A combined *up the hole* Drilling/CPT equipment for near-shore site investigation

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ABSTRACT: Drilling and CPT operations in off-shore investigation campaigns are normally carried out using geotechnical vessels equipped with wire-line core drilling technology together with a *down-hole* CPT system (i.e. Wison). This paper describes a simple but efficient and robust alternative for drilling/CPT investigations in near-shore environments, where jack-up platforms can be used, by means of a combined *up-hole* (deck) system, called TOTEM, a new in-house development. Spanish practice is also reviewed and reference made to the results obtained from underwater piezocones and *up-hole* tests from a jack-up platform.

1 INTRODUCTION

Historically, geotechnical exploration campaigns in Spain were based on rotary soundings with continuous core extraction with SPT and undisturbed sampling.
However, since the Eighties, an increase in public investment in infrastructure has encouraged the application of new site investigation techniques that, combined with existing techniques, gave rise to what is referred to subsequently as Spanish GI Practice.

This report summarises this exploration methodology and describes its adaptation and the development of in-house equipment for use in complex situations such as marine geo-technological projects.

2 BRIEF HISTORICAL CONTEXT

Since 1974, (Decree 2215/1974, July 20th), Spanish legislation controls the activities of organisations and laboratories of quality control for the building industry. The required criteria and conditions are specified, and so, too, are the procedures and methods of inspection and recording to be used in the activity, as well as the availability and capacity of personnel, equipment and other resources. In the case of laboratories, there is also regulation of the required technical and environmental conditions for the facilities where the activity is carried out.

Accreditation is mandatory for any geotechnical study carried out for the building industry. In practice, it is also a requirement of most public and private tender specifications for civil engineering projects such as railways, roads, ports etc.

3 CURRENT SPANISH GI PRACTICE

3.1 *Drilling equipment*

Spain has a thriving and well-developed industry for the manufacture of driling machinery and core barrels, drilling bits, rods, mud pumps, etc. The design and production of equipment for geotechnical investigation is particularly advanced and is fully adapted to meet the demanding standards of the current norms. All equipment allows rotary drilling and is manufactured with an automatic drive device for the SPT test and/or percussion sampling; units can be deployed as a trailer or be self-propelling, and are mounted on wheels, skids or tracks. Figure 1 shows an example of a self-propelling wheel-mounted geotechnical drilling rig. This particular rig is a combined CPT/drilling rig with independent pushing equipment, following a design developed by the authors that has proved particularly useful in Spain.

Figure 1: Wheel-mounted geotechnical drilling rig.

The units just described are basically intended for on-shore work. However, with certain modifications, they can be easily adapted for near-shore investigations operating from the deck of a jack-up platform. Figure 2 shows an adapted track-mounted drilling rig in action from a jack-up platform deck.

Figure 2: Adapted on-shore track-mounted geotechnical drilling rig working from jack-up deck

3.2 *Core-barrel rotary samplers and undisturbed samples in borings*

Unlike other countries, in Spain it is a matter of standard and accepted practice to carry out rotary drilling with continuous core extraction, within which different types of undisturbed samples are taken as well as SPT and other types of geotechnical in situ tests are carried out. The most commonly-used core sample tubes are manufactured according to ISO norms (simple, double and triple). Core sample diameters of between 132 and 32 mm can be obtained with maximum borehole diameters of 146 mm.

Fixed piston samplers (Shelby , Osterberg, etc.) are sometimes employed for soft soils. However, a large percentage of Spanish sites include layers that are unsuitable for this type of sampling because of high stiffness, the presence of hardpans, large gravelly fractions…. The use of a thick-wall sampler and a dynamic drive procedure similar to SPT has then become common practice for "undisturbed" sampling, even in cases where piston pushing might have been more appropriate. The quality of those driven samples is inferior to the piston retrieved ones and it is therefore necessary to take into account the extraction method when results are being interpreted.

