Underpinning the foundations of the Aura Brewery Castle, Turku, Finland

Kari C. Avellan[1]

[1] KAREG Consulting Engineers, Toolontorinkatu 11B, Helsinki, 00260, Finland

ABSTRACT

The old Aura Brewery Castle brick buildings were built on timber cohesion and end bearing piles. The piles have been subject to changing conditions over the years. The main objective of the work was to prevent additional settlement of the buildings, which was causing structural damage. For this purpose, various studies of the structures and foundations were done, and several solutions applied. One of them was to provide a water supply system with sheet wall enclosure, to keep the water level over the wooden rafts and cohesion piles. Moreover, for keeping the water level constant, the author designed a set of drainage systems for the project. Studies also have shown excessive settlement for the extended northern part of the building, lying partly on rotten piles, and partly on end bearing timber piles, that had to be underpinned with jacked steel piles.

Keywords: underpinning; timber piles as cohesion piles; steel piles; pit work

1 INTRODUCTION

In the old Finnish capital of Turku, the Aura Brewery Castle (Auran Panimolinna, Fig. 1 and 2) represents a fine example of industrial brick architecture of its time. Siting on Lantinen Rantakatu, Westbank of the Aura river (corner of Wechterinkuja), it was built in several phases starting with the main building erected between 1884 and 1885.

Fig.1. View of the Aura Brewery Castle on Lantinen Rantakatu, Westbank (KAREG internal archives)

The northern part was extended on Wechter alley side between 1891 and 1892, and some interiors renovated in 1949. The inner courtyard was realized in 1893 adjacent to the Boiler room wing.

A second building, a warehouse, was added at its western side in 1902. The boiler wing has since been renovated in 1937 and a canopy built on the courtyards side. Furthermore, the Boiler room Wing (including the pot rooms) was again extended in 1952 to the northwest, about three meters. The brewery itself moved out in the mid 1970's, and a vocational School replaced it until the early 2000's, when again facilities were renovated to meet the requirements of modern offices.

Fig.2. View of the Aura Brewery Castle on Lantinen Rantakatu corner of Wechterinkuja ,Wechter alley (KAREG archives)

2 SCOPE OF WORK

The expertise of KAREG Oy was requested in the late 1990's for a general assessment of structures, mostly geotechnical aspects related to the timber piles

of the buildings, including the noticeable inclination towards the Westbank street, which had been the subject of earlier surveys and geotechnical investigations by other consulting firms.

Apart of new surveys realized over an extended period, onsite studies and pile load tests were performed. Designs were implemented for foundation work, including, jacked steel piles, pit work, shotcrete, filling concrete, and temporary anchors (Fig. 3.). An important part of the work consisted in a design solution for maintaining the water table consistently over the existing wooden pile heads. Overall, KAREG was responsible for the project as technical consulting engineer and acted occasionally as onsite supervising specialist.

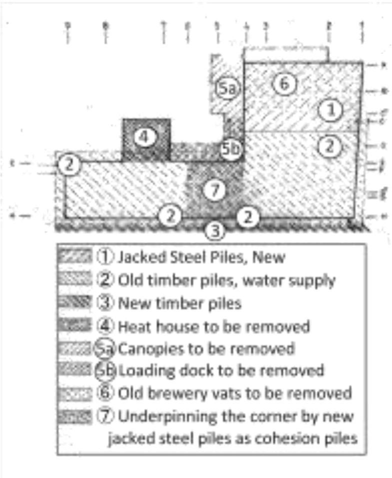

Fig.3. Removed parts of the building and pile types throughout the building sectors (KAREG internal archives)

3 MONITORING OF THE BUILDING

Several factors affect the settlement of buildings founded on wooden cohesion piles. In Finland the post-glacial uplift of the whole *Fennoscandian* region is a consideration to be factored in the long term (Fig. 4.).

