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Feedback on static axial pile load tests for better planning and analysis

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ABSTRACT: Static load tests are usually carried out to either aliment extended databases from which design bearing capacity of piles are derived, control the design, or develop new piling methods. However, testing practices have evolved with time, usually with the expansion of the scope of the standards regulating these tests, but also because of the cost involved with such tests, making it difficult to achieve representative results and maintain a certain continuity of the results over the years. Therefore, it is most important to carry out and analyse such tests in ways that are adapted to their purposes, and reproducible. This publication aims to provide some feedback about the way to plan for and to conduct static axial pile load tests, having in mind that when planning and then performing a static pile load test, many factors can and will impact its preparation, the protocol followed to carry it out, and the results and their subsequent analysis.

1 INTRODUCTION

Static pile load tests are the most reliable way to assess correctly the ultimate bearing capacity of piles and their behavior.

However, nowadays, as they are usually time consuming, difficult, and expensive to carry out, the design bearing capacity of piles is often derived from the analysis of extended databases, (which need to be constantly alimented with new results) of piles that were statically loaded to the failure.

Yet, these tests are still conducted routinely, for design and control purposes alike. Furthermore, for the development and validation of new tools or new piling process such as pressed-in piles/sheet piles or Gyropress Method (GIKEN LTD, 2018), static pile load tests are mandatory.

At the same time, testing practice have evolved over the years, leading to testing standards being more inclusive and therefore in a certain way more permissive.

Hence, the precise purpose of the test should be always defined in advance and known from every actor, as they will define the preparation of the test as well as the testing method and load steps sequence and duration. Also, thorough soil investigations and detailed planning, preparation and execution are necessary, to ensure that the tests provide results that can be exploited, given their actual purposes.

Furthermore, analysis should be done by experienced engineers, following a method that will ensure the proper interpretation of the results.

However, there are few technical papers that systematically summarize this information, as until now it has been treated as the know-how of the engineers conducting such tests. Therefore, throughout the whole paper, a number of static axial pile load tests carried out or analysed by Université Gustave Eiffel and Railway Technical Research Institute are analysed through a new light, in order to illustrate in details the most important points to focus on for a static axial pile load test in terms of organisation and execution, and to serve as feedback for future pile load tests.

First, the different purposes that may be the reason for carrying out a static axial pile load test are described in details, as they will most probably impact the setup and execution method of the test pile.

Depending on the predefined objective of the test, the load steps sequence and duration are defined, and the pile may be instrumented or not. Thus, the consequences of the choices made for the loading sequence and step duration as well as for the nature and position of this instrumentation are studied.

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Then, the possible impacts of the chosen time-frame (or planning) are assessed, taking into account not only the nature and state of the soil, but also the nature of the material constitutive of the pile.

A discussion is also made about the way to interpret measures.

Finally, conclusions are drawn from this detailed study for the planning of a static axial pile load test, its setup and protocol as well as for the analysis of the data achieved during this test, taking into account all these background parameters.

2 REASONS FOR CARRYING OUT A STATIC PILE LOAD TEST

2.1 *Control tests: Verifying the overall behavior at Serviceability Limit States (SLS)*

The kind of test carried out to control the behavior of a pile under a certain load (usually under SLS load, or slightly higher) is often called a control test: its purpose is therefore only to observe the displacement of the head of the pile under this predefined load, and to compare this measured displacement to the calculated one on one hand and to the acceptable displacement for this given project on the other hand.

Therefore, this kind of test provides the first part of the load-settlement curve.

The only other information given by this kind of test is the time-displacement curve and the load-creep rate curve up to the maximum load applied.

Sometimes, the step under the SLS load is maintained for a longer time, to expressly observe the evolution of the creep rate of the pile under this load.

2.2 *Conformity tests: Validating a design value or bearing capacity*

The conformity tests are usually carried out to validate a design value, by carrying out a static load test on a pile by loading said pile up to its geotechnical resistance (or at least up to its theoretical failure).

These tests are usually carried out on instrumented piles, as the level of load applied is sufficient to determine the unit shaft friction mobilization for each level, and even the mobilization of the base resistance.

In some countries, conformity tests can be used as control tests (AFNOR, 2012).

2.3 *Tests carried out for the development of new methods, and for the creation or alimentation of a database*

These tests usually take place outside the scope of an actual project. Their main purposes are to determine the specific base resistance and unit shaft friction that can be mobilized in a given soil, whose state and nature are well documented. The piles are therefore instrumented.

In order to build a database on which reliable and sound design rules will be based, it is absolutely necessary to perform all the tests the same way, as well as to analyze them with the same procedure (Baguelin et al., 2012 and Burlon et al., 2014).

3 PREPARATION AND PLANNING OF A TEST PILE

3.1 *Definition of the purpose of the test*

Defining the clear purpose of the test will bring the engineers to choose whether the pile shall be instrumented or not, to define loading sequence and the steps durations, as well as to choose to build the test pile in a certain way so as to ensure that the goals of the test are performed.

The first three topics will be covered in the following paragraphs.

The last is also very important: planning for a test pile whose purpose is to determine the geotechnical resistance of the pile or the pile base resistance, especially on large diameter piles in strong soils, it may be necessary to apply great efforts (higher than 15-20 MN) to mobilize its overall resistance.

In this case, it may be possible to perform a test on a pile of slightly smaller dimensions (AFNOR, 2005b). On the other hand, if the aim of the test is to validate a base resistance, the pile may be over-drilled or tubed over a certain length, so as to decrease the shaft friction on the upper part of the pile, reducing at the same time the overall effort to apply on the test pile. If the last solution is retained, it is important to note that it will have a direct impact on the measured strains and on the interpretation of the results, as can be seen on Figure 1 (see paragraph 3.3.2).

