Qualification of TUBA® system for Ménard Pressuremeter tests under the ARSCOP program

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ABSTRACT: The program ARSCOP gives to French geotechnicians the opportunity to analyze the problems encountered during the execution of pressuremeter tests. In order to avoid poor tests in sandy and gravel soils, because of difficulties in maintaining borehole pockets in such soils, Fondasol Company has developed a new system named TUBA® designed to advance casing during drilling with material removal. The lowest element of the casing consists of a slotted tube. After reaching the depth of drilling wanted, the drill rods are removed and the pressuremeter probe takes place in the slotted tube maintained in the soil. The pressuremeter tests are thereafter conducted, from the bottom to the top of the hole, by raising the casing at each depth of test.
The paper presents the system, and then tests carried out with TUBA® in a gravelly, sandy and silty Holocene alluvium experimental site and are compared with a standard method of drilling.

Keywords: TUBA; drilling; Ménard pressuremeter; casing.

1. Introduction

Drilling through superficial soils is often problematic as the soil tends to collapse in the borehole. These collapses jeopardize the displacement of the measurement equipment in the borehole and lead to poor quality results. Over the years, the engineering has progressed and new technologies have been developed. With the introduction of percussion drilling methods, it became possible to drill into any type of soils and rocks. Several casing systems installed while drilling have emerged which enable to maintain the borehole walls. The most widespread is the ODEX system marketed by ATLAS COPCO. It is based on the joint use of a pilot bit and a reamer slightly wider than the external diameter of the casing.

In the case of pressuremeter tests in collapsing soils, the use of a casing system installed while drilling enables to considerably increase their execution speed. Indeed, traditionally, the drilling must be interrupted every 3 to 5 meters, then the pressuremeter tests are performed every 1 to 1.5 meters and then a casing system is set in the borehole.

With a casing system installed while drilling, the first tube is slotted and the borehole is entirely drilled and cased in one time. Then the drill rods are raised back and the pressuremeter probe is moved down in the slotted tube. The pressuremeter tests are performed from the bottom to the top of the borehole without any other manoeuver than the raising of the whole system tubing – slotted tube – pressuremeter probe.

For such an application, the STAF system developped by APAGEO is an adaptation of the ODEX system with a diameter of 64 mm instead of 76 mm [1]. But the current tool in addition to its high price, is often difficult to remove and requires an experimented operator. Moreover, the upwelling of cuttings may hamper the introduction of the pressurematter probe in the slotted tube after the extraction of the drill rods.

Fondasol company has developed a new system of drilling, TUBA®. In the following, we describe this new system and then, we compare this method with a standard method thanks to comparative tests on an experimental site. Both tools TUBA® and STAF systems are in accordance with STDTM (slotted tube with disintegrating tool and mud circulation) method described by the ISO 22 476-4 standard [2].

2. Presentation of TUBA®

The TUBA® is a system of a slotted tube with material removal allowing to perform expansion tests (Fig. 1). It uses a drilling tool common in the drilling industry (generally a rotopercussive cross bit or button bit). The lower part of the tube is sealed to protect the housing of the pressuremeter probe from the cuttings. The connection system consists of a hexagonal rod that can freely penetrates into a tool holder and rotate the drilling tool and therefore allows fast manoeuvers. The diameter of the casing is 63 mm and the diameter of the drilling tool is 66 mm according classical Menard pressuremeter test.

Figure 2 shows the slotted tube and the drilling tool. The hexagonal drill rod passes through the slotted tube and is connected to the drilling tool.

3. Tests on an experimental site

3.1. Site description

The experimental site is located near the city center of Strasbourg. According to the geological map (Figure 3), the soil is composed of gravelly, sandy and silty

Holocene alluvium. From a topographic point of view, the site is nearly flat.

