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# Geophysical and geotechnical surveys for submarine cables installations: main applications and methods

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***Abstract* – The industry of submarine cables, both for power connection and for telecommunication (TLC) has experienced growing development in recent years and these assets have become strategic. We describe here the main methods and procedures that are followed during geophysical and geological investigations (site surveys) preparatory to the installation of submarine cables.**

## I. INTRODUCTION

The industry of sub-marine cables offers to geologists the opportunity of exploring very long corridors of the seafloor across a wide range of different, sometimes challenging, geo-morphological environments and settings.
In Italy, for instance, several power and TLC cable connections crossing both continental shelves, slopes and deep basins in the Adriatic and Tyrrhenian seas have been recently designed (Fig.1).

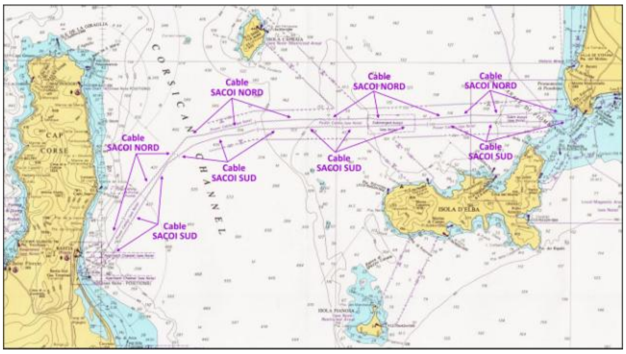


*Fig. 1. SACOI (Sardegna-Corsica-Italia) powerline cable connection operated by Terna SpA, Italy.*

Geophysical and geological investigations are critical for the economy of such projects for several reasons: a) the optimal cable routing is selected in order to minimize the interference with geo-morphological constraints, geo-hazards and human activities; b) a detailed under-standing of the sub-seafloor stratigraphy and geo-technical properties is necessary in order to choose the best burial technology during the laying of the cable and reduce operational risks; c) the geo-morphological information, implemented with oceanographic and biological data are essential for habitat definition and thus for environmental analysis.
Generally, the entire survey work includes a first, pre-engineering (mostly geophysical) survey covering a relatively wide corridor followed by a more detailed survey along first appraisal cable routes. This second pre-lay survey includes geophysics, geotechnical samplings and further visual and acoustical inspections through a Remotely Operated Vehicle (ROV).

## II. HYDROGRAPHIC AND GEOPHYSICAL SURVEYS

Generally pre-lay surveys are carried out along already established routes and include swath bathymetry with Multibeam Echosounders (MBES), Side-Scan-Sonar (SSS), high-resolution seismics, sub-bottom profiling and magnetometry. Physical measurements of the water column and currentometry are usually carried out through Conductivity/Temperature/Depth (CTD) probes and (Acoustic Doppler Current Profiler (ADCP) systems. Positioning of each sensor is ensured by Differential Global Positioning System (DGPS) with Real Time Kinematic (RTK) correction in near-shore areas and accurate metrology of the vessel offsets. Hull-mounted transducers (e.g. MBES) provide a higher accuracy (in the order of dm in shallow water) with respect to towed sensors (e.g. SSS tow-fishes and magnetometers) which are positioned through Ultra Short Base Line (USBL) subsea methods.
In shelf areas (< 200 m) swath bathymetry is acquired through medium-high frequency (200 - 400 kHz) MBES whose resolution is typically depth-dependent due to the geometrical spreading of the

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acoustic footprint. In near-shore areas, MBES footprints allow for high redundancy soundings per square meter, resulting in Digital Terrain Models with even dm-scale cell size. Such very high resolution DTMs are currently used not only for bathymetric purposes but also for checking SSS data positioning and assisting in target detection, which is one of the main tasks of the pre-lay survey (Fig.2).

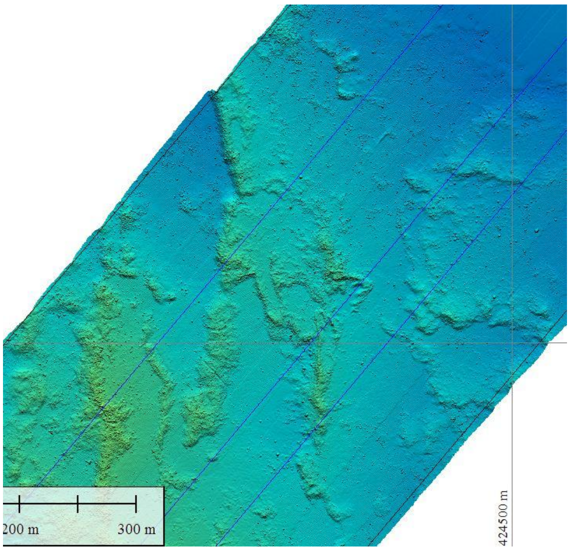


*Fig. 2. Example of high resolution DTM (0.25m cell size) of a glacial Till outcrop (Baltic sea offshore Germany).*