Furthermore, when planning for a load test, if there are multiple purposes for it, it shall be studied if these purposes are compatible with each other. Indeed, given the cost of such a test, engineers could be tempted to optimize this cost by trying to use it for multiple purposes such as the determination of the resistance through a dynamic load test and a static load test (Figures 2 and 3) or such as the study of the creep rate under an extra long step as well as the determination of the creep load of the pile (see paragraph below).

It can be seen on Figure 2 that the repeated impacts induced deformations greater than 3500 µdef each time. Eurocode 2 (AFNOR, 2005a) fixes the ultimate relative deformation of concrete in compression ε_{cu} at 3.5/1000. Here, this deformation is significantly exceeded during each impact. These levels of deformation therefore very probably damaged the pile head (which was confined by a ferrule), and even more the top of the shaft of the pile (under the head ferrule) at the place where the maximum deformations were felt, causing a cracking and irreversible damage to the upper part of the pile, followed by deeper plastic deformations.

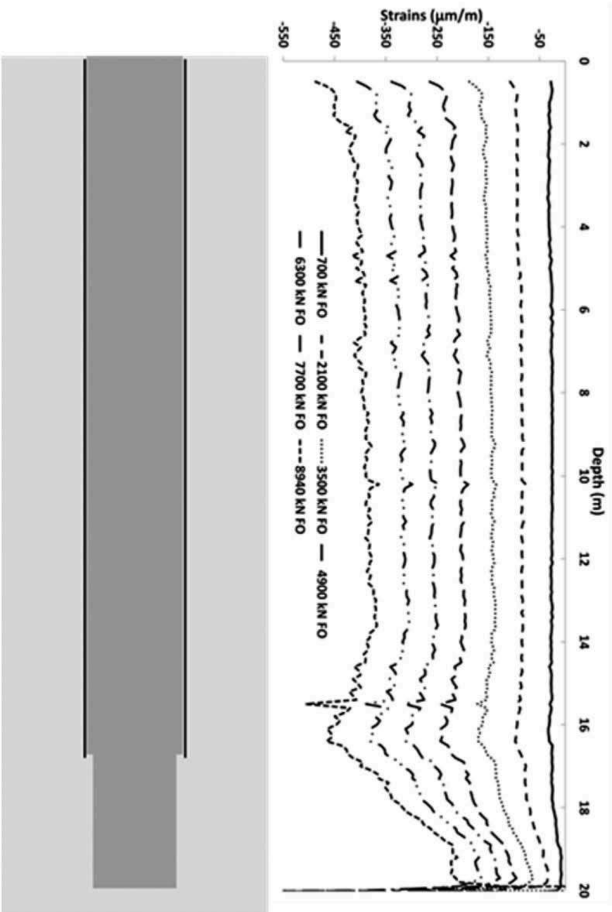

Figure 1. Longitudinal section of a pile with variable geometry and strain measures along the shaft, for different load steps.

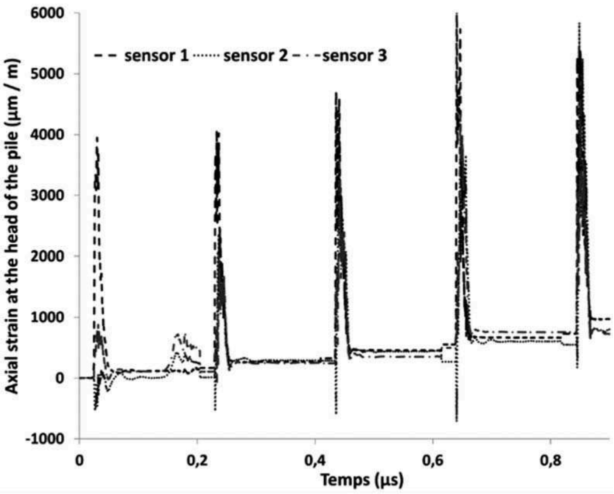

Figure 2. Strains-time relationship during a dynamic load test.

In addition, it can be seen in Figure 3 that the measures of strains (at the first level at 0.3 meters deep) and displacements at the head show a notable and increasing dispersion from the level at 3000 kN: this reflects an inclination of the head increasing hand in hand with the increase of the applied load,

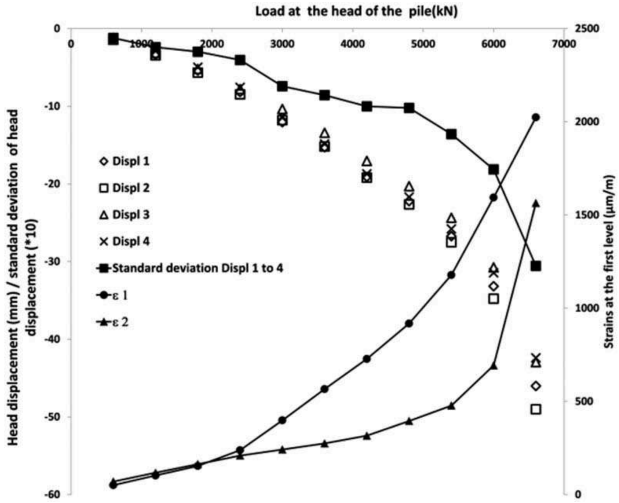

Figure 3. Head displacement and strain measures at the top level during a static load test carried out after a dynamic load test.

and therefore a displacement of the head of the pile which is not representative of the shaft.

3.2 *Determination of the loading sequence and load steps durations*

3.2.1 *Loading sequence*

The loading sequence has a direct impact on the results of the test, and more precisely on the precision of the derived values such as the overall resistance of the pile or its creep load. Many procedures exist that specify different loading sequences (Szymkiewicz et al, 2020).

