CHAPTER 0
Introduction

Pile design is an activity where the theory, the experience and the experiment still have a similar weight. The designer can have the best knowledge of the used material and of the applied load (in magnitude and history), a potential uncertainty remains because the main structure interacts with a highly variable and evolving material: the soil. Due to this variability, and in order to be able to design this kind of structure, the method generally followed in the pile design is a semi-empirical method based on a rational approach and based on the experiment and experience. The soil fundamental properties and their implication in the pile/soil interaction are generally mixed with the result of field or model testing. However, these methods are dependent of the pile type, the pile installation, the pile material, the type of soil and, last but not least, the type of testing.

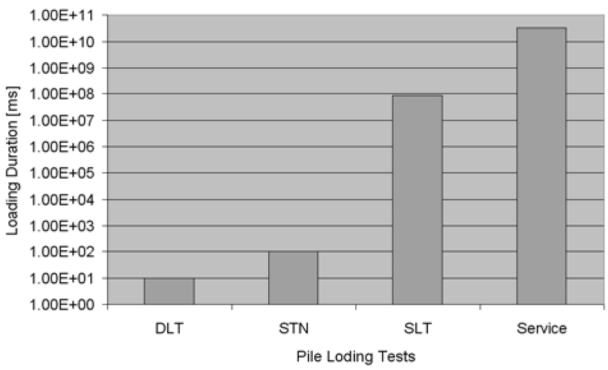

Figure 1 : Durations of the loading procedures

The methods of testing aims to match as best as possible with the real load history applicable during the foundation life. International codes and specifications exist and inform of the correct procedure to apply in order to perform a reliable and sound pile testing. However, the economical and practical aspects generally counter this objective. It is not possible to carry out a test in the same conditions than the real load history.

Different testing procedures have been developed. Most of them want to evaluate the working loads and simulate the load-settlement curve defining the pile/soil response to a given load history. These methods can be characterized, inter alia, by the rate of implementing: slow procedures (like the static load test – SLT) can be carried out during a long period (up to 3 days) and rapid methods (like the dynamic load test – DLT) lasts barely a fraction of a second. But this rate of loading have a strong influence on the measurements and, consequently, on the complexity of the underlying post-treatment and interpretation. Indeed, the soil, in addition to its high level of variability is subject to time-dependent behaviour. This can be translated in terms of creep, relaxation or strain rate effect. This rheological behaviour varies with the type of soil, the stress history and the type of loading. The faster the pile test, the more developed the loading rate effect in the pile/soil reaction. Many authors focused their research on a specific and narrow aspect of this influence either on a laboratory or a rational aspect or from field test point of view. This specific intersection of the rheologic behaviour of soil under dynamic conditions and its influence on the result of a pile test performed at a certain velocity is the framework within this research has been undertaken.

In the last 5 years, since 1998, two ambitious national researches have been organised by the Belgian Building Research Institute in order to execute an experimental test campaign able to lead a proposal of semi empirical design methods of axially loaded piles using installation coefficients. This program is organised equally in two typical types of soil met in Belgium: the tertiary overconsolidated Boom clay in Sint Katelijne Waver (Belgium) and the sandy bearing stratum of Bruxellian sand in Limelette (Belgium). The program included the intensive geotechnical investigation of both sites and the installation of 30 piles to be loaded statically, dynamically and by the statnamic[1] procedure. The 30 piles are composed of 5 types of cast in place soil displacement screw piles plus a prefabricated driven pile as reference.

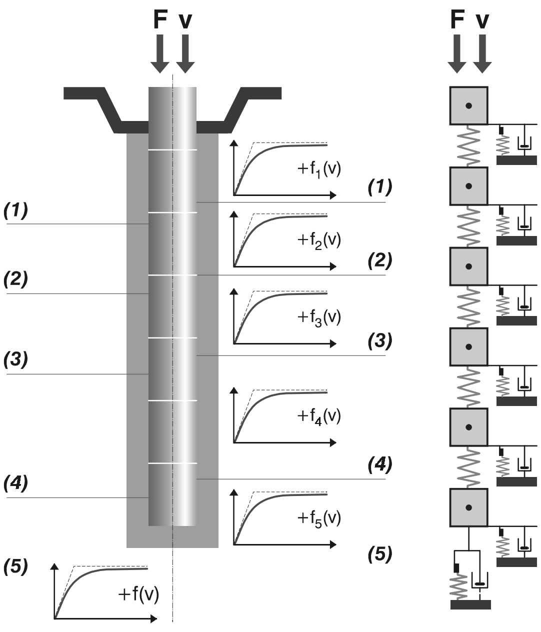

Figure 2 : Pile soil model representation (schematic and modelled)