Over time, the water table lowers in relation to the ground level, causing the wooden rafts and timber piles to rotten. In the past 120 years the water level has decreased 0.60 m in relation to the earth level.

More specifically for this project, monitoring the building was realized using six reference points which were in use for observation since 1993 (Fig.5.). Observed settlements were from 4 mm to 14 mm over a 6 years period, shown in Table 1. During the monitoring period 1993-1996 the biggest settlement was 14 mm. The medium water level, which is in this case the upper ground water level for the extended part on Wechter alley, decreased under the wooden raft and under the tops of the timber piles as in Table 1.

In another study, inclinations of the main façade wall were calculated by simple geodetical method, measuring on the ground level the distance perpendicular to the façade and measuring the angle to one reference point at its highest point.

Fig.4. Isolines of modern velocities (mm/year) of the post-glacial uplift for the Fennoscandian region (Ekman , Rosentau et al.)

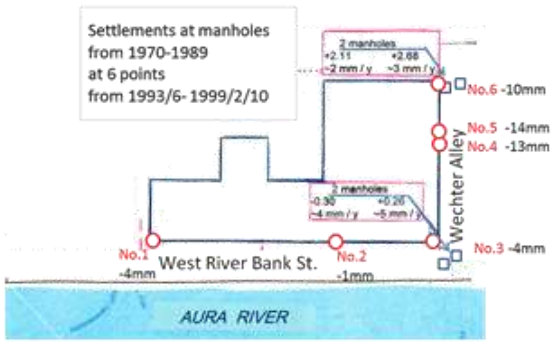

Fig.5. Position of 6 reference points (Maa ja Vesi Oy) and settlement rates mm / year, taken from manholes of rainwater pipes under Wechter alley (City of Turku surveys, 1970-1989)

The more important tilting values as horizontal displacement (71 mm and 95 mm) occurred for the wall facing the Westbank of the river and confirmed the general settlement suspicion, that the Westbank street is consolidating. The thickness of clay was verified on the Westbank Street to be about 19 m, and on the yard side about 12 m.

4 BUILDING UPRIGHTNESS

The estimated horizontal movements and cracking of the buildings brick façade were cause for concern (Fig. 6). The main inclinations as shown in Table 2, were observed on the Aura River (Westbank) façade of the building, were the façade itself, sitting on old wooden cohesion piles, is settling due to the consolidation process.

It was however determined that the settlement for the extended part on Wechter alley was more significantly progressive, as shown in Table 1. Should the settlement had continued there, part of the building could have been in imminent danger of collapse.

Table 1. Monitoring data of observed settlements in mm of the 6 original points (Maa ja Vesi Oy, KAREG internal archives)

Point	6.10.-93	18.4.-95		19.3.-97		1.7.-99		2.10.1999	
	height	height	diff.	height	diff.	height	diff	height	diff.
1	+3.106	+3,105	-1	+3,103	-3	+3,103	-3	+3,102	-4
2	+3,143	+3,142	-1	+3,142	-1	+3,142	-1	+3,142	-1
3	+3,057	+3,056	-1	+3,054	-3	+3,052	-5	+3,053	-4
4	+4,462	+4,459	-3	+4,454	-8	+4,449	-13	+4,449	-13
5	+4,729	+4,725	-4	+4,720	-9	+4,715	-14	+4,715	-14
6	+5,577	+5,575	-2	+5,570	-7	+5,567	-10	+5,567	-10

Visual observation and monitored settlements showed that the wooden rafts and timber piles were partially rotten. This was confirmed by digging test pits.

