Large-scale in-situ tests for proven foundation techniques in representative Vienna ground

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1 Introduction

The Municipal Authority of Vienna (Municipal Department 29 - Bridge Construction and Foundation Engineering) initiated a comprehensive research project that included load tests on various proven foundation techniques. The motivation for this project of the City of Vienna was triggered by the paradigm changes of the new standards. Those include the design option for load carrying capacity and serviceability based on load tests.

The Institute of Geotechnics at TU Wien has been consulted as a scientific accompaniment to the research project and is principally responsible for the conception, monitoring, and evaluation of the different tests.

2 Research project “Unteres Hausfeld”

2.1 General

The aim of the project is to determine characteristic soil parameters and to gain information on the suitability of different foundation techniques in representative Viennese ground. This is of relevance because the normative specifications changed fundamentally by releasing the new ÖNORM B 1997-1-3 (Eurocode 7: Geotechnical design - Part 1-3: Pile foundations). For pile load tests performed in comparable subsoil it is intended to reduce the standardized scattering factors and, thus, the standard model factors. Analogously, these provisions also apply to micro piles, anchors and jet grouting piles.

2.2 Location and geology

The test field of the research project is located in the 22nd district of Vienna and, thus, in one of the largest city extension areas. Geologically, the area is situated in the Vienna Basin and within the alluvial soils of the Danube. The area is attributed to the Quaternary / Holocene formation. Beneath the Quaternary formation the Miocene sediments of the Vienna Basin (Upper Pannonium) appear. (MA29-2016)

Fig. 1: Geological Map of Vienna, www.wien.gv.at

The following soil layers were encountered:

- bedding / topsoil
- sediments
- Quaternary gravel
- Miocene sediments (silt, sand)

2.3 Test program

The main part of the test program consists of the static load tests on different foundation techniques. In addition, cyclic load tests are carried out on lateral loaded piles and energy piles.

According to ÖNORM B 1997-1-1, five load tests are necessary to reduce the scattering factor ξ to 1.0. The load tests are referenced to a specific soil layer, representational to two soil types, the Quaternary gravel and the Miocene silt. The skin friction in the upper layers is eliminated by a double steel tube to test the addressed layer only.

Furthermore, the loading direction as well as the manufacturing process, is varied. This results in the following variety of static load tests:

- Bored piles
    - 5 piles with casings, in the Quaternary gravel
    - 5 continuous flight auger piles (CFA), in the Quaternary gravel
    - 5 piles with casings, in the Miocene silt
    - 5 continuous flight auger piles (CFA), in the Miocene silt
- Micro piles
    - 5 micro piles, in the Quaternary gravel, axially loaded, compression
    - 5 micro piles, in the Quaternary gravel, axially loaded, tension
    - 5 micro piles, in the Miocene silt, axially loaded, compression
    - 5 micro piles, in the Miocene silt, axially loaded, tension
    - 5 micro piles, in the Miocene silt, axially loaded, tension, post grouted
- 5 jet grouting piles, in the Quaternary gravel, axially loaded, compression
- 20 ground anchors, in the Quaternary gravel, tension
- 12 pull out tests on steel elements, anchored in a horizontal grouted cut-off (made of jet grouting), in Miocene silt

Special pile tests

- Energy piles
    - Pile with casings, in the Miocene silt
    - Pile with casings, in the Quaternary gravel
- Lateral loaded piles
    - Pile, in the Miocene silt
    - Continuous flight auger pile (CFA), in the Quaternary gravel

2.4 Test area

The area is composed of two separate fields. Test field 1 is designed as a shaft structure. On the one hand it is used for load tests on bored piles and ground anchors and on the other hand it provides insights for a bottom sealed shaft structure with grouted piles between bored piles and a horizontal grouted cut-off. The test field 2 is used for bored piles, micro piles, jet grouting piles, pull out tests and special pile tests.

The arrangement of the reaction piles and the test elements has been chosen in a way that all tests can be handled with the same steel load frame.

