Chapter 3

Test set-up and regime

3.1 Introduction

The experimental research is focused to determine the effect of excess pore water pressures generated during pseudostatic loading in the pile bearing capacity. To get a reliable experimental answer to the topic, a series of tests in *fully saturated sand* have been performed in the Geotechniek Laboratory of TU Delft. The chosen model is the calibration chamber one, previously used by Broere [16]. The test-set up was designed by J. Dijkstra [5] as part of his master thesis on evaluation of loading rate-effects in pseudostatic loading of piles embedded in unsaturated sand. Therefore, for the results of this research to be comparable with Dijkstra's ones (comparison of dry and saturated situation) the same testing equipment is used. If any differences with his procedure, those will be explained and justified in the following sections.

3.2 The calibration chamber

The experimental tests are performed in a *calibration chamber*, that approximately represents the in-situ case at a scale 1:10. As presented on the literature study, calibration chambers have been widely used over the years to correlate between soil properties and cone resistance. Therefore, the soil properties are regarded as a known input, good insight and reliable data about the soil sample should be obtained. However, though many aspects of the soil sample in the calibration chamber tests can be controlled, the test set-up itself strongly influences the results. Parkin [17] studied the influence parameters on calibration chamber testing and concluded that, part from the preparation method of the sample, the boundary conditions are influential. The different chamber types based on the boundary conditions have been previously presented, as well as the fact that the extent to which the boundaries may effect the measurements depends mainly on the ratio diameter of the chamber-to-diameter of the cone. The placement of the tests in the chamber has been elected in order to neglect those effects.

The calibration chamber at Geotechniek is the same as previously used by Broere [16] and Dijkstra [5]. Consists in a 1.9m diameter rigid wall tank as shown in the plot. The total depth is of 3.23 m and of these, 2.5m approximately (depends on each vibration time, hence, sample density) are filled with sand. At the bottom of the chamber there are a certain number of drains embedded in a filter bed and connected to a pumping installation, they are used to saturate the sand bed from below and fluidize the sand.

After the sand bed is fluidized, while the water table is higher than the sand top level, two vibrators fixed at the tank walls are used to vibrate the sand while draining water to a fixed phreatic level chosen 15cm below the surface of the sand to guaranty the fully

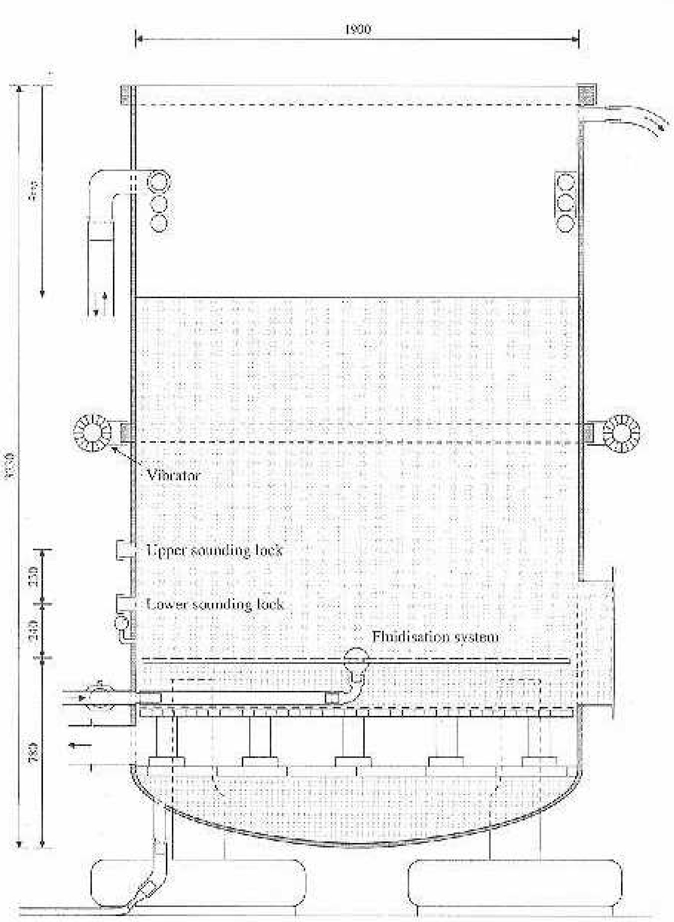

Figure 3.1: Calibration chamber

saturation of the pile tip area. In coming sections the sample preparation is described in more detail.

It can be seen that this calibration chamber does not fit in one of the groups defined by Parkin [17]. instead, it lies somewhere between type BC2 and BC3; it has rigid walls and rigid bottom and the top is a free surface which has not been loaded in any of the tests. The fact that it is a rigid wall calibration chamber makes it special in comparison to most of the calibration chambers used in general research. The boundary effect induced by the rigid walls is larger than for flexible walls, the chamber diameter-to-cone diameter ratio should exceed 56 for those to be negligible.

