TESTING AND REINFORCING OF EXISTING FOUNDATIONS FOR CONVERSION OF INDUSTRIAL TO RESIDENTIAL BUILDINGS

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ABSTRACT

Several buildings around the old industrial sites of the Stella brewery in Leuven are being converted to residential buildings. To maintain the historical context of this former industrial site, the buildings are not demolished but renovated and the foundations are mostly reused and reinforced. In cases where the existing superstructure and foundations are maintained and reinforced, this leads to different loads on the piled foundations. Since little information is known about the existing piles, the designers must assess the allowable pile load when reusing the foundation. This allowable load is determined by the structural and geotechnical capacity of the piles, which was investigated through static load tests, impedance measurements to obtain the actual pile length and destructive testing of concrete cores. The difficulty of testing working piles in existing buildings is discussed, as well as interpreting the results and translating them into design values. Finally, the resulting reinforcement of the foundations using VHP grouting is discussed.

Keywords: reuse of piles, static load testing of working piles, VHP grouting

INTRODUCTION

The area of the Vaartkom in Leuven was and still is defined by the presence of the Stella Artois brewery. In the 20th century, the site was characterized by several industrial buildings associated with the brewery, consisting of malthouses, grain silos and warehouses all situated around the canal's cul-de-sac and small port. After the destruction during World War II, many of the buildings were rebuilt on the rubble of the older buildings. This last part can be taken literally, since much of the new piling work was carried out through the rubble of the older buildings.

At the end of the 20th century, many of the industrial activities had left the site and the brewery eventually moved to a nearby location. The area remained desolate. As early as the late nineties, redevelopment of the site had started. Due to the size of the site, this is currently one of Europe's biggest redevelopments that continues up to today.

Some of the existing buildings, such as the Hungaria and Silo site, are being transformed into residential buildings while keeping the original historic appearance. This means that much of the original façade is restored and remains intact, as well as much of the inner structure of columns and flooring.

Although the CO_2 reduction was not the driving factor for this specific case, the possible reduction compared to demolishing and rebuilding is of course significant. Even when only considering the foundation, the reuse of the existing piles led to an optimal use of reinforcement and accompanied reduction of material usage.

FOUNDATION REUSE

For the Hungaria project, the building was stripped and a sprayed concrete liner was used to strengthen the original concrete columns, ceilings and floors. The added weight of this sprayed concrete, as well as the changed floor loads, leads to an increase in the foundation loads compared to the original designed loads as presented on the construction drawings.

The original design existed in reinforcing the original piled pad foundations, consisting of smaller pile groups of 3 to 4 piles per column.

The existing piles are Franki piles, which is a type of driven cast-in situ pile, which was very commonly used in the period during which the building was built. This type of pile is often installed with an enlarged pile base, but there no information could be obtained on whether this was the case or not for this site.

The second, the nearby Silo site, consists of former grain silos that are being transformed into residential buildings. The foundation consists of similar Franki piles, but also of large diameter bored piles underneath the former grain silos.

In total, 4 static load tests were carried out for both projects. Site preparation and foundation reinforcement was carried out by Smet F&C, and the load testing was carried out by Buildwise (formerly BBRI).

INSPECTION OF WORKING PILES

The testing of an existing pile poses several challenges. The piles are situated underneath the existing pad foundations in an existing building and first must be made accessible. This was done by carrying out a braced manual excavation in which the foundation pad and piles (upper 1.5m) were unearthed (see Figures 1 and 2).

Fig. 1. Braced excavation around existing pile – Franki pile

Fig. 2. Braced excavation around existing pile – bored pile

The information that can be obtained from these inspection pits is already very useful. Especially for the silo site, where it was discovered that the piles and their location were not accurate according to the original design drawings, with lesser piles underneath different shapes of foundations.

The inspections also allowed for the measurement of the pile diameter, which also differed from the original drawings. Regarding the pile diameter, one must be careful to extrapolate these findings, since only the top section of the pile could be measured (which can be greater than intended, especially in the softer top soil layers present here).

Before removing a section of the existing piles, the bearing capacity of the remaining piles within the pile group should be checked. For the silos, which are empty now, enough piles were present underneath each pile group, and the test piles could be cut without additional reinforcement.

This was not the case for the smaller pad foundations underneath the Hungaria building, which needed to be reinforced. For that, micropiles were installed at each side and were connected to the foundation pad with wailing beams as illustrated in Figure 3.