Side Scan Sonar systems generally adopt double frequency (e.g. 300 to 600 kHz) tow-fishes, which travel at a fixed altitude (e.g. 5 to 10 m) above seafloor, thus allowing maximum resolution regardless of water depth (Fig. 3).
Despite lower accuracy in positioning SSS still represents the most powerful tool for acoustic target detection because it can obtain cm-scale resolution and provide insights into the nature of the object (e.g. hard, soft etc.) based on the strength of the backscatter energy. This last parameter is also very important for classifying seabed depositional settings and sediment grain size.

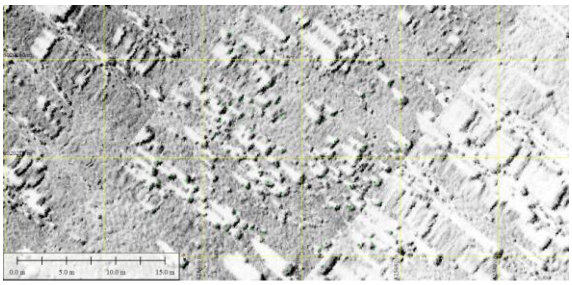

*Fig. 3. Example of SSS mosaic (600z) in a boulder field area close to area of Fig.2.*

The Sub-surface stratigraphy is acoustically explored through sub-bottom profilers (SBP) which use single (e.g. 3.5 kHz) or modulated "Chirp" (e.g. 1-12 kHz) frequencies (Fig. 4). In recent years, the introduction of parametric transducers has largely improved the focusing of the acoustic beam, thus allowing a better spatial resolution. Penetration attained by parametric SBP is largely dependent on sea-bottom nature and may vary from 50 m, in the case of relatively soft sediments (e.g. silts, clays) to a few meters for coarse, deposits (e.g. gravel) to even null for bedrock. In case of fine-grained sediments, vertical resolution is in the order of 10 cm, which is largely sufficient for exploring the uppermost 5-10 m of the stratigraphic succession that is the common target depth for cable lay surveys. SBP are less effective for the detection of buried sub-metric object due to the limits imposed by spatial resolution, whereas they are very helpful for detecting pipelines or large-diameter cables.

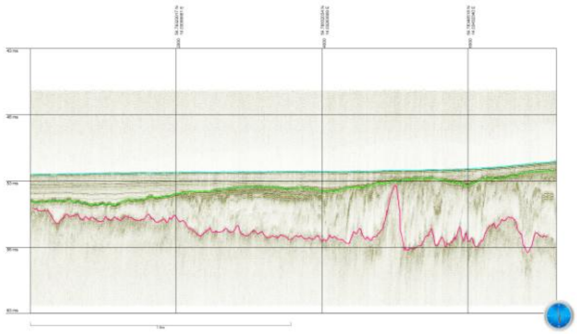

*Fig. 4. Example of SBP record, Innomar SES 2000 parametric sonar (ca. 30 m water depth, Baltic sea offshore Germany).*

In areas where the occurrence ferro-magnetic debris or even Unexploded Ordnance (UXO) is suspected, a high-resolution magnetic survey (using coupled gradiometers) is also required in order to detect all possible obstacle or hazards that may hamper cable-lay operations. Very frequently, a gradiometer system comprising two or more marine magnetometers is used. This system can be coupled to the SSS in tandem tow and operated on all survey lines.
Magnetic survey is very helpful also for detecting pipelines and cables crossing the route, especially if they are buried and cannot be detected acoustically (Fig. 5). Their magnetic anomaly is largely dependent on the pipeline size and in the case of cables, whether they are in service or not.

