative to the digital twin of the breakwater, another code is implemented to assign the block number to each element observed in the video. The deliverable is a video with an overlay indicating which accropode is being observed at all time and the digital twin in parallel. This method enables to keep on using the acoustic positioning method only for real time navigation and use the optical sensor for post-processing positioning as this is even more accurate and easier to analyse for the NRL offline surveyor.

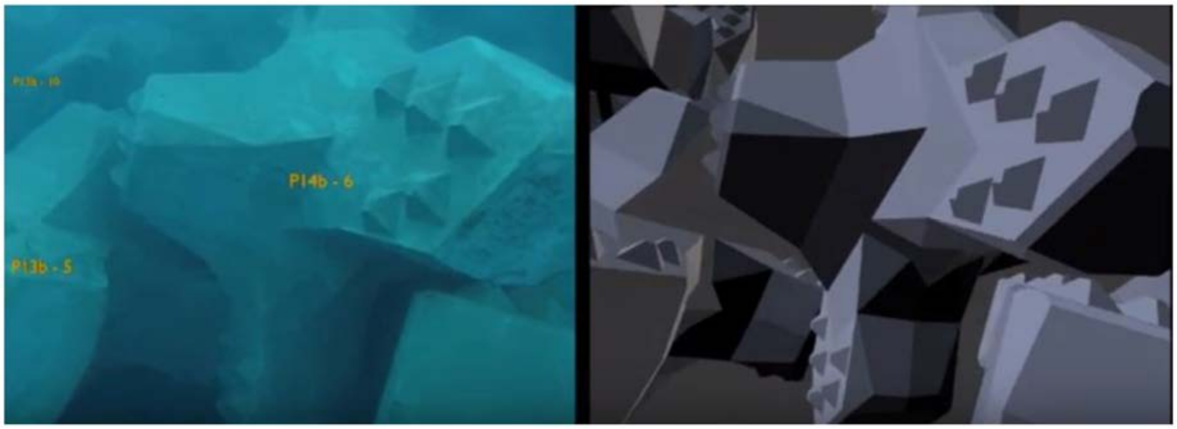

Figure 16—Seawall video georeferencing by optical sensor and numbering of concrete armour unit as overlay on the video

Links

https://www.youtube.com/watch?v=XVnwdQXPQHA – SEABIM – georeferenced subsea video inspection by optical sensor

https://www.youtube.com/watch?v=UrI9rMjVqAY - georeferenced subsea video inspection by acoustic sensor

https://www.youtube.com/watch?v=bxJICeVWSNI&feature=youtu.be – SEABIM – 3D breakwater reconstruction from subsea video