3.3 The sand

3.3.1 Sand properties

The sand is the same as Dijkstra [5] used and it was already in the calibration chamber. Although in the tank preparation testing normally sand is regarded as an homogeneous sample with reliable knowledge of its properties, some unknown sand was added to the original used by Broere [16]. Therefore, it is important to keep in mid that it is probably not an homogeneous samples and that the input properties are not fully known. A sieve analysis to get a general idea was carried out and the results are hereby presented. It can be qualified as a moderately coarse sand. More detailed properties cannot be obtained with confidence due to the inhomogeneity of the sample, standard values that agree with the type of soil determined by the granulometric curve will be used when needed.

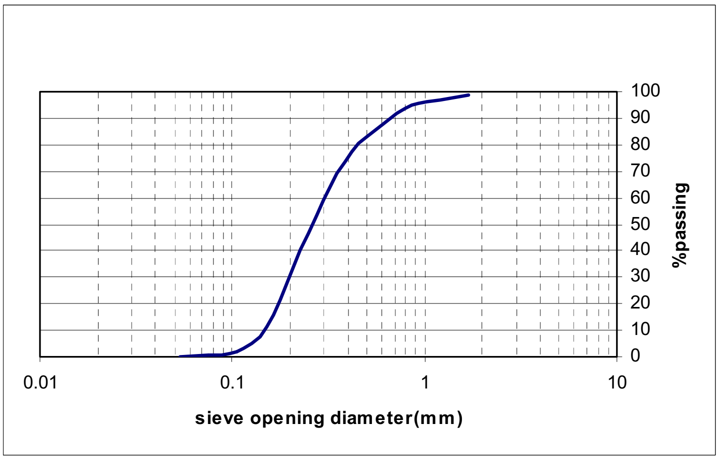

Figure 3.2: Granulometric curve

Some characteristic soil definitions:

- Characteristic soil effective size: $D_{10} = 0.135mm$
- Coefficient of uniformity: $C_u = \frac{D_{60}}{D_{10}} = 2.22$
- Coefficient of concavity:$C_c = \frac{D^2-30}{D_{10}D_{60}} = 0.89$

3.3.2 Preparation of the soil

Within each test series the sand used is the same only the density, i.e. preparation, changes.Calibration chamber samples have been normally prepared by means of the pluviation method by most researchers worldwide. This is not the one used in this research: the preparation consists in fluidizing the sand during 1,5h and then vibrating it. Introducing variations in the vibration time, the density of the sample can be changed. Logically, longer vibration periods will produce denser packages than shorter ones. Mainly three different vibration times have been used: 5, 10 and 15 min. To complete the density range, also tests in non-vibrated sand and 30 min vibrated sand have been performed. Broere [16] carried out some experiments in the same tank and listed a relationship vibration time-relative density. The sand he used is still in the tank but some more was added before this thesis started and with no knowledge of its nature. Comparing the sieve curves for his and our sand it can be concluded that they are really similar, the sand added after Broere must have been of a similar kind. Thus, Broere's table can be used, if not to get the exact value of density, yes to get an idea.
The procedure to prepare the samples can be schematized in 3 steps:

1. Fluidization: 1,5h.
2. Vibration: 0, 5, 10, 15 and 30 min. Changes in vibration time change the density of the sample.While vibrating the sand is kept under water, making the process more effective.

3. Drainage: Phreatic level is set at 15 cm below the surface.

However, this sample preparation procedure introduces some problems but, on the other hand, requires less time and manpower to prepare the soil. The main handicaps introduced by this method are:

- Leads to less uniformly densified samples. Broere noted that this density variations may be responsible for uncertainty in relative density of 10% or less.
- There are vertical deviations in stratification after each tank preparation

3.4 Overview of the test series

3.4.1 Test regime

The 'piles' used in the research are standard sounding rots of 3.33cm of diameter and 1,2m long each. They are pushed into the soil with a sounding device at a standard CPT speed to reach a depth of 60 cm below the surface,then the properly called tests are started.
It has been pointed out above that the test regime is the same one as used by Dijkstra [5] owing to the fact that one of the purposes of this research is to compare dry and saturated tests in order to quantify the effects induced by the pore pressures. This regime was designed to reproduce different loading rates, mainly, static and pseudostatic. A total of 3 different loading rates, corresponding to different test types, are used. Each test series consists of 4 tests of 3 different types:

1. CPT (installation test)
2. Static 1
3. Pseudostatic
4. Static 2

In total, 6 quantities are measured:

1. Tip resistance
2. Shaft friction
3. Pile acceleration (only pseudostatic)
4. Displacement (only static and pseudostatic)
5. Force on the pile head
6. Pore pressures⇒ Note:we are measuring total pore pressures, this is to say, hydrostatic plus excess pore pressures. For the analysis we will have to subtract the hydrostatic value to the measured one, to see how much water pressure the pseudostatic test generates.

Two static tests, before and after the pseudostatic are carried out. The purpose is to evaluate the changes in the soil that have been generated because of the pseudostatic test.