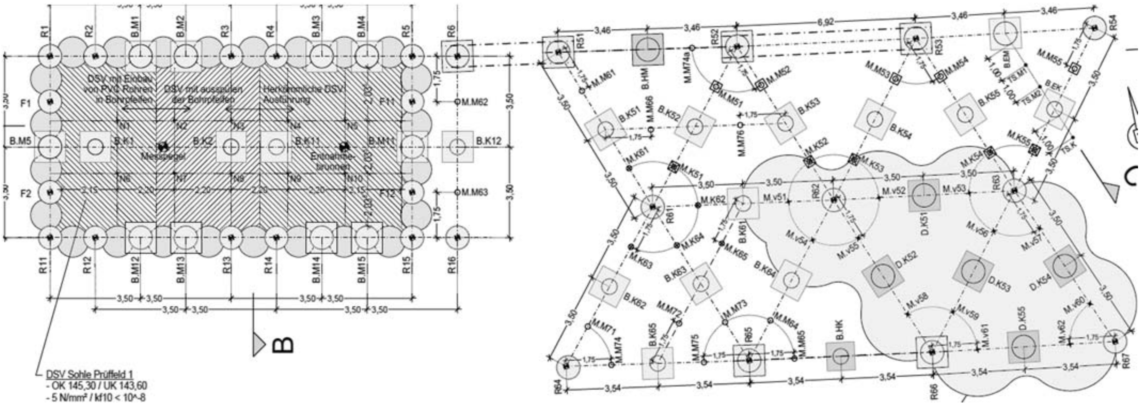

Fig. 2: Ground plan of test field 1 and 2 (Project plan MA29, 2018)

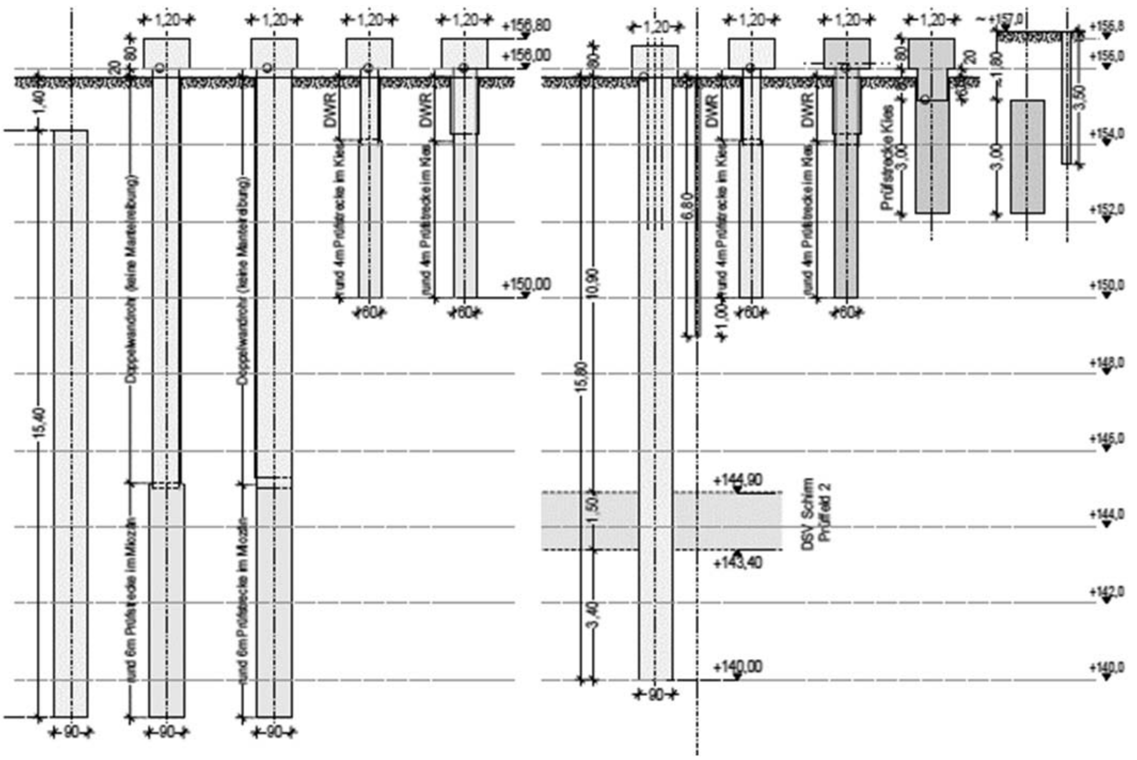

Fig. 3: Cross section of test field 1 and 2 (Project plan MA29, 2018)

3 Pile testing

3.1 Standards

Regarding pile load tests ÖNORM B 1997-1-3 refers to “EA Pfähle” (DGGT, 2012) until the new European standard for load tests will be released. The static load tests are conceived based on the “EA-Pfähle”.