3.3 *In situ test practice*

Use of *in situ* tests as opposed to drilling (with the exception of SPT) remains uncommon (estimated at about 5-10% of all geotechnical projects) due, in part to the geology of the Iberian Peninsula where soft soils usually only occur in river basins, lake areas, deltas and marine environments.

Characterisation of soils and, in particular, soft soils, is the area in which the greatest advances have been made in recent years with the introduction of static penetrometers in Spain (around 20 years ago) to which other *in situ* techniques have gradually been added including dilatometers and pressure-meters (PBP), vane-test (FVT), Marchetti Dilatometer (DMT), etc. in accordance with specific regulations (UNE, XP, ASTM, EN-ISO, etc.). More details on the practice and usage of CPTu testing in Spain can be found in the national Report submitted to this Conference.

4 NEAR-SHORE UP-HOLE DRILLING/CPT

4.1 *Introduction*

The Spanish coast stretches for more than 4,900 kilometres and is strategically located with regard to Europe, the near East and North Africa. Port and harbour activity has therefore acquired great importance and, with it, the development of marine geotechnics. Over the last ten years, port development in Spain has given rise to important investment in marine geotechnics and the associated specialisation in the area by domestic companies.

To best cope with the site investigation demands associated with such developments, the authors have developed a combined *up-hole* core drilling/CPT work methodology based on three basic criteria:

- robustness, simplicity and manoeuvrability of the equipment
- versatility to enable different tests to be carried with a single maneuvering tool
- adaptation and specialisation for work in the marine environment

This philosophy has led to the development of a cost-efficient customised equipment that allows near-shore campaigns to be carried out while meeting demands for high quality results and also achieving notable reductions in operation time, with the associated reductions in cost. The system thus developed has been baptized as TOTEM and it is described below.

4.2 *Specific constraints of near shore geotechnical investigations*

This section explains the specific constraints associated with near-shore geotechnical investigations, where the depth of water allows work to be carried out from auto-elevating jack-up type platforms. The need to work within such constraints underpins the newer developments described afterwards.

In marine areas with low water depths (<30-40 m) the geotechnical investigation campaigns are mainly intended for port infrastructure developments where the objective is the acquisition of the greatest amount of data in a limited time period, time being a limiting factor in such projects. One common practice for this type of investigation is to carry out wire-line core drilling, a system whose virtues include the ability to achieve relatively great depths (up to around 1,000 m) with high level production (around 100 m/day).

However, the majority of near-shore geotechnical campaigns do not require such depths; it is unusual for them to reach more than 50 to 60 metres below the sea bed. Another usual requirement for this type of campaign is to perform in situ tests and/or high quality undisturbed sampling at regular intervals within the borehole. Ensuring quality, both in sampling and in coring is one of the basic conditions that influence campaign design.

In such a context, the wire-line technique loses its competitive edge as depth of survey and drilling speed are relatively less important factors at lower depths. Based on our own experience with both methods as well as an informal survey of other geotechnical rig operators, we have established the tentative productivity curves illustrated in Figure 4. For depths below 40-50 m the interrupted wireline method has no advantage over up the hole coring (see Figure 4).