Usually, when performing a static pile load test, each load increment is of equal magnitude, and this load increment is chosen so as to reach the calculated resistance in eight or 10 steps. This is usually enough to determine the resistance or creep load cited above.

However, if for any reason the equal magnitude between steps is not respected, it can have a detrimental impact on the precision of these values, as seen on Figures 4 and 5.

On these Figures 4 and 5, it can be seen that the change in step magnitude between 6000 kN and 7500 kN occured at a crucial time, and that the creep rate – axial load curve (drawn following the French practice) presents a gap not allowing to assess with precision the creep load.

The same could be applied to the determination of the overall resistance, which may be determined on the load-settlement curve following a criteria different from country to country.

Some testing procedures allows for the decreasing of the magnitude of the steps when approaching the failure load (AFNOR, 2018), with the express purpose to determine more accurately the behavior of the pile to refine the determination of the pile resistance.

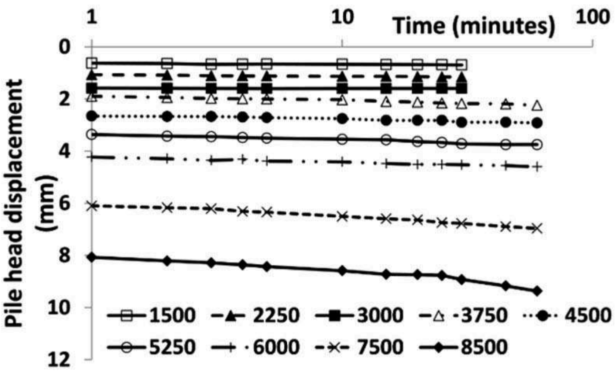

Figure 4. Head displacement – time relationship.

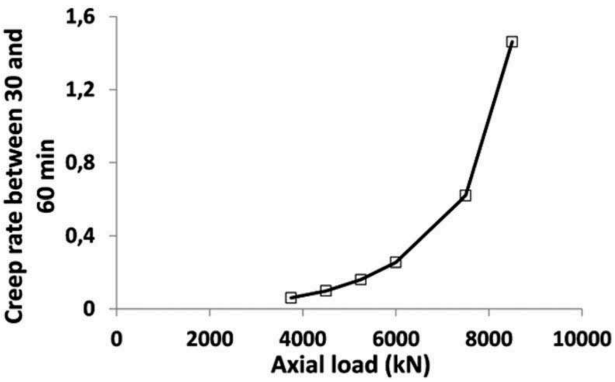

Figure 5. Evolution of the creep rate with the axial load.

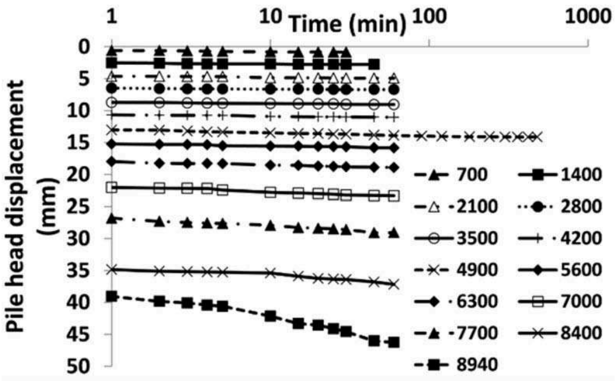

Figure 6. Head displacement – time relationship for a load test with an extra long step.

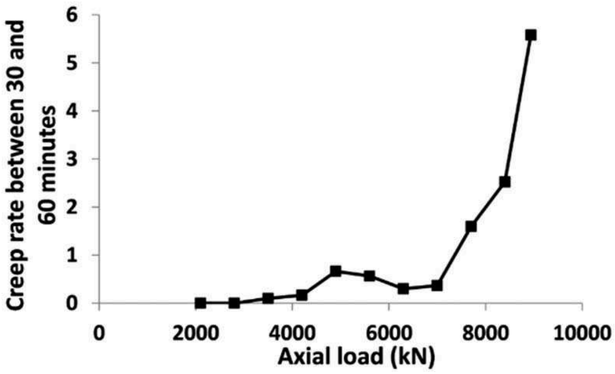

Figure 7. Evolution of the creep rate with the axial load for a load test with an extra long step.

Under these high loads (compared to the resistance of the pile), and particularly in some soils allowing for a very important creep, this particular adaptation may on the contrary decrease the resistance of the pile.

3.2.2 *Steps duration*

Step duration also has an impact on the results of the test.

While the measure of strains along the shaft does not vary so much with time, meaning that the mobilized shaft friction and base resistance do not evolve with time, pile displacement evolve with time: creep rate and displacement are indeed criteria which are scrutinized when deciding if the load step can be shortened or must be lengthened, depending on the local practice.

Obviously, lengthening a step under loads higher than the creep load may have an impact on the overall resistance, as seen in the previous paragraph.

Furthermore, it can also have an impact on the displacement behavior of the pile for the few next steps. Figures 6 and 7 show the results of a test pile for which an extra long step under the estimated service load was performed. As a result, it caused strain hardening of the soil, and it can be seen that the creep coefficient decreased for the next few steps.

3.3 *Force input system and types and distribution of sensors*

3.3.1 *Force input system*

While the load shall, whenever possible, be controlled with a very accurate load cell, the choice of the force input system that will be used to apply the force should be compatible with the maximum load to apply.

This system is almost all the time composed of one or multiple hydraulic jacks controlled by a single hydraulic pump.

While in theory it may be possible to test a 1 MN resistance pile with a 10 MN system, this would be to the detriment of the accuracy of the load control. Hence, the estimated displacements and the overall resistance of the pile should be taken into account when choosing the jack and the pump. The jack section and the estimated displacements for the first few load steps should be correlated to the debit of the pump, so as to ensure to maintain a load closest to the target value.