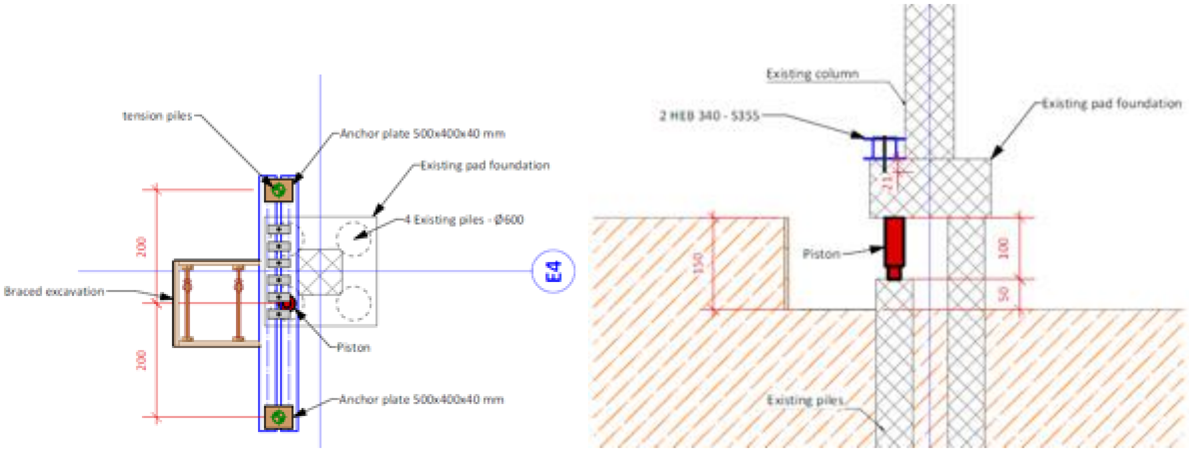

Fig. 3. Reinforcing existing pad foundation with micropiles

The micropiles are designed to relieve the foundation so the upper part of one pile, the test pile, can be removed, but also to serve as tension piles while loading the test pile. In this case, the required maximum test load is higher than the estimated actual column load.

For testing the piles underneath the silos, the silos were once again filled with sand as ballast to serve as reaction mass.

MEASURING PILE LENGTH

The Franki piles were probably driven to refusal, and an exact pile length was not known. Also, reinforcement is not always present along the entire pile length, which makes the use of magnetic methods to determine pile lengths not possible here.

The bored piles appeared to be unreinforced piles, so magnetic methods could certainly not be used.

Low strain integrity testing was used to determine the pile length. Although this method has its limitations, it remains a fast and easy method and is used a lot in practice (French & Turner, 2012).
The pile was tested using the impulse response method, according to the principles of the French standard NF P 94-160-4 (1994). After removing the pile sections underneath the foundation pads, each remaining pile part was struck by an instrumented hand-held hammer on top of the cutting surface of the pile, while the pile head velocity was recorded using a motion sensor attached to this cutting surface. Analysis of the tests was carried to deduce the pile length (from the time and frequency domain signals).

Depending on the assumed wave velocity, a difference of about 10% can be obtained. In this case, an upper bound value of 4000 m/s was used. The higher values correspond to shorter piles, which was further used as safe assumption.

Table 1. Measured pile lengths

Hungaria - Franki	4.1m
Silo - Franki	7m
Silo - bored	7m
Silo - bored	7m

The reported lengths are measured from the top of the pile after cutting. It could be concluded from these tests that the tip of the bored piles is situated approximately 2m deeper than the driven piles.

STATIC LOAD TESTING

Hydraulic jacks were placed between the existing foundation and the cut pile (see Figure 4). Displacements between the top of the pile and the foundation were measured with 2 LVDTs. Movement of the foundation itself was monitored independently through topographic measurements. This allowed not only to correct the relative pile head settlement to absolute values, but also to check the possible uplift of the existing foundation.

Fig. 4. Set-up for pile testing of working pile

Maintained load tests were performed with a constant time increment of 1h, independent of the observed creep. The results of the pile head displacement versus applied load for both bored piles are presented below. Both piles have a similar length and diameter and are installed in similar conditions.