3.2 Principle and instrumentation

The installation of piles and the instrumentation on the pile heads are equal for all load tests. Static loads are applied and held by a hydraulic jack and are measured with a load cell. The abutment for to the jack load is provided by a steel beam that is attached to two reaction piles located at least 2.5 m away from the test pile. Pile head deflections are measured in relation to a fixed reference beam using five displacement transducers and one dial gauge. Telltale measurements are made in reference to a fixed point and using a rotating laser. Pile head and telltale deflection data are continuously recorded. A typical load test arrangement is shown in figure 4.

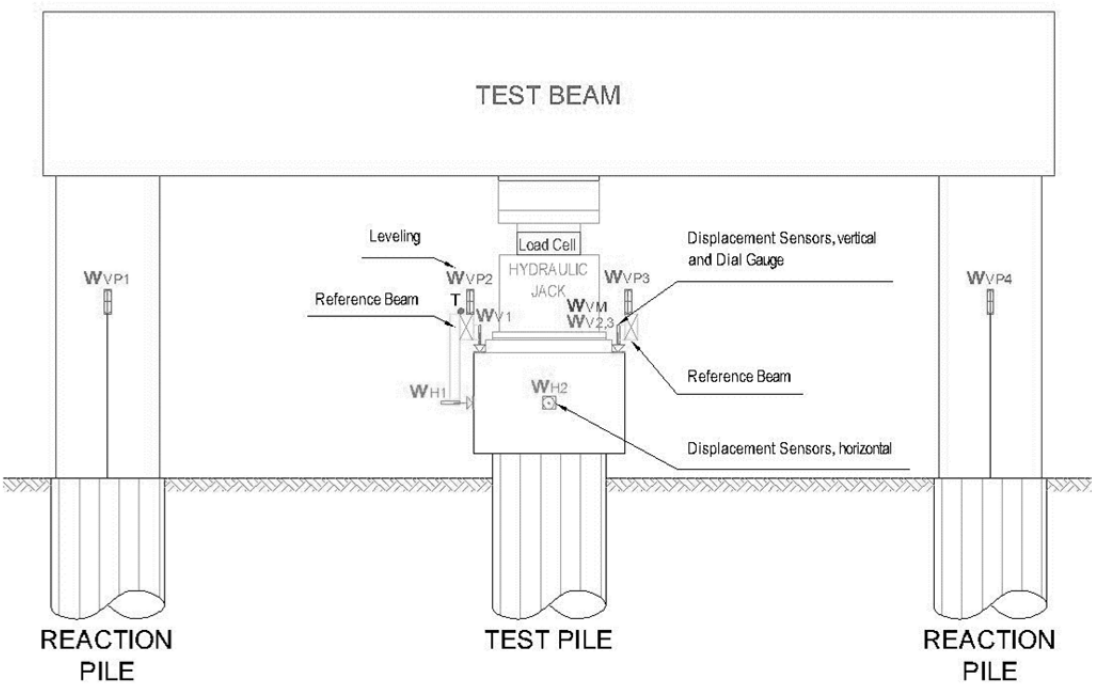

Fig. 4: Arrangement load test (TU Wien)

The ability of piles to transfer loads relies on friction along the pile R_s and on end bearing R_b.

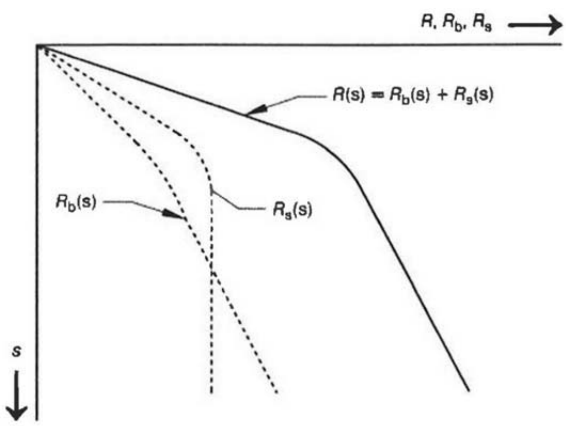

Fig. 5: Resistance settlement curve of a pile, DGGT (2012)