With the courtesy of the BBRI, it is possible to use this wide amount of data generated by these two research programs as raw material of a precise research focused on the loading rate effect. Indeed, the testing procedures are ranged on a wide spectrum of loading duration or loading rate (Figure 1) and the comparison of their results in a comparable environment could result in a better comprehension of the loading rate effect on the range of high and low velocities.

This research aimed to analyse the influence of the loading rate by modelling the pile/soil interaction system in a mass/spring/dashpot system supposed to represent the pile, the soil and the constitutive relationships existing between them. These relationships account for the static and the so-called dynamic behaviour (Figure 2).

The dynamic measurements are introduced as input in the system and the pile/soil interaction system parameters are obtained from a back-analysis process where the matching between a measured and a

[1] A load controlled testing procedure of which the loading rate is intermediate between the SLT and the DLT.

calculated curves issued from the pile/soil response is used as quality control. This optimisation process allows to identify the “static” and the “rheologic” parameters from dynamic measurements. When the “static” parameters are obtained, a simulation of the equivalent static load-settlement curve is obtained and compared with the real one measured on field. There is a large amount of parameters to be optimised. A rational technique is required to perform this analysis but this process must be guided in a geotechnical way. The parameters have to be sorted and managed in function of their relative weight and reliability. An automatic technique has been developed based on the systematic study of the vicinity of the combination of parameters in order to find a better combination or to know the evolution of the matching criterion with a slight variation of the parameters.

<u>Chapter 1</u> describes the three load testing procedures (measurements, procedure and methods of interpretations) and their main methods of interpretation. An overview of the wave equation applied to pile dynamic analysis is also given.

<u>Chapter 2</u> is dedicated to the load rate effects through literature. An overview of the specific results focused on this behaviour is given allowing to make a first synthesis of the trend observed between the measured soil reaction and the rate of loading applied. The Smith aspect (1960) is also investigated and the link between the rheologic parameters (J, quake) and the soil type is summarized. Finally, the main lumped models describing the loading rate effects are listed and compared.

<u>Chapter 3</u> is focused on the description of the pile/soil interaction model. Both pile and soil models are detailed and the main algorithms used for the dynamic analysis and the simulation of the static load-settlement are described. After, the dynamic data from the dynamic load tests on prefabricated piles are analysed: different aspects are investigated, namely the relationships existing between the maximum quantities and the quality of the signals in the post-treatment or during the acquisition.

<u>Chapter 4</u> is dedicated to the back-analysis procedure and the automatic optimisation process. The description of the method and the main algorithms used are given. A short analysis of the uniqueness of the solution and a large analysis of the sensitivity of the matching result to a parameter perturbation are proposed. Afterwards, This technique is used to perform a complete set of analysis (6 blows) on the measurements of the pile A7 (prefabricated one) in Sint-Katelijne Waver, and on 6 blows of the pile B8 (prefabricated) in Limelette. Conclusions about the reliability of the pile/soil model and the need of the slippage between the pile and the soil taken into account are drawn.

<u>Chapter 5</u> is a consequence of chapter 5. The simple SDOF model describing the pile/soil interaction behaviour defined in chapter 4 is replaced by two other propositions of modelling where the soil adjacent to the pile is defined with its own motion system of reference. this allows to introduce the slippage at the interface between pile and soil. These models are either the 1-D radial approach with concentric cylinders of soil surrounding the pile or a DDOF (Double Degree Of Freedom) system similar to the classical one but where pile and soil have their motion dissociated during the slippage. Description, comparison and a special attention to the slippage event are proposed for both approaches.