Figure 8 shows the load-time curve of a test performed on a very small pile (R_c = 230 kN) performed with a system design for the test up to 5000 kN: the applied load is clearly not constant and often higher than the target load.

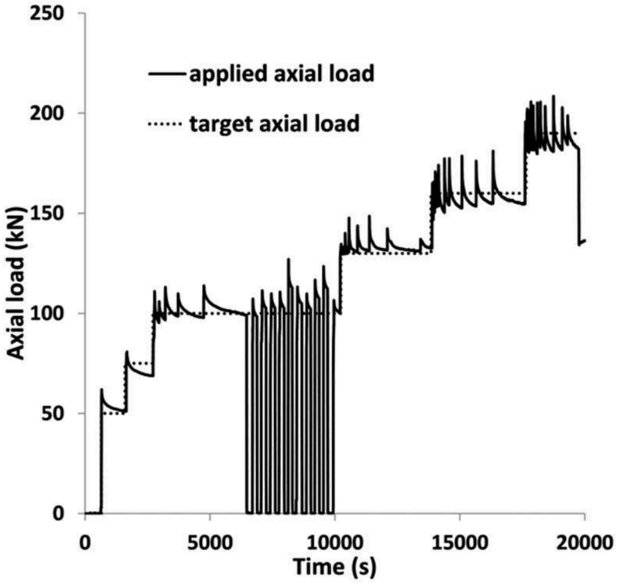

Figure 8. Comparison of the target load and the applied load during a load test using a manual pump.

Furthermore, whenever possible, the pump shall be an automatic one, allowing to maintain a constant load without the intervention of the operator, who may not be always close to the pump for the whole duration of the test for different reasons.

Results showed in Figure 8 were achieved with a manual pump, without any automatic regulation.

Figure 9 shows parts of the load-time curve of a test where transversal and axial loads were applied at the same time. The axial load was applied with a manual 2500 kN system, while the transversal load was applied with an automatic 1000 kN system. It can be seen that the transversal load is clearly more constant than the vertical load.

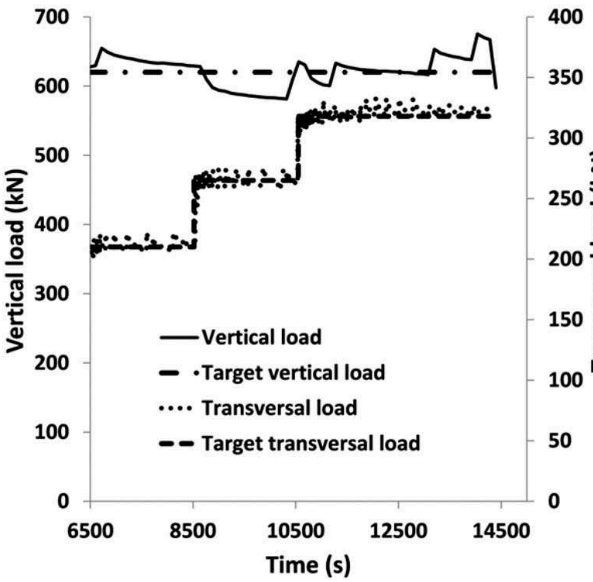

Figure 9. Comparison of the target loads and the applied loads during a combined load test.

3.3.2 *Types and distribution of sensors*

Regarding the displacement sensors localized at the head of the pile, their number should never be less than three, and preferably four.

Indeed, these numbers ensure that if a moment occurs, because the load is applied with any eccentricity or for any other reason, it could be seen instantly during the test, and precautions could then be taken (Figures 3 and 10).

Concerning the instrumentation embedded or inserted in the pile, while its choice should in theory be transparent in regards to the analysis method and therefore to the results, it should also be linked to the purpose of the test and to the geotechnical context, as it will have an impact on the planning (see paragraph above) and on the precision of the measures and could very well have an impact on the overall results of the pile (Szymkiewicz et al., 2021).

While embedded sensors of different technologies (mostly vibrating wire strain gauges, resistance strain gauges and optical fiber) are providing almost identical measures (Figure 11), it is not the case for retrievable extensometers (Figure 12).

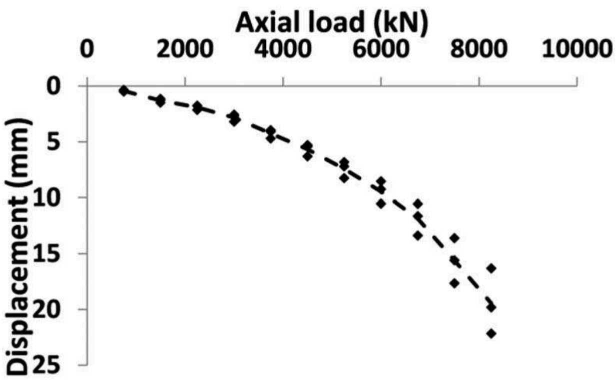

Figure 10. Evolution of the dispersion of measured pile displacements during a static load test performed on a pile with an eccentricity.