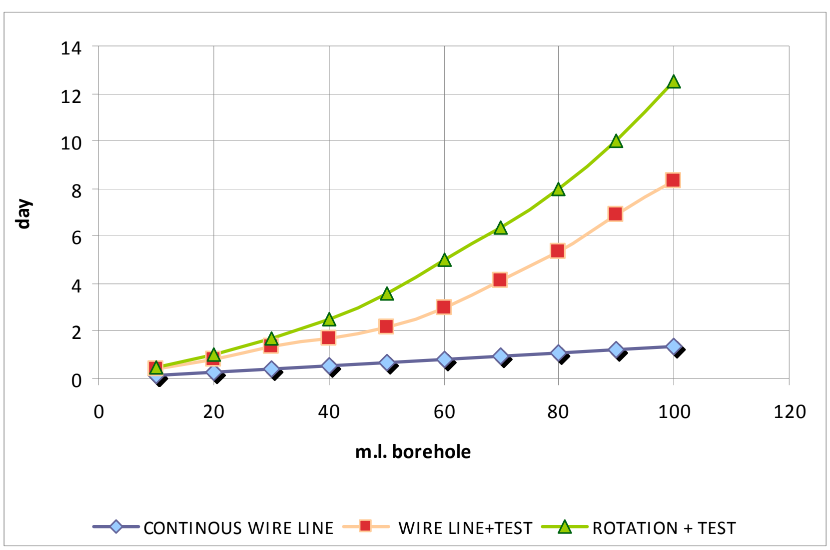

Figure 4: Wire line vs. Rotation system

In this type of GI campaigns, the most common *in situ* test is the CPTu. For off-shore work (where depth of water is considerable) underwater down-hole equipment is available (i.e. Wison system by A.P. van den Berg), as are seabed rigs. However, the later are not always operable in port and harbour areas: it may be necessary to advance a borehole due to the presence of coarse fill blankets, large obstacles like piled jetties might be present, etc.

Working within these constraints, a specific methodology has been developed for work under the following conditions:

- water depths <10-40 m
- possibility of surface fill and/or interbeded hard layers (i.e. drilling through)
- survey depths under 60 m (from seabed)
- high quality core and undisturbed samples
- in situ testing (cptu, fvt, dmt, pbp, etc.)
- versatility and optimisation of equipment in order to reduce campaign time

4.3 *Description of TOTEM equipment*

This equipment was designed and developed by Igeotest R&D department to perform all types of static-drive marine geotechnical surveys (CPTu, DMT, SCPTu, SDMT and CPM). The equipment is controlled from the surface from a jack-up style platform. It is particularly recommended for use in conjunction with conventional drilling equipment. The whole survey is carried out using the drilling machine. It permits borehole drilling and sampling and CPTu (or other pushed tests, like DMT, SDMT…) to be performed at a single point without repositioning, thereby increasing speed and manoeuvrability. Figure 5 shows a diagram and picture of TOTEM adapted to conventional survey machinery.