Hereby these tests are described:

CPT

Consists on the installation of the pile at a certain depth (60cm) into the soil, hence, it is a strain controlled test. It is performed with a standard sounding machine, thus, the velocity can be also perfectly controlled and kept constant at 20mm/s.

Static tests

The proper static test would consist in charging the pile top 2 or 3 times its bearing capacity really slowly, taking the test more than 1 day. Static tests are expensive in both economical and temporal terms, for this Dijkstra [5] designed a mechanism to reproduce the static loading. He carried out the test with the same sounding device but keeping it under a very low loading rate of 1mm/s. The main drawback of this way to proceed is that the test and the velocity are controlled manually, making it almost impossible to assure a constant and really low loading velocity. Again it is a strain controlled test: only 2cm axial displacement are allowed, then the test is stopped.

Pseudostatic test

Commercially, pseudostatic tests are performed with the *STATNAMIC* device. Here the pseudostatic loading rates are reproduced (as large as 250mm/s). Consists on dropping a known mass (63.9 kg) with 6 springs (in total 69 kg) on the pile head. A protection cap is placed on top of the pile to avoid damage. The dropping takes place into a steel tube to maintain the loading axially and prevent the generation of bending stresses. The falling height is of 30 cm, thus the initial velocity is 2.4 m/s. Contrarily to the static and CPT tests, this is a stress controlled test. The pile acts statically (this is one of the key assumptions of the pseudostatic tests) but there is no reason to expect the soil to act statically.

3.4.2 Equipment

Loading mechanism

The different loading mechanisms and loading rates were presented in the test descriptions. To sum up, there are two different mechanisms used, one for (a) CPT and static tests and one for (b) pseudostatic tests.

- **Hydraulic actuator**: Constant rate penetration test equipment. Consists in a loading frame fixed to two beams that provide the reaction force when the actuator pushed the pile into the soil. Two level arms control the speed of the penetration, one for the standard CPT velocity ($20mm/s$) and a slower one.
- **Pseudostatic loading**: Dijkstra designed as system composed of [1]:drop mass, aluminum guiding tube, springs and trigger bar. The aluminum tube is meant to guide the dropping mass when falling towards the pile head. The trigger consisted in an aluminum bar and an aluminum rod to hold the ram and launch it to hit the pile.

Measuring tools

For the CPT the equipment consisted in: piezocone, personal computer, software and amplifiers. For the static and pseudostatic tests we also want to measure the force at the pile head, acceleration and displacement, so other electronic equipment is needed.

- **Piezocone**:In order to measure pore pressures, the cone used by Dijkstra has been substituted by a standard piezocone, hence, it would be more appropriate to talk about CPTU than CPT. The cone used has a shoulder placed piezometer. The different types of piezometers have been presented in the literature study. In our case we have type 2, that consists in an electrical cone with a pore pressure sensor located between the tip and the friction sleeve. Smits [18] prefers this kind of cone as it protects the porous element against damage during penetration, it is easy to change its components and the measured pore pressures are not too sensitive

[1] see Dijkstra [5] for detailed description and reasoning of the mechanism

to stress variations in the porous element. This position not only measures the compression induced pore pressures but also slightly registers the effects of localized shear deformation.

- **Strain gauge**: It was used to measure the force at the pile head. Has a bandwidth of $20kHtz$ and measures with a time step of $0.05ms$.

- **Acceleration transducer**: It was only used in the pseudostatic test. Recording the acceleration it is possible to quantify the dynamic component of the test and the behavior of the soil. Besides, integrating the acceleration over time it provides the velocity. The frequency was $20kHtz$. It was installed outside the cone, mounted on a steel plate.

- **Displacement gauge**: It consisted on a linear stroke potentiometer. It measured the movement of the rod, as it was mounted on one of the fixed beams. The measuring pinpoint was placed on the same steel plate as the acceleration transducer, providing that displacement and velocity data had no time differences.

3.4.3 Test location

The penetration tests cannot be randomly located. Dijkstra [5] performed three tests per tank preparation. In this research, only one test per preparation, located 'in the center' is carried out. After one test, the soil is already disturbed and a new preparation has to be made. According to this, tests were performed in the morning and in the afternoon the tank was prepared again.
The reasons why only one test, and not three as Dijkstra, was performed for each preparation are:

1. Allow the soil to freely develop its failure shape, without interference of previous failures.

2. Neglect boundary effects.

The key difference between Dijkstra's research and this one is that now the sand is saturated. The waves will propagate faster and larger areas of the soil will be under the effects of the tests.
Wesley [19] proposed that the ratio chamber diameter-to-cone diameter needs to be in excess of about 35 for loose sands ($D_r \approx 30\%$) and 60 for dense sands ($D_r \approx 90\%$). The ratio in this experiments, with the Geotechniek calibration chamber and the standard cone of 3,33cm of diameter, is of 52,77, approximately 60. From here it can be concluded that the best option is to place just one test in the middle of the chamber, although it is more time-consuming and generates more scatter among individual tests due to variations in the preparation of the sand bed, it will give the best and more reliable results. Also this placement is the best to guarranty soil's freedom to develop its own shape every time.