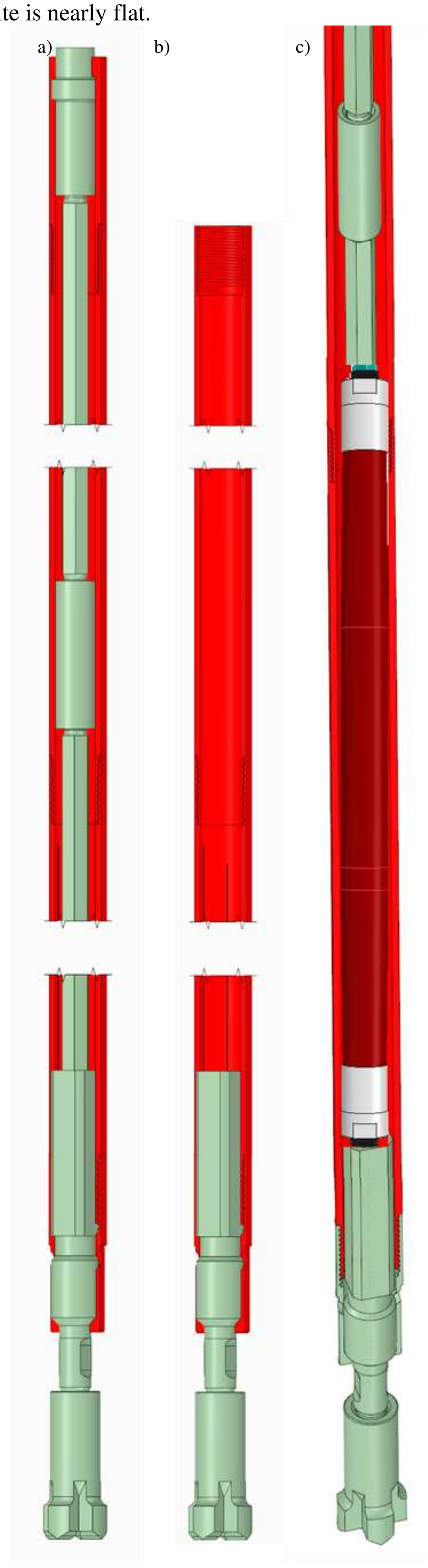

Figure 1. TUBA® system. a) The borehole is carried out and the casing is advanced while drilling. The lowest casing is slotted. b) At the end of the drilling, the drill rods are removed. c) The pressuremeter probe is moved down in the slotted tube and the pressuremeter test is performed. At the end of each test, the whole system is raised up to the next test location.

Figure 2. TUBA® system on a drilling machine.

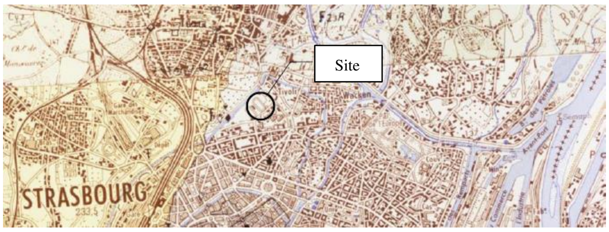

Figure 3. Site location.

3.2. Program performed

A drilling team of Fondasol carried out in March 2019, 13 boreholes to a depth of 15 m or 20 m (Table 1). A total of 187 pressuremeter tests were performed every 1 to 1.5m according the ISO 22 476-4 standard. In 9 boreholes (S1, S2, S4, S5, S6, S8, S9, S11 and S13), a slotted tube has been driven without ground displacement (RPM method). In the other 4 boreholes (S3, S7, S10, S12), the TUBA® system (STDTM method) was carried out. S3 was discarded due to a failure in the procedure. Figure 4 shows the map layout of the experimental site.

The length of the central measuring cell of the probes l_c is given in Table 2, as well as the outside diameter of the probes d_{ci} and the outside diameter of the slotted tubes d_{ct}. Table 2 also provides the calibration parameters: the inside diameter of the calibration tubes d_c, the volume loss factor a, the volume obtained in the volume loss calibration test Vp, the original volume of the central measuring cell Vc and the ultimate pressure loss p_{el}.

Figure 4. Map layout of the boreholes where pressuremeter tests were carried out.

Table 1. Program carried out.

BH	Type of procedure/equipment	Total depth (m)	Number of tests performed
S1	RPM	20	16
S2	RPM	15	13
S3	RPM	20	16
S4	TUBA	15	13
S5	RPM	15	13
S6	RPM	20	16
S7	TUBA	20	16
S8	RPM	15	13
S9	RPM	15	13
S10	TUBA	20	16
S11	RPM	15	13
S12	TUBA	20	16
S13	RPM	15	13

Table 2. Probes characteristics.