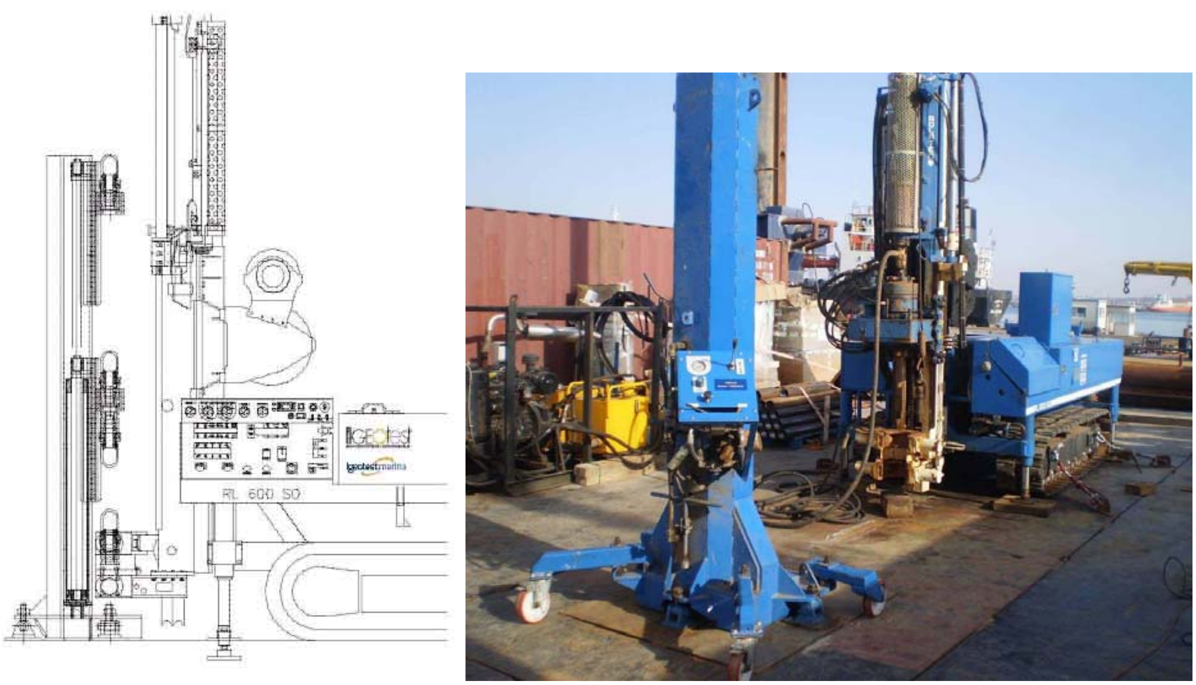

Figure 5: TOTEM adapted to conventional survey machinery.

The TOTEM system consists of a single heavy duty hydraulic cylinder with a 200 kN thrust capacity which is anchored to the jack up deck. The system is independent from the drilling rig but uses the same power pack by means of fast-on couplings. Once the CPT ram is positioned in the vertical of the casing, the CPT cone and rods are downloaded to the borehole bottom in sections of 3 to 6 m, thus diminishing maneuver time. When CPT is finished, the rods are also uploaded with the drilling rig winch.

4.4 *Other CPTU testing details*

For CPTu tests, the equipment is fitted with NOVA RW (Geotech AB) 10 cm^2 type electronics in order to carry out of CPTu surveys without cables. This improves manoeuvrability and reduces the risk of breakdowns.

The tests are carried out from the platform deck, in the interior of an special casing to avoid rods from bending. The rest of the methodology is similar to the standard CPTU.The survey is controlled from a mobile office which is fully equipped with all computer and electronic facilities necessary for the management, processing and dispatch of results.

4.5 *Interpretation and comparison with seabed system*

When it comes to interpreting up-hole survey results, it is important to know the starting conditions of the test in terms of: seawater page, initial depth from the seabed, zeroed, tide…

Common practice is to zero the sensor at deck level allowing for easier control by the operator, thereby avoiding errors and possible decalibration of the cone. The parameter readings taken in these conditions should be corrected as they differ from those obtained from underwater equipment due to the hydrostatic presure. The overload effect is particularly relevant in cases where the water column exceeds 30 m. The correction factors a-net and b-net vary in each case and should therefore be calculated before the results are interpreted (see Equation 1 and 2 below):

$$qt = qc + [1-(a-net)](u2) \qquad (1)$$

$$fst = fs - [1-(b-net)](u2) \qquad (2)$$

Figure 6 shows a comparative for a survey carried out using the TOTEM equipment from a jack-up style platform with a 30.0 m waterdepth and 55.0 m survey depth (from seawater level) and other carried out with a seabed system, both in the same area in the Mediterranean Sea.