Table 2. Calculated data of geodetical measurements of façade lines, with highlighted critical values (KAREG internal archives)

Castle street yard side			Wechter alley			Westbank			Southwest		
Line	mm	inclin.	Line	mm	inclin.	Line	mm	inclin.	Line	mm	inclin.
1(A)	+1	1:7000	A	+28	1:250	**1**	**+71**	**1:125**	E	+20	1:350
2(A)	+5	1:1000	B-C	+41	1:220	**2-3**	**+95**	**1:105**	H	-2	1:3500
4(A)	+9	1:600	C	+6	1:1500	5	+43	1:200			
4(C)	-14	1:500	D-F	+7	1:1500	4	+40	1:225			
			F-G	+11	1:1000	9	+19	1:400			
			H	+7	1:1300						

5 INVESTIGATION OF BUILDING FOUNDATIONS PHASES I AND II

To determine the condition of the foundations, several test pits were realized under them, the main ones being test pits KK 1 (Westbank, exterior wall, lines 4/H) and KK 2 on courtyard side (exterior wall, lines 8/E, Fig.7,8 and 9). The timber piles in KK 1 were between ø 22…24 cm each, with lengths between 7.0…8.0 m, 4 piles in a row, c/c ~0.55 m. The timber piles in KK 2 were from ø 19…23 cm each, with lengths variating between 8.5…10.0 m, 4 piles in a row, c/c ~0.55 m. Wood samples were taken from piles, which were then examined for resistance and strength properties. Some old timber piles were test-jacked for 24 h period for creep load tests, as described in ISSMFE Axial Pile Loading Test-Part 1: Static Loading, to determine the pile settlement properties.

The research on wood quality concluded that the timber was in good condition and the piles functional. Also performed were Swedish Weight Sounding Test and Vane Shear Test and gathering of soil samples. The groundwater surface in the test areas was above the piles at the time of the investigation.

Fig.6. Observed cracks in facade of building extension on Wechter alley (KAREG internal archives)

For a second stage investigation, pits were excavated in KK 3 (the outer wall of the Westbank) and KK 4 (boiler room). Of these test pits, wood samples were taken from each top of pile.

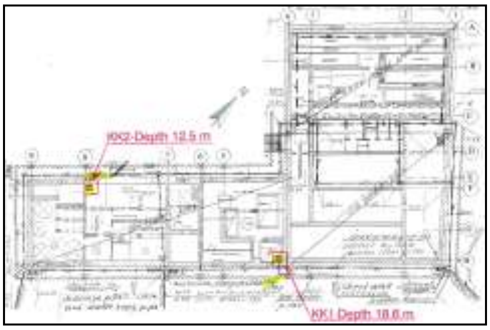

Fig.7. Foundation wall plan with test pits KK 1, KK 2, water supply pipes, drains, perimeter sheet-pile fencing and clay depths (KAREG internal archives)

6 SURVEY OF GROUNDWATER TABLE

In the past, upper ground water table observations were made from several groundwater observation pipes in the area. However, these pipes are, as a rule, clogged and unreliable for precise measuring. For this study, the table measurements were taken from excavated test pits. The results were in accordance to the Turku City elevation measurement standard as shown in Table 3. In the monitoring data, water level is affected by the pumping of the test pits. During pumping, KK I and KK II (Fig. 7 and 8) had high output water flow for several hours at first. After pumping for the study concluded, refiling occurred relatively slowly. The normal level of groundwater recovered in the pits only after several days.

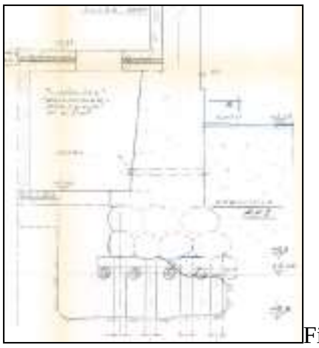

Fig. 9 Exploration pit

Fig.8. Section of pit KK I on Westbank side (KAREG archives)

Table 3. Monitoring data of Water table level variations in meters (KAREG internal archives)

	KAREG Oy 1999				Maa ja Vesi Oy 1997			
	KK I	KK II	KK III	KK IV	KO 1	KO 15	KO 16	KO 17
22.9.99	+0.66	+0.61	+0,24	+0,50	+0,67	+0.62	+0.56	+0.81

7 WESTBANK STREET SETTLEMENTS

Since 1970, the city of Turku has completed monitoring the levels of water-running pipes of rainwater and sewage lines. The Westbank settlement has been estimated roughly to be 1…2 mm a year. The settlement of clay layers (consolidation) also contributes to this. Consolidation is ongoing and expected to last for centuries.