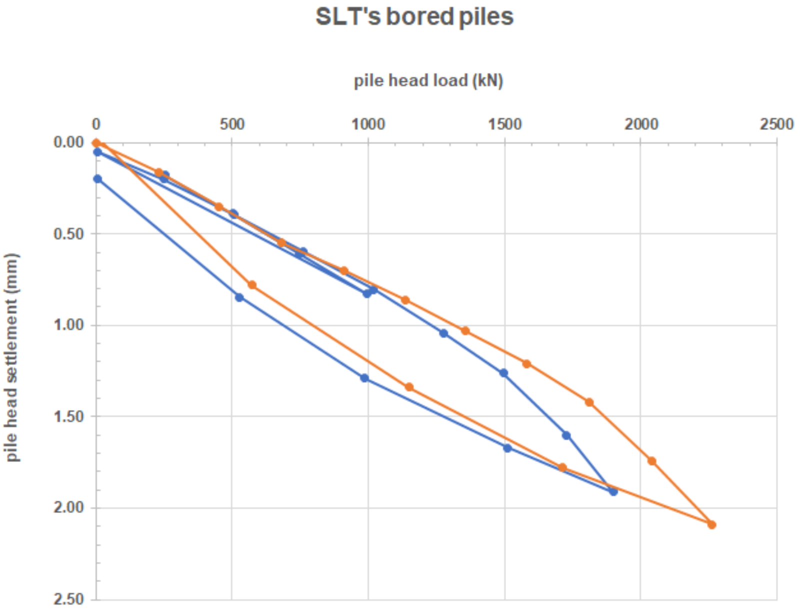

Fig. 5. Results of 2 SLTs on bored piles

The creep rate in both cases was negligible up to the maximum test load. When considering an ultimate pile base settlement of 10%, which corresponds to 100 mm in this case, the piles remain completely in the elastic domain and are far from their ultimate load. Total plastic deformation after unloading was smaller than 0.5 mm. Although the historic load on the piles was not known, it is believed that this load was not higher than the test load. Possibly due to this almost purely elastic pile behavior, the load deformation curve does not allow for an estimate of the maximum historic load on the piles.

The result of the load test on the driven c.i.s. Franki pile is presented below (see Figure 6).

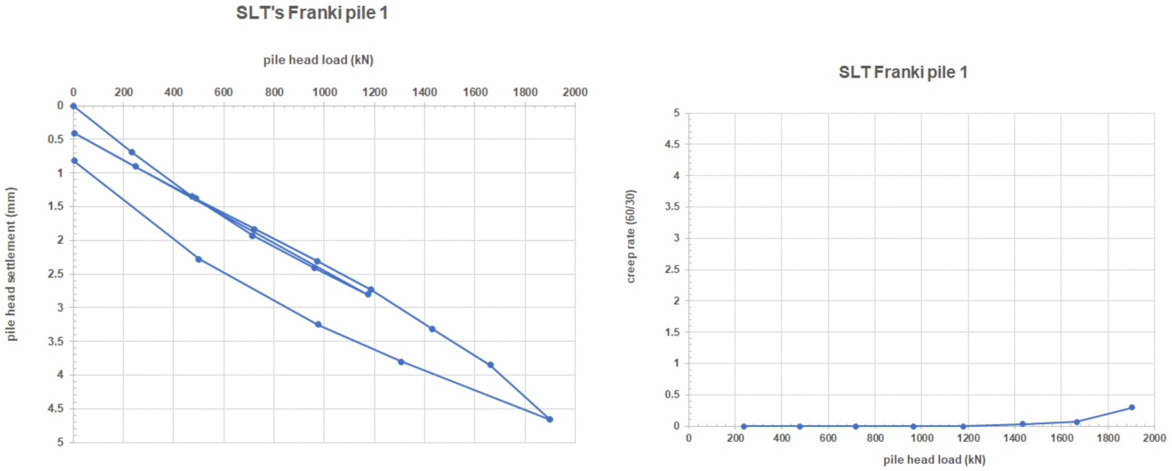

Fig. 6. Results of SLT on Franki pile (Silo)

Only the final load step showed a measurable creep settlement, but it is expected that the pile is still far from its ultimate load bearing capacity.

The results of the load test on the second Franki pile are presented in Figure 7, and lead to very similar results, although at lower values (please note this pile was very short).