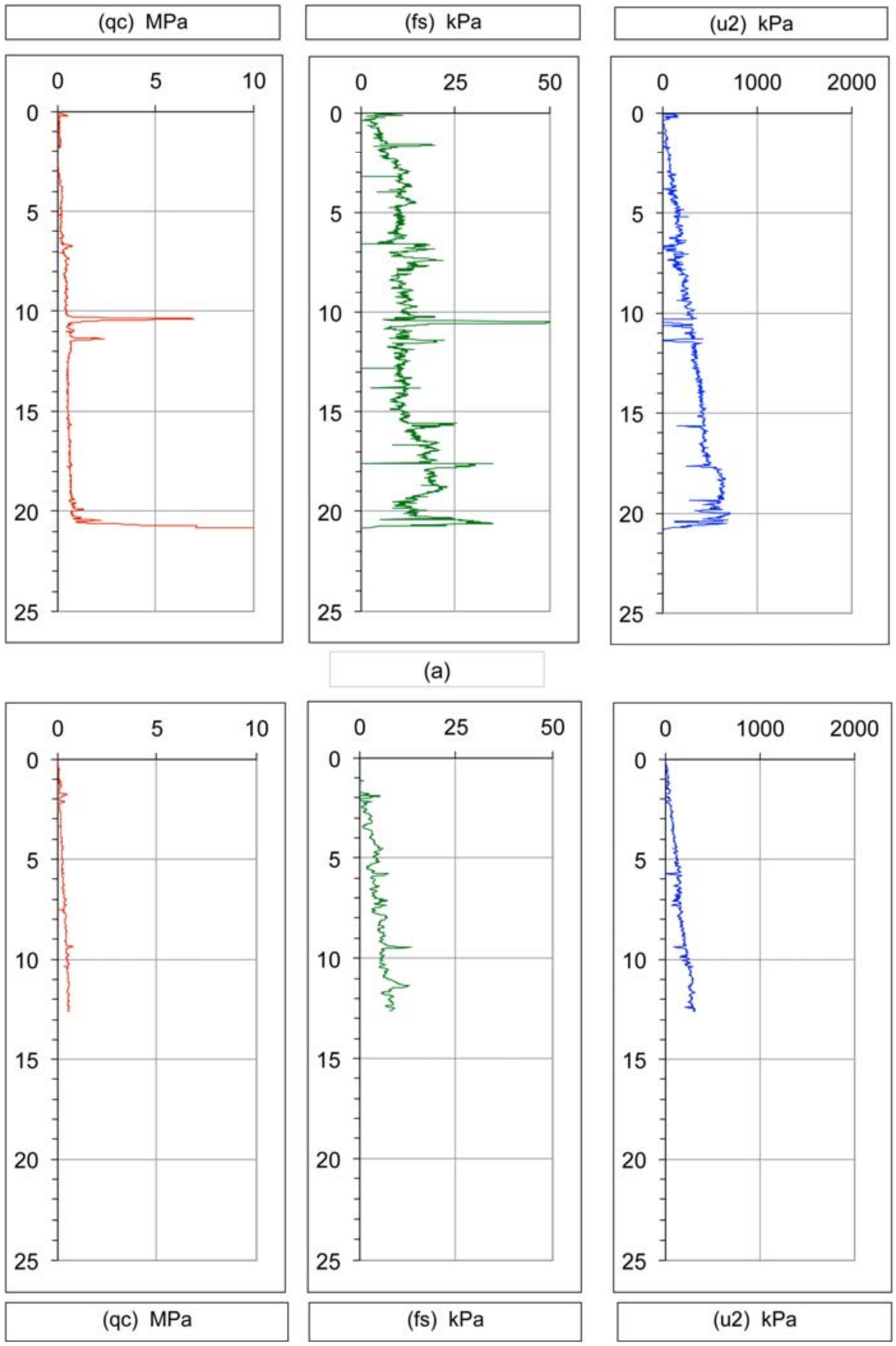

Figure 6: CPTU test carried out using *up hole* system TOTEM (a) and seabed system (b)

5 CONCLUSIONS

Near-shore geotechnical survey campaigns, where continuous coring, sampling and in situ testing are required present very specific challenges to combine high quality results and high productivity. We have described here a solution in which basic elements from Spanish current GI practice have been combined with newer developments such as the TOTEM system. This combination has offered optimal results in circumstances where the deployment of more complex marine depth equipment seems unjustified. The equipment is particularly beneficial where the combination of CPTU and borehole coring and sampling is required.

Special attention must be paid to the up the hole or down the hole zeroed of cone in order to apply the proper correction to account for hydrostatic effect.

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