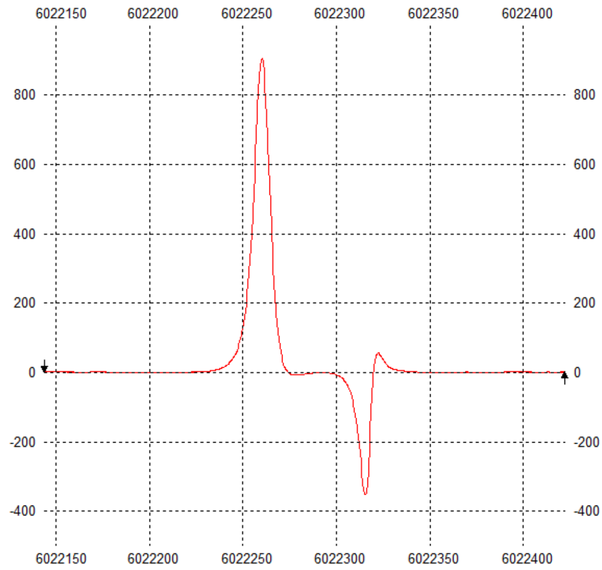


*Fig. 5. Example of magnetic anomaly across two 45" diameter pipelines, note the different amplitude of the response (Baltic sea, offshore Germany).*

## III. GEOTECHNICAL SURVEYS

The burial depth for power or TLC cables is generally variable between 1 m and 3 m, except for from particular cases (e.g. shipping lanes, protected marine areas), where deeper burial is required. Seabed sampling (vibro or gravity corers) and Cone Penetrometer Test (CPT) probes are therefore carried out in the uppermost few meters beneath the seafloor with quite regular spacing along routes. In areas where geophysics indicates a variable stratigraphy the density of sampling can be increased accordingly. The test procedures performed on samples are generally conducted in accordance with the actual standards and in-line with industry best practices. Onboard the sample liner is recovered from the vibro-corer barrel on deck and then cut into 1 m long cores (Fig. 6). In situ thermal conductivity test (TRT) and Sulphate Reduction Bacteria (SRB) are then executed at the base of each 1m cores (Fig. 7).

*Fig. 6. Vibro-corer with 3 m barrel at sea.*

In the laboratory, core samples are split, photographed and visually described according to the standards that include details on the general geology of the study area. Torvane and Pocket Penetrometer tests are then performed, and the results combined with the in-situ SRB and TRT test results and presented in individual VC log sheets.

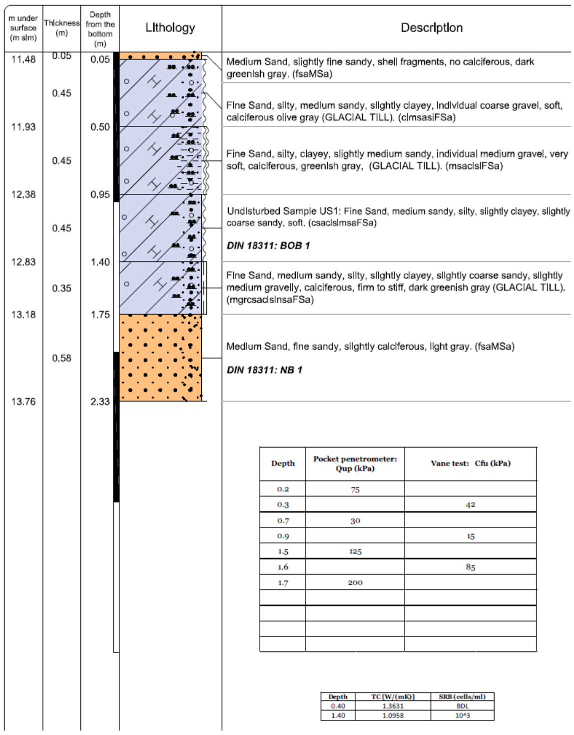


*Fig. 7. Example of lithological log and in situ geotechnical (vane test and Pocket Penetrometer) and bio-physical parameters (Thermal Conductivity and SRB).*

CPT probes are carried out up to 3-6 m penetration. The piezocone projected areas range from 499 $mm^2$ and maximum capacity of 35 kN to 1001 $mm^2$ and maximum capacity of 50 kN for very soft soils. Pore-water pressure is measured on the cone shoulder and the frame/cone inclination recorded during each test.

During CPT data acquisition, the following calculated/corrected parameters are processed prior to the estimate of soil type behavior:

1) Corrected cone resistance
2) Net cone resistance
3) Pore pressure parameter
4) Friction ratio
5) Pore pressure ratio

Cone resistance, friction ratio and pore pressure ratio are then used as a guide to define soil behaviour type during CPT interpretation (Fig. 8). Empirical plots are used as best practice for seabed CPT in the standard industry procedures to distinguish drained (granular soils) from undrained penetration (cohesive soils).