The water running level of the stormwater drain Wechter alley side, area 6 (Fig. 3) was lower than the wooden rafts. According to the measurements taken from manholes at the corner of Westbank and Wechter alley, there is a significantly bigger settlement locally, of about 4.5 mm per year (Fig.5).

9 SEA LEVEL VARIATION AND GROUND WATER LEVEL

The seawater level (MW2000) in comparison to the Turku elevations standard, was measured at -0.291. By monitoring statistical variations of the annual average of seawater level, MW estimations are for the year 2025: -MW2025 =-0.320 Turku elevations standard.

Considering the lowering of the water table of 1 mm on average and post-glacial uplift of 5 mm a year (25 x 5 + 25 = 150 mm), the upper groundwater table can be roughly estimated to decrease by 150 mm, this, without knowing the effect of Climate change.

For this reason, a design solution to keep the water table consistently over the wooden rafts was decided, which consisted in fencing the perimeter of the buildings with a Sheet Pile Wall (Fig. 7.), creating a water table pool, thus maintaining the cohesion support of the existing timber foundation system of the old building block and warehouse, the water level to be automatically maintained alternatively by pumping or draining according to dry or rainy periods. Another simple design solution was to hammer at equal distance new timber piles (Ø 350 mm) in the area facing the Westbank which also extended cohesion of the system outwards of the Westbank street facade.

10 THE BUILDING CORNER AT WESTBANK STREET AND WECHTER ALLEY

This main corner of the building at Westbank street and Wechter alley presented special conditions which had to be dealt with separately. There is one main entrance door at this corner, and pressure (negative skin friction) coming from the street is an important consideration all along the Westbank due to the progressive lowering of the water table and consolidation process. This corner is the only sector of that building which was designed to be underpinned with new jacked steel piles as cohesion piles. (Fig.3).

11 CONCLUSION

This project presented a variety of engineering challenges. Detailed surveys and precise monitoring preceded all design solutions. The main concern was to produce a strengthening and water level protection scheme which would prevent further settlement of the buildings and surrounding area. The objective was also that the building, adjacent land area, including the surrounding roads, would work geo-technically as a whole. The work was conducted with respect to this excellent heritage building and the design brought to a satisfactory conclusion. Its implementation would insure the structural integrity and preservation of this significant example of industrial architecture.

REFERENCES

Avellan, K. C. (2009). Strengthening and underpinning the foundations of the Ministry of Employment and the Economy of Finland at Alexander Street No.4 and 6. 17th International Conference on Soil Mechanics & Geotechnical Engineering, Alexandria, Egypt.

Canadian Geotechnical Society (2006), Canadian Foundation Engineering Manual 4th edition, Vancouver B.C.

Finnish Association of Civil Engineers. Helsinki, Finland (1986)..Foundation Engineering Handbook RIL166, In Finnish.

KAREG Consulting Engineers, Helsinki Finland (2018) Internal archive and database.

Tomlinson. M.J. (1980). Foundation Design and Construction, 4th edition, Pitman Publishing Limited, Bath England.

Ekman, M.A., (1996). Consistent map of the postglacial uplift of Fennoscandia. Terra-Nova, Vol.8, No.2 pp.158-165

Rosentau A., Meyer M.Harff J., Dietrich R., Richter A., (2007). Relative sea level change in the Baltic Sea since the Littorina transgression. Zeitschrift fur Geologische Wissenschaften (Journal of Geological science), Vol. 35, No1-2, pp.3-16