There are different methods to measure the load distribution along the pile. At first, it can be measured by embedding strain gauges (Rebar / "Sister Bar") or installing an extensometer at different depths along the pile. The load distribution and the actual end-bearing load are obtained by calculating the loads at different depths. Another method for determining the actual end-bearing load taken by the pile tip is to measure it directly by installing a pressure cell between the pile tip and the ground below. Geokon, Inc. (2013)

Both methods are used in this project and are combined by using the following instrumentation:

- Retrievable Extensometer (Geokon Model A-9) with 5 transducers:

  The system consists of pneumatically actuated anchors with spring loaded transducers that are connected to each other in series by a single connecting rod. When installed the anchors are fixed in place and the transducers measure the deformation between the anchor positions. The connecting rods are held in tension to eliminate errors due to bowing and friction. Geokon (2013)

- Rebar / "Sister Bar" Strain Meters (Geokon Model 4911A/4911)

  The Model 4911A Vibrating Wire Rebar Strain Meter consists of a short length of high strength steel welded between two 18" (457 mm) long sections of reinforcing bar. It is designed to be welded between sections of the structural concrete reinforcing bar. Geokon (2016)

- Pile Tip Pressure Cell (Geokon Model 4855)

  The basic cell is manufactured to be close to the diameter of the pile. It is comprised of two circular stainless-steel plates welded together around their periphery, leaving a thin space between the plates filled with de-aired hydraulic oil. This oil filled space is connected via a pressure tube to two vibrating wire pressure sensors. End-bearing pressure applied normal to the plate is balanced by a corresponding build-up of internal oil pressure, which is measured by the sensor. The use of de-aired hydraulic oil guarantees that the modulus of the pile tip pressure cell is equal to or greater than the modulus of the surrounding concrete. Geokon (2013)

A large number of tests and different types of piles (piles with casing / CFA) require distinguishing 3 types of instrumentation intensity:

- Typ I: Extensometer + Strain Meters + Pile Tip Pressure Cell
- Typ II: Extensometer + Strain Meters
- Typ III: Extensometer

3.3 Test procedure

The test procedure has been set up specifically for each load test series, according to “EA Pfähle” (DGGT 2012). Every test consists of two load cycles. In the first test cycle, the load is added gradually by four increments from the preload to the characteristic design load and by two increments back to the preload. In the second test cycle, the load is added gradually by eight increments from the preload to the maximum load and by four increments back to the preload.

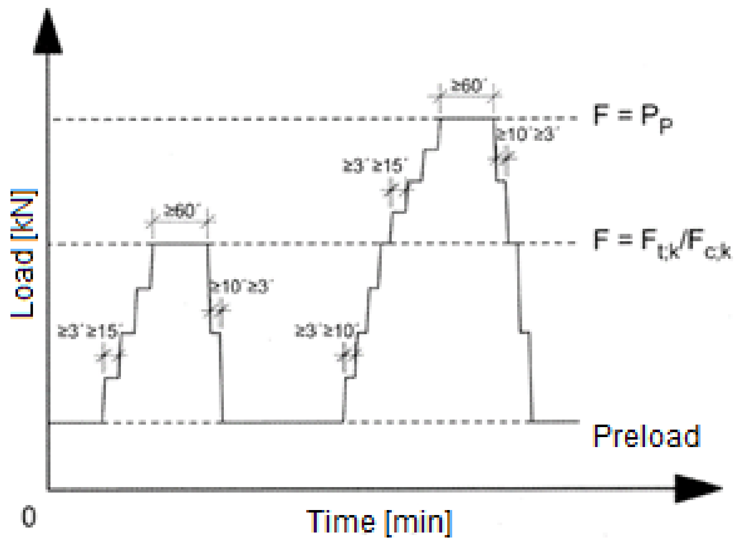

Fig. 6: Test procedure of a pile load test, DGGT (2012)

Each load increment has a minimum monitoring time of 15 or 10 minutes. On the top load of each load cycle the minimum monitoring time is 60 minutes for gravel and 180 minutes for silt.

The settlement rate comprises another criterion to add a load increment. It must be lower than 0.1 mm within 20 minutes from the preload to the characteristic design load and lower than 0.1 mm within 5 minutes from the characteristic design load to the maximum load.

The tests were carried out up to the maximum load of 6,000 kN or to a maximum settlement of 20 cm.

3.4 Schedule

The test phase started in June 2017 and is expected to continue until the end of 2018. All load tests have already been carried out except the tests on energy piles. These special tests start in May 2018. The evaluation of the tests is currently in progress and results will be published later.

4 Literature

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