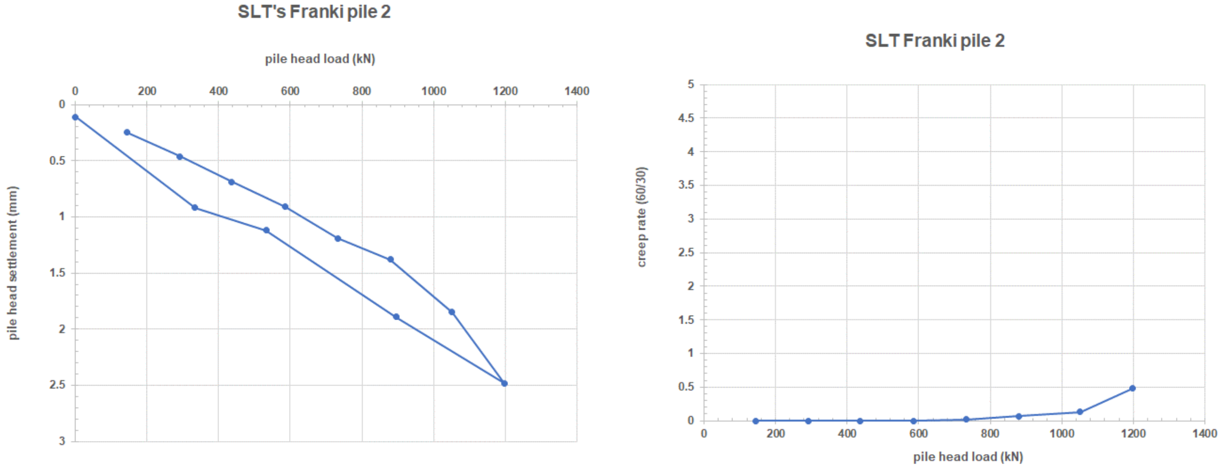

Fig. 7. Results of SLT on Franki pile (Hungaria)

INTERPRETING THE RESULTS OF THE SLT

Since there are no specific guidelines regarding the reuse of existing piles, reference is made to the general Eurocode when designing (a new) pile foundation based on the results of load tests (NBN EN 1997-1 7.6.2.2).

The design value of resistance is determined as:

$$R_{c,k} = min\left\{\frac{(R_{c;m})_{avg}}{\xi_1}; \frac{(R_{c;m})_{min}}{\xi_2}\right\} \qquad [1]$$

With $R_{c,m}$ = measured ultimate value, $R_{c,k}$ = characteristic value, ξ_1 and ξ_2 = correlation factors depending on the number of tests.

n	1	2	3	4	>5
ξ_1	1.40	1.30	1.20	1.10	1.00
ξ_2	1.40	1.20	1.05	1.00	1.00

In the case of a rigid construction, the values mentioned above can be multiplied by a factor of 1.1.

Since the design is based on the results of the load test, γ_{Rd} can be taken as 1 and $R_{c,k} = R_{c,d}$. As in all of the above mentioned cases, the ultimate load could not be reached. R_m is taken equal to the maximum applied load during the test. In Table 2, the results are presented, considering the bored piles as one pile type and the Franki piles as two separate pile types.

Table 2. Design pile resistance $R_{c,d}$

Hungaria - Franki	855kN
Silo - Franki	1359kN
Silo - bored	1428kN

As a reference, the results of a design based on the CPTs according to the Belgian guidelines, at that time (Buildwise, 2016), are presented in Table 3.

Table 3. Design pile resistance $R_{c,d}$

Hungaria – Franki	D_s = 0.46m, D_b=D_s	$R_{c,d}$ = 916kN
Silo – Franki	D_s = 0.40m, D_b=1.5xD_s	$R_{c,d}$ = 1338kN
Silo – bored	D_s = 1m, D_b=1D_s	$R_{c,d}$ = 3233kN

The design of the Franki piles conforms well with the design values based on calculations, if an enlarged based is considered for the silo site but not for the Hungaria site. Or put otherwise, without an enlarged base, the result from the silo site cannot be explained through calculations.

For the bored piles, the design based on CPTs shows that possibly a much higher capacity is present in the piles. This could also be observed in the tests, which show a very stiff pile behavior without any creep up to the maximum test load.

In both cases, it must be remembered that the necessary information for a design based on CPTs only was not possible without the inspections carried out and are only reliable after confirmation through load testing.

DESIGN OF FOUNDATION REINFORCEMENT

Based on the results of the Hungaria site, the necessary reinforcement around the existing foundation pads was greatly optimized and only minor reinforcements through VHP grouting and micropiling were carried out. The works were carried out in 2017 and 2018 and the newly transformed building is now completed.

The design of the grain silos is still ongoing and is being adapted to the results of the pile load tests presented here.

CONCLUSION

The results of pile inspections and static load testing on existing driven and bored piles were discussed. A combination of these results with visual inspections, measurements and low-cost investigations, as well as additional design verifications, led to the possibility of reusing the existing piled foundations. The allowable load on the reused piles probably even surpasses the historic or originally designed load.

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