Probe	d_{ci} (mm)	d_{ct} (mm)	l_{cs} (mm)
RPM	44	60	210
TUBA	44	63	210

Probe	d_c (mm)	a (cm³/MPa)	Vp (cm³)	Vc (cm³)	p_{el} (MPa)
RPM	65	0.99	195	502	0.48
TUBA	68	2.04	234	529	0.35

3.3. Results

Globally, the quality of the pressuremeter tests is good, their interpretation was easy and few probes burstings happened. Figure 5 shows an example of a pressuremeter curve obtained with the TUBA® system.

Figure 6 and Figure 7 introduce the Menard moduli E_M and the net limit pressures p_{LM}* calculated for all the pressuremeter tests. These two parameters globally increase with depth in every borehole. The investigations have enabled to identify, under a layer of embankment and silt, a layer of sand which density varies from loose (p_{LM}*<0.5MPa) to very dense (p_{LM}*>2MPa) (Figure 8). The only layer that has a sufficient number of measurements for a statistical analysis is the layer of very dense sand. Therefore, only this layer is taken into account in the following.

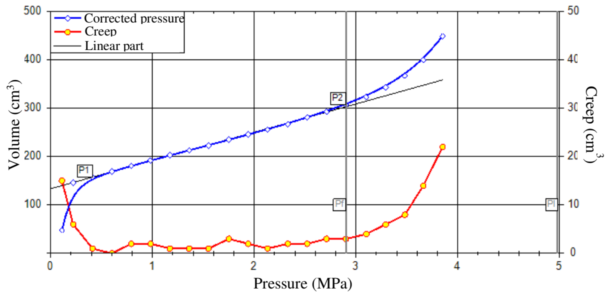

Figure 5. Example of a pressuremeter test performed with the TUBA system at 14.5m depth in the borehole S12 in the layer of the very dense sand.

For the TUBA® system, a total of 35 values of E_M and 25 of p_{LM}* were used for the statistical analysis. These numbers raised up for the standard procedure to 95 values of E_M and 76 of p_{LM}*. The results of the statistical analysis are gathered in Table 3. It can be seen that the two methods give very similar results in terms of Ménard modulus (42.6 MPa for the standard procedure and 41.9 MPa for the TUBA® system) and net limit pressure (4.2 MPa for the standard procedure and 4.1 MPa for the TUBA® system). The standard deviations are quite high especially for the Ménard modulus but they are very close to each other (20.3 MPa for the standard procedure and 18.1 MPa for the TUBA® system). Concerning the standard deviations of the Ménard net limit pressures, it appears that they are somehow exactly equals (1.3 MPa).

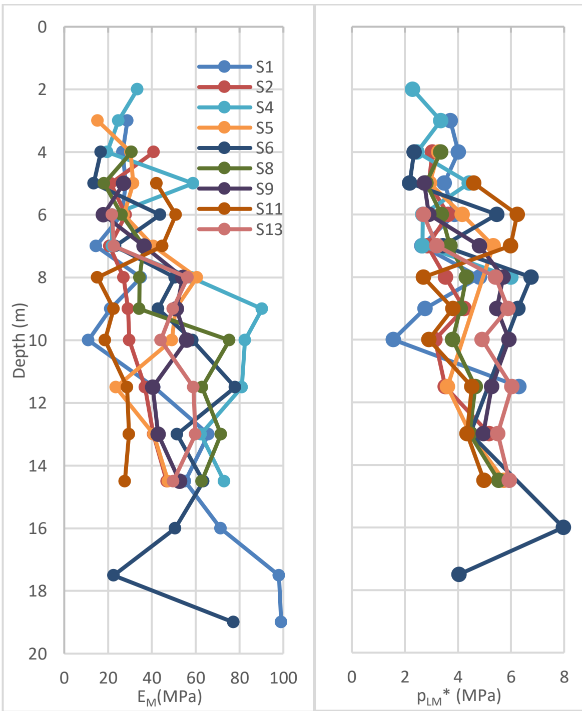

Figure 6. Menard moduli (E_M) and net limit pressures (p_{LM}*) inferred from the pressuremeter tests performed using the Driven Slotted Tube procedure (RPM). Only the measurements that are used in the statistical analysis are represented.