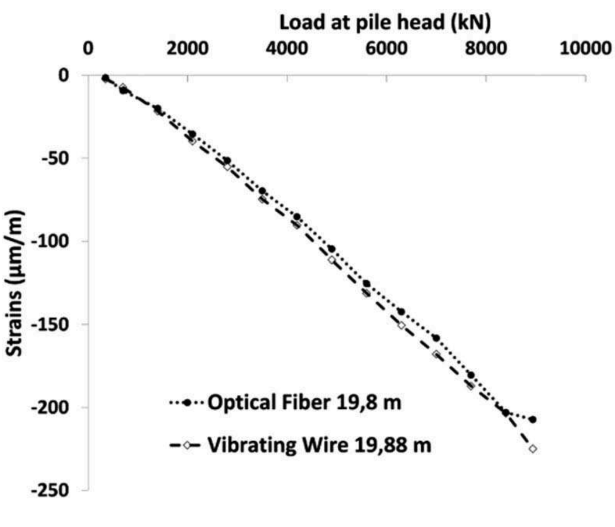

Figure 11. Comparison of measured strains in a bored pile with a optical fiber and vibrating wire strain gauges.

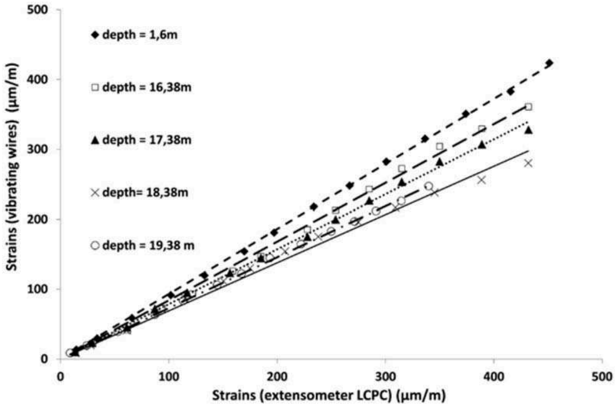

Figure 12. Comparison of measured strains at different depths in a bored pile with a retrievable extensometer and vibrating wire strain gauges.

The embedded sensors are measuring the strains over a length equal to their own length, while the retrievable extensometers measures strains between two anchors assumed to be fixed, and moving with the pile itself, making the strain measurement 'global' compared to the 'local' measurements achieved with embedded sensors.

However, the achieved results will be very comparable, as the equivalent modulus of the pile used to interpret the data will be adapted to the different levels of deformations (see paragraph 4).

Distribution of the sensors along the shaft is also a very important topic. Regardless of the purpose of the test, the first level of sensors shall be positioned just under the head of the pile, but under the ferrule, so as to estimate the real stiffness of the shaft.

A number of three to four sensors per level is necessary to achieve redundancy. However, the number of sensors per level could be decreased for deeper levels, as moments should not occur at these depths, as can be seen in Figure 13, presenting the standard deviations of deformations at each level, for a test where an important eccentricity (and therefore a moment) was noted.

When not using distributed sensors like optical fiber, it is important to place sensors at the levels of the interlayers, so as to be able to estimate the unit shaft friction of each layer. Furthermore, when the pile does not have a constant geometry, like on Figure 1, it is important to have two very close levels, one on the upper side of the transition zone, and another on the lower side, so as to be able to estimate the impact of the change of geometry on the stiffness of the pile more precisely, from which efforts will be derived. Otherwise, interpretation must be difficult and shaft friction may be underestimated (Figure 14).

Furthermore, when assessing the pile base resistance, it may be interesting in some cases (very long piles, problematic soils) to densify the number of levels above the base: this way, if any problem occurred during the concreting phase (collapsed walls for example), the sensors will provide useful information (Figure 15) and allow the engineer to understand what happened and not to interpret blindly the data.

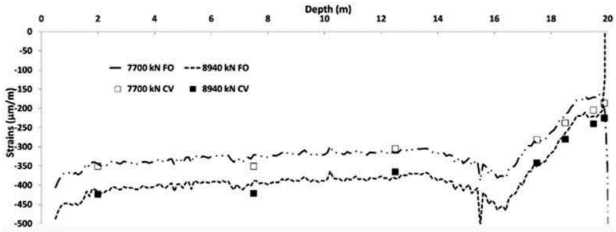

Figure 14. Comparison of strains measured along the shaft with optical fiber (FO) and vibrating wires strain gauges (CV) on a pile with a variable geometry.

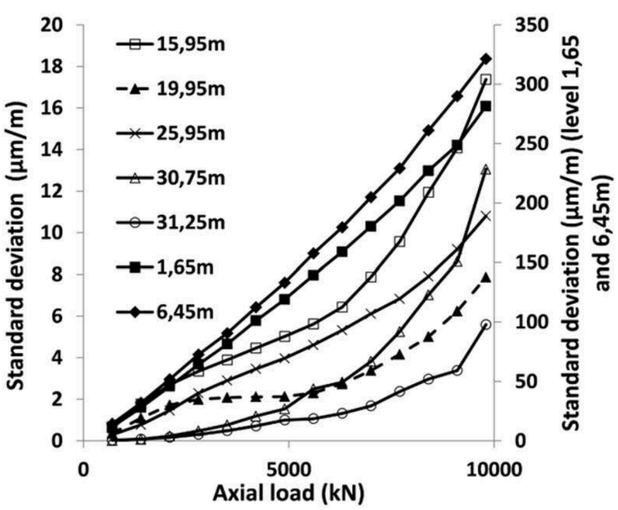

Figure 13. Evolution of the standard deviation of the strains at different depths.

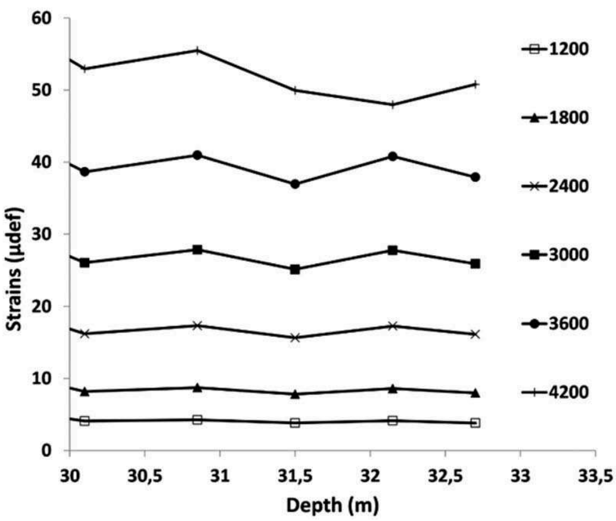

Figure 15. Strain measures at the base of a pile with a concreting default.