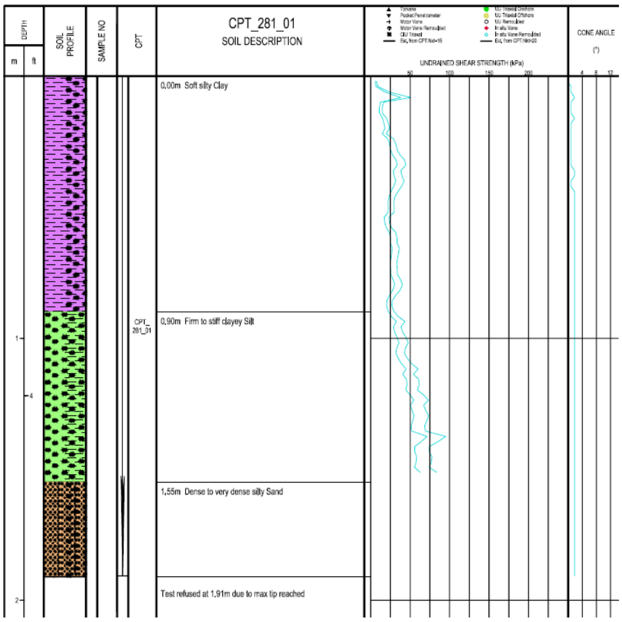


*Fig. 8. Example of CPT log with the processed shear strength. Soft clays above form to stiff and dense sands.*

The consistency terms (Relative density for granular soils and Shear strength for cohesive soils) are based on the following table and it is in accordance with the ISO-DIN standards.

| Term | Relative Density (***Dr*** ) % | Term | Undrained Shear strength (***Su***) kPa |
|---|---|---|---|
| Very loose | 0 – 15 | Very soft | < 20 |
| Loose | 15 – 35 | Soft | 20 – 40 |
| Medium Density | 35 – 65 | Firm | 40 – 75 |
| Dense | 65 – 85 | Stiff | 75 – 150 |
| Very dense | 85 – 100 | Very stiff | 150 – 300 |
| | | Hard | > 300 |

## IV. ROV SURVEYS

ROVs are commonly employed in the latest stages of the survey for several purposes including: 1) Visual inspections of previously recognized acoustic targets or natural, potentially hazardous features (e.g. pockmarks outcrops, scarps); 2) In-situ geophysical survey with sensors fitted to the ROV e.g. MBES, SSS, SBP; 3) Detection of buried or exposed cables or pipelines crossing the designed route by cable or pipe trackers that recognize the induced electro-magnetic field; 4) Removal of small debris or objects away from the cable route corridor by work-class ROV equipped with manipulators. The main advantage of ROVs survey, apart from visual inspection, is the proximity to the target, which greatly improves accuracy and detection power (Figs. 9 and 10).

*Fig. 9. Work-class ROV fitted with cable tracker.*


*Fig. 10. Image of marine growth (sponge) during ROV visual inspection. Dardanelles strait, November 2015.*

## V. GEOLOGICAL MODEL

The construction of a geotechnical profile necessary for the burial assessment must be guided by a geological model of the stratigraphic setting which takes into accounts background information, scientific literature, geophysical (seismic stratigraphy, sea-bed classification) and core samplings results (Fig. 11).

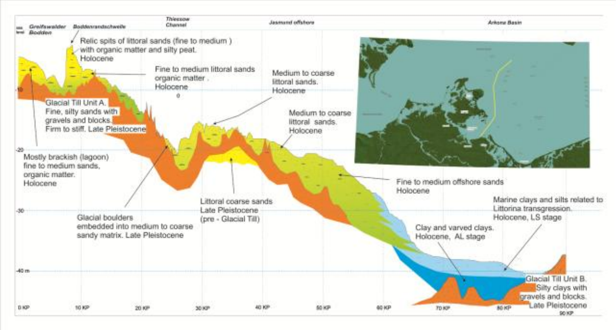


*Fig. 11. Geological section along a 80 km cable route connecting an offshore windfarm off Rugen island (Baltic sea, Germany).*

## VI. DELIVERABLES

The results of the entire survey are reported in the frame of narrative reports, digital and paper charts, media (video, photo) and sample data analyses. Usually charting includes a set of North-Up charts issued at appropriate scales (generally from 1:1.000 to 1:5.000) that cover with sufficient detail the entire corridor and another set of Alignment Sheet charts, which are oriented along each rectilinear section of the cable route.

Charts are implemented with geological profiles resulting from the interpretation of geophysical and geotechnical data, integrated with lithological, and CPT logs. All data are then synthetized by engineers who have to decide the best-fit technology for cable burial for each section of the route, depending on the type of soils (e.g. jetting for relatively loose sediments, mechanical trenching for very stiff soils). This “burial assessment” profile has to take into account geological constraints (e.g. hard soils or bedrock) and main geotechnical parameters, notably shear strength for cohesive soils, relative density for granular soils and liquidity limits for sands.

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