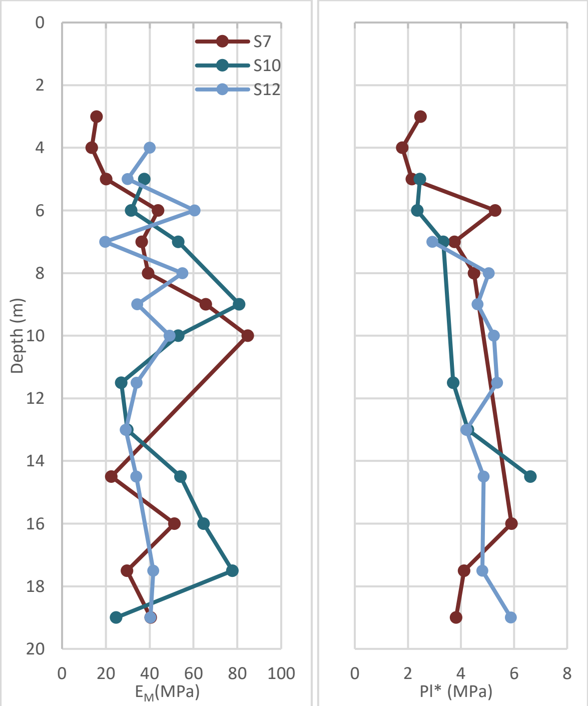

Figure 7. Menard moduli (E_M) and limit pressures (p_{LM}*) inferred from the pressuremeter tests performed using the TUBA® system. Only the measurements that are used in the statistical analysis are represented.

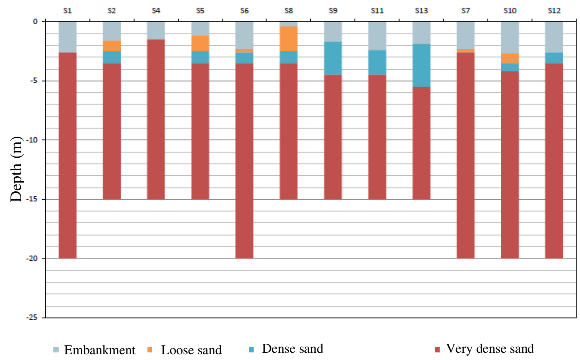

Figure 8. Synthesis of the lithological. Only the layer of very dense sand (p_{LM}*>2 MPa) had a sufficient number of values to carry out a statistical analysis.

Table 3. Average values of Pl* and EM between in the layer of very dense sand.

	μ_{Pl*}	σ	μ−σ	μ+σ	μ_{EM}	σ	μ−σ	μ+σ
DST	4.2	1.3	2.9	5.5	42.6	20.3	22.2	62.9
TUBA	4.1	1.3	2.8	5.4	41.9	18.1	23.8	59.9

3.4. Discussion

The similarities in the average values of the Ménard parameters show that the TUBA® system could successfully be used in place of the standard procedure. Also, there is no degradation in the measurement accuracy using the TUBA® system as the standard variations do not change. In both equipment, the standard variations are quite high which can be explained by heterogeneities in the mechanical properties of the soil in the layer of the very dense sand.

Sometimes, the limit pressure could not be extrapolated as the soil did not creep during the test. A total of 32 measurements are concerned (8 values for the TUBA® system and 24 values for the standard procedure). For the majority of the tests concerned, it is due to the fact that the test is aborted when a pressure of 5 MPa is reached. It results in a distortion in the results, the limit pressure of the soil being underestimated.

It should also be noted that four pressuremeter tests performed with the TUBA® system, two in S6, one in S10 and one in S12, led to Ménard modulus higher than 100MPa. It is possible that these values are due to local heterogeneities, but due to measurement uncertainties, Ménard modulus greater than this value can‘t be considered as specific measures and have not been taken into account in the statistical analysis.

4. Conclusion

The TUBA® system is an innovative procedure that enables to perform pressuremeter tests in sandy and gravels soils. The casing is advanced while drilling and the tests are carried out from the bottom of the borehole to the top enabling to save a considerable amount of time. It is constituted by classical tools commonly used in the drilling industry which leads to a decrease in the price and in the complexity of the equipment.

These in-situ tests have shown that the TUBA® system provides Ménard parameters that are very close to the ones obtained with a standard procedure without losing any accuracy.

Other cross-tests should be performed in less dense soils, in order to confirm the relevance of the method.

References

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[2] CEN Geotechnical investigation and testing – "Field testing- Part 4: Ménard pressuremeter", NF EN ISO 22476-4, 2015.