3.4 *Preparation*

Preparation of the pile is necessarily linked to the purpose(s) of the test, as well as to the choices of sensors and their distribution.

For example, a retrievable extensometer is particularly well adapted for the instrumentation of driven piles (but also for CFA piles), as the sensors are not present during the critical phases and therefore cannot suffer from it. However a reservation needs to be placed beforehand on the pile.

On the contrary, the use of embedded sensors implies the intervention of a team of external workers during the realization phase, as well as extra care during the manipulation phases of the cages.

Concrete formulation shall also be chosen with precaution, to ensure that the test can be carried out up to the maximum target load, but also, in the case of CFA piles notably, that the reinforced cage (playing the role of the instrumentation support) can be inserted in the fresh concrete without too much vibrations, which could damage the sensors.

Furthermore, the pile head shall be, whenever it is possible, encased in a ferrule, so as to increase the strength of the concrete, especially when high stresses (20 MPa or more) should be reached during the last load steps.

3.5 *Planning*

Depending on the type of pile (displacement pile of bored pile), the nature of the soil and the material constitutive of the pile, the waiting time between the realization and the test of the pile shall differ.

For steel piles and concrete driven piles, the main factor influencing the length of the waiting period is the soil set up (Augustesen et al., 2006, and Jardine et al., 2006): during this phase, excess pore water pressures induced during the setup of the pile will dissipate. This duration is therefore strongly dependent on the permeability of soils.

Concerning cast-in place piles, concrete strength on the day of the test should be enough to accept the maximum target load.

Furthermore, the modulus of the concrete shall also be taken into account, especially when working with special formulations and long piles. Performing a test on such a pile at a young age (or with a formulation different from the formulation which will be used during the actual project) could lead to the overestimation of the pile head displacement, and could therefore lead to overdesign of the piles for a project.

The example presented in Figure 16 shows that a difference in modulus from 20 to 50 GPa induce

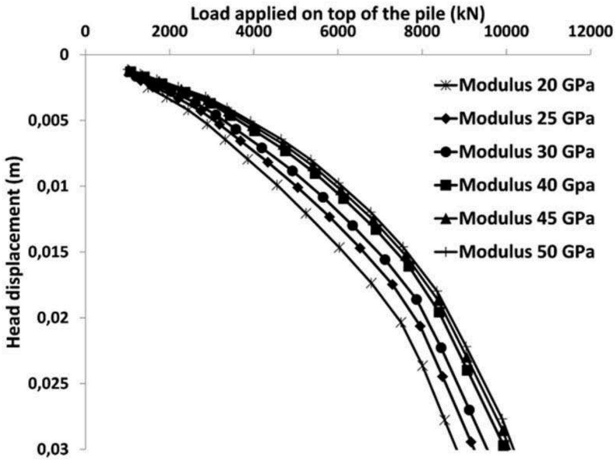

Figure 16. Load-settlement curves for a same pile with different modulus.

a difference in displacement of about five millimeters under a load between 4000 and 6000 kN, which for this particular project was the estimated SLS load.

This is particularly important to take this aspect into account when planning to perform a test whose objectives are to determine the settlement under SLS load and to determine the resistance of the pile at the same time, as the second objectives may necessitate the use of a special formulation in prevision of the very high loads applied at the head of the pile.

4 INTERPRETATIONS OF THE MEASURES

As said in paragraph 3.3.2, the choice of the sensor impacts (among other things) the level of deformations that will be reached during the test.

Nevertheless this just implies that the modulus used to interpret the data will differ from one type of instrumentation to another.

4.1 *Modulus determination and load distribution*

Except when embedding a load cell at the base of the pile, the usual information given by the instrumentation distributed along the pile is measures of deformations.

These deformations are then just multiplied by the cross sectional area of the pile and the modulus of the pile to obtain efforts (or loads), from which unit shaft friction are calculated (by subtraction between two levels), and base resistance as well.

In a first approach, some codes such as the French National application standard for the implementation of Eurocode 7 (AFNOR, 2012) relative to deep

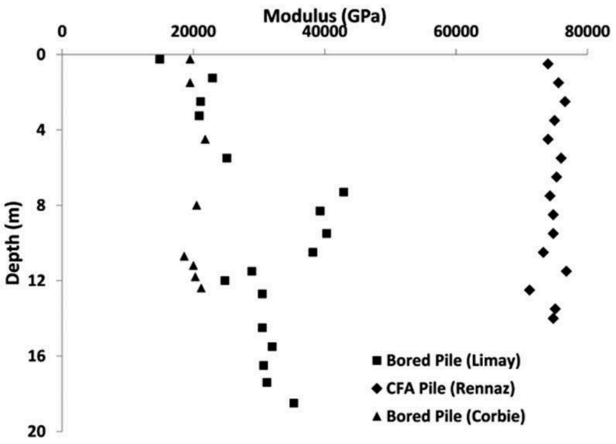

Figure 17. Variability of the modulus in cast-in place piles.

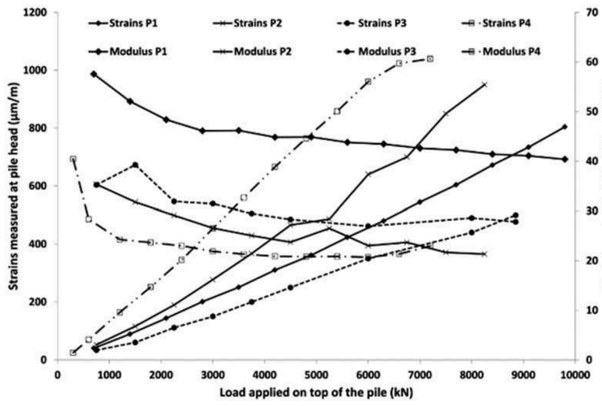

Figure 18. Evolution of strains and modulus during load test for four different piles.

foundations give values for the concrete modulus: in this case, 20 GPa.

However, for concrete piles, the modulus values can be very variable, depending on the age of the concrete (as discussed in paragraph 3.5) and its formulation.

Therefore, it is necessary to determine this modulus for each project. Figure 17 (partly issued from Bustamante and Doix, 1980) shows the great variability of the modulus of pile concrete, through the results of modulus determination tests carried out on specimens cored from piles.

It is also necessary to take into account the reinforcing steel bars of the cage inside the pile. The French standard NF P 94-150-1 (AFNOR, 1999) proposes the equivalent modulus method, taking into account the modulus of each material in the pile as well as their respective cross sectional area.

This method is often non-representative of the stiffness of the pile. Indeed, the values of the concrete modulus are given for a unique strain level, generally very small, leading to modulus values higher than in reality (see for example the value for the CFA Pile, on Figure 17) and, if used as it is, to incorrect interpretations, as the base resistance would be greatly overestimated in this case.

Therefore, it is mandatory to take into account the strain-dependency of the modulus.

To do so, multiple authors proposed different methods, summarized by Lam and Jefferis (2011).

Of these methods, the one proposed by Fellenius (2001) seems one of the most commonly used.

However, a simpler method would be to use, as stated in paragraph 3.3.2, the first level of strain gauges to assess the stiffness of the pile, in function of the applied load. Then, knowing the cross sectional area of the pile, the modulus can be easily estimated (Figure 18).

From there, it is possible by approximation by segments or polynomial approximation, to determine the modulus for each strain level, and then the load corresponding. This is the approximation by segment of the P4 case from Figure 18 that is presented in Table 1: the two boxes (Load 1800 kN at 1 m depth and Load 7200 kN at 17.65 m depth) showing the almost same exact measured strains, albeit for different load steps and at different depth, result in the same load.

If the pile body is a composite of two materials, it is better to consider the effect of breaking the adhesion between the two materials as necessary. One example is a steel pipe soil cement pile made by inserting a ribbed steel pipe into a mixed soil cement as shown in Figure 19 (JASPP, 2017). The ribs of this pile are attached to the entire outside and the inside near the tip, where ground resistance is required. On the other hand, most of the inner surface that does not contribute to skin friction has no ribs attached. Therefore, as the vertical load increases, the adhesion between the soil cement and the inner surface of the steel pipe will break off on the inner surface, and the axial rigidity of the entire pile will decrease.

Figure 20 shows the relationship between the output of the strain gauge of the steel pipe at the pile head and the axial rigidity calculated back from the applied load in the loading test with a steel pipe diameter of 800 mm and a soil cement diameter of 1200 mm (Nihei et al., 2011). At the initial stage of loading, it has the rigidity calculated under the condition that the adhesion between the soil-cement and the inside of the steel pipe is not broken. However, as the strain increases, the back-calculated axial stiffness decreases to the rigidity of the steel pipe alone. By considering the strain level dependency of such a composite material, the axial force distribution can be evaluated properly.

Table 1. Example of the analysis of the data, linking the measured strains and the stress level to the loads.

	load applied on top (kN)													
	Depth (m)	300	600	1200	1800	2400	3000	3600	4200	4800	5400	6000	6600	7200
strains (μdef)	1	25	70	164	252	346	454	560	666	764	858	960	1024	1039
	2	23	62	147	227	317	417	515	618	717	816	932	1022	1173
	3.75	23	51	116	183	253	333	411	488	563	637	722	804	881
	6.5	16	37	81	125	174	228	281	335	390	452	518	583	640
	9.5	9	20	47	77	110	143	177	215	254	294	342	389	436
	12.5	7	16	35	59	88	121	159	193	231	266	307	347	388
	15.08	5	10	18	31	48	71	97	126	155	186	221	257	299
	16.65	5	9	17	27	42	63	87	111	138	164	194	228	266
	17.65	5	9	16	26	40	60	83	105	130	152	183	214	251
	18.65	5	8	16	25	38	57	79	99	122	140	163	187	223
	load applied on top (kN)													
	Depth (m)	300	600	1200	1800	2400	3000	3600	4200	4800	5400	6000	6600	7200
modulus (Gpa)	1	40	28	24	24	23	22	21	21	21	21	21	21	21
	2	40	30	25	24	23	22	22	21	21	21	21	21	21
	3.75	40	33	26	24	24	23	22	22	21	21	21	21	21
	6.5	40	37	28	26	24	24	23	23	23	22	22	21	21
	9.5	40	40	34	28	27	25	24	24	24	23	23	23	22
	12.5	40	40	38	29	28	26	24	24	24	23	23	23	23
	15.08	40	40	40	39	34	28	27	26	25	24	24	24	23
	16.65	40	40	40	40	36	30	28	27	25	24	24	24	23
	17.65	40	40	40	40	36	31	28	27	26	25	24	24	24
	18.65	40	40	40	40	37	32	28	27	26	25	24	24	24
	load applied on top (kN)													
	Depth (m)	300	600	1200	1800	2400	3000	3600	4200	4800	5400	6000	6600	7200
load (kN)	1	297	600	1197	1795	2392	3000	3600	4200	4800	5400	6000	6600	7200
	2	282	571	1107	1632	2215	2823	3377	3914	4543	5171	5912	6490	7200
	3.75	277	517	921	1328	1798	2315	2783	3226	3633	4011	4576	5101	5584
	6.5	199	412	679	983	1268	1635	1984	2327	2662	3022	3395	3735	4059
	9.5	111	245	490	656	882	1086	1289	1547	1804	2067	2369	2656	2933
	12.5	90	192	402	513	731	958	1174	1401	1653	1887	2151	2397	2647
	15.08	66	121	220	362	498	608	793	984	1153	1350	1591	1827	2098
	16.65	56	111	200	321	457	574	729	893	1059	1201	1407	1637	1886
	17.65	55	105	194	310	442	561	697	851	1012	1136	1327	1539	1790
	18.65	55	99	188	298	426	546	664	808	964	1068	1194	1359	1601

5 CONCLUSIONS

Static pile load tests are expensive, long tests, the results of which can considerably impact the design of the foundations of a structure or building.

Because of these high stakes, it is a priority to plan thoroughly these tests, and to carry them out in the conditions.

However, the actual testing standards and recommendations are now tending to be more and more inclusive in terms of loading procedures, and do not describe in details the planning and the different steps of the analyses one has to follow when performing such a test. This can have a great impact on the overall results of the test on one hand, and on the other hand on the consistency and reliability of the database they are part of.

Hence, throughout this communication, all the most important topics relative to the preparation and the performing of such tests have been discussed, in order to help plan and carry out future tests:

– the main reasons for carrying out these tests,
– the need for a clear definition of the objectives of the tests,

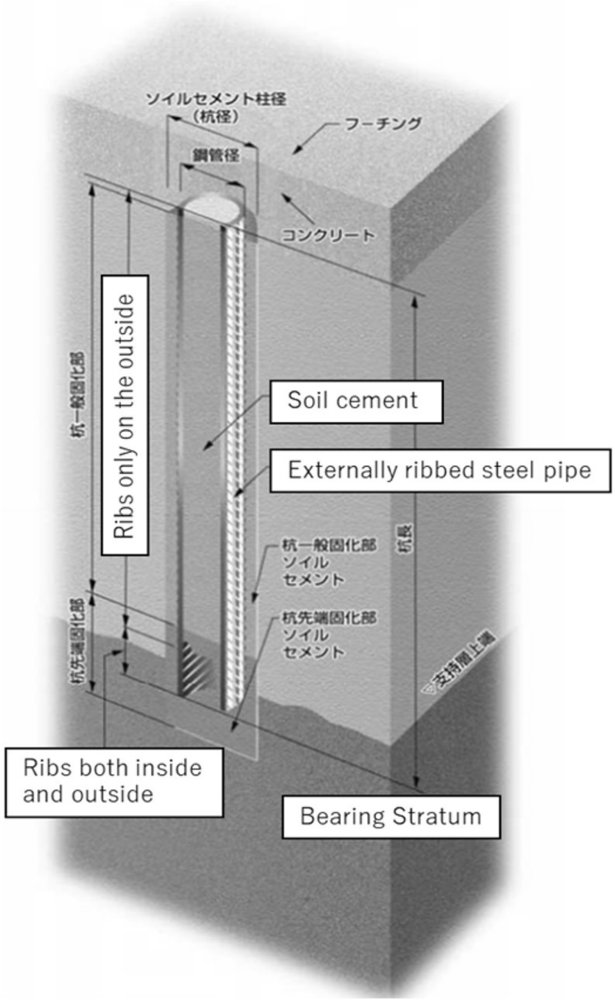

Figure 19. Outline of steel pipe soil cement piles (JASPP, 2017).

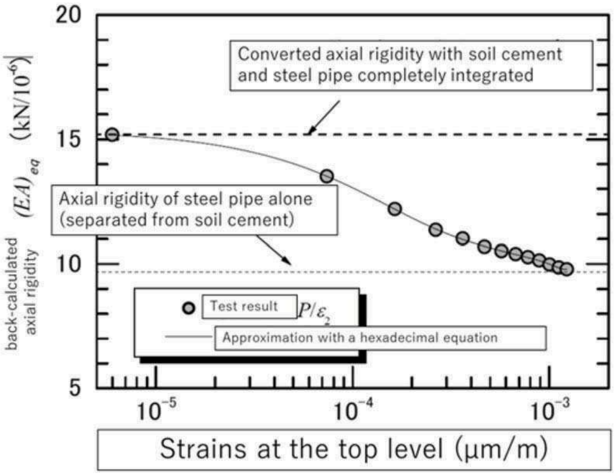

Figure 20. Relationship between strain of steel pipe at pile head and axial rigidity by composite of steel pipe and soil-cement.

- the importance of the choice of sensors, if the pile is to be instrumented, as well as their number and distribution along the shaft, as this choice will impact the planning of the test as well as the realization of the said pile,
- the realization of the pile (ranging from the pertinent choice of its constitutive materials to its geometry and reinforcement), which may in certain ways dictates that the test will run smoothly, or not,
- the waiting time between the realization of the pile and the day of the test,
- the importance of the loading sequence, load step magnitude and durations, as they will have direct consequence on the achieved results,
- the choice of the force input system.

Furthermore, some information was given to ensure that the interpretation of the strains measures is done correctly, with a focus on the importance of the modulus in the analysis of these tests, its variability, and a simple solution to assess it.

For more complex or longer load tests, carried on geothermal piles for examples, or on piles from an actual building, it would also be interesting and certainly necessary to study the impact of weather (temperature, sun, wind) and creep of the concrete on the behavior of the pile.

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