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Strengthening the foundations of the main building of Tartu University, Estonia

Renforcment des fondations de l'edifice principal de l'Université de Tartu, Estonie

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ABSTRACT
Strengthening the foundations of the historical Tartu University main building took place in 1995 and was completed in 1996. The work was the second state of the whole strengthening project and covered the central part of the building. The northern part of the building had been strengthened earlier by the end of 1977. The strengthening work was carried out by method of underpinning, using jacked piles. Steel tube piles were jacked down under the structure, using the structure itself as counterweight. Reinforced concrete beams were constructed on both sides of the thick external wall of the main entrance. The concrete beams were pressed with post-tensioned anchorage against the structure before piling. Inside the building massive pillars were supported by steel beams and jacked piles. A field load test was performed on each pile and the rate of settlements was measured. Archeological diggings were carried out side by side during the strengt hening work.

RÉSUMÉ
Le renforcements des fondations du bâtiment historique pricipal de l'université de Tartu a débuté en 1995, et a été complété en 1996. Ce projet était la seconde phase du projet complet de renforcement, et couvrait la partie centrale de l'édifice. La partie nord de l'édifice avait été renforcée plus tôt, en 1977. Le renforcement a été réalisé par méthode de reprise des efforts en sous-oeuvre en utilisant des pieux de fondations vrillés. Des pieux faits de tubes d'acier ont été installés sous la structure existante en les vérinant contre celle-ci. Les épais murs extérieurs du bâtiment ont été supportés de chaque côté par des murs de béton, et la structure entiére a été contrainte par des ancrages pré-tendus avant l'installation des pieux. A l'intérieur de l'édifice, des pilliers massifs ont été supportés contre des pieux avec poutres d'acier. Des tests d'application de charges ont été réalisés sur chaque pieu, et les niveaux de tassement ont été mesurés.

1 HISTORY

Tartu University was founded in 1632 when the King Gustav II Adolf of Sweden signed the Foundation Decree for the ***Academia Dorpatensis*** in Tartu. During the Northern War of 1700-1721 Tartu suffered great destruction. Among others the Academia buildings were all destroyed in 1700-1704 and the Academia in Tartu was closed until the next century.

The University of Tartu was reopened in 1802 as the ***Kaiserliche Universität zu Dorpat*** with a status of the Russian State University. The foundation act was confirmed by the Russian Emperor Alexander I. The following years 1805-1807 saw the rise of a new university building in place of the old Maria Church, which was also ruined during the Northern War. The new university main building was planned by architect J. W. Krause, and represents a good example of empire style architecture. The southern part of the building rests over ruins of the old Maria Church.

Half century later, from 1856 to 1858, two side buildings were built behind the main building, north and south, planned by architect K. Rathaus. The southern side was built on the ruins of the old Maria Church. At the same time the University Church (later University Library) was built in the backyard of the main building apart from other buildings. The Church was ready in 1860, making the block of university buildings complete as they are today.

Tartu University is located in the very heart of the old historical center of Tartu, and the main building itself will reach 200 years of age in 2007.

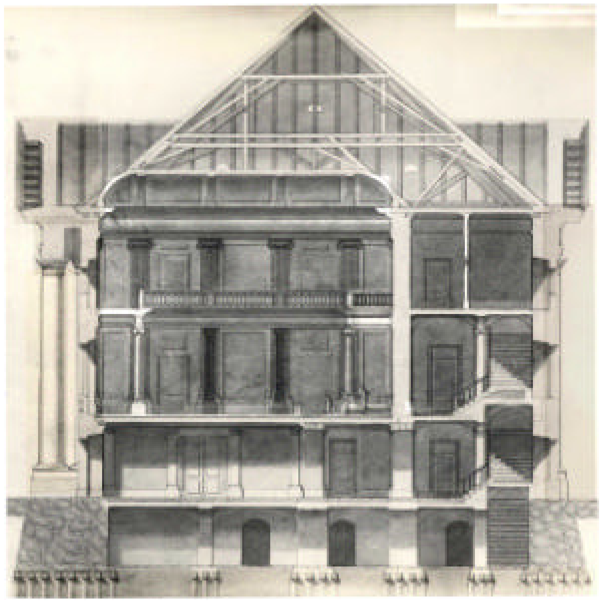

Figure 1. Historical section of the building.

2 OLD STRUCTURES

Outer dimensions of the main building are 36 m x 11-14 m with three floors above ground level and a cellar. In the center of the building, the main hall and the doric style columns of the main entrance reach up to the third floor level.

Massive brick walls and pillars of the building rest on massive stonework at ground level and under. At the cellar level the walls are from one to 1.5 meters thick and the external wall of the entrance is 3.5 m to 4.5 m thick stone and brick masonry. The external walls are laying from three to four meters under the street level.

Massive stones are set over two to three layers of timber rafts, which are supported on timber piles. The timber rafts stay at the level of about five meters below the street level. The basic soil is soft freshwater marl. The thickness of the marl layer varies from 3 to 5 m and the deformation modulus is about 2 MPa. Marl is laying on very dense layer of gravelly soil. The structures and the Dorian columns upon the foundation of the entrance wall are shown on the left side in the historical section of the building (Figure 1).

3 REASON FOR THE STRENGTHENING

The level of the ground water in Tartu has slowly lowered in time. In the last few decades it had dropped below the level of the timber rafts. As a result the rafts and the heads of timber piles have been rottening and the building had started slowly to sink.

The northern part of the building was strengthened first, the work realized in 1977. This work was done using bored piles on both sides of old cellar walls, supporting concrete beams which were cast through the walls. The designer and site manager of the project was professor V. Jaaniso of Tallinn Technical University. He was also the supervising engineer of the project in the years 1996…1997.

In early 1990's it was noticed that the situation under the center part of the building started to be critical. In pre-work archeological diggings the wooden rafts were in some places totally rotten leaving empty cavities at a place they used to be. To proof the situation of cavities, the main author of this paper was asked to be in situ under the foundation (Photograph 1). Especially the area of the main entrance needed immediate repair to prevent any serious damage of the building (Photograph 2).

Photograph 1. In situ proof under foundation.

4 STRENGTHENING WORK

The strengthening work was carried out by method of underpinning, using jacked piles. Steel tube piles were jacked down under the structure, using the structure itself as counterweight. Thick external wall under the main entrance of the building for which it was not possible to dig underneath, were supported both sides with concrete beams and the whole structure was pressed with pre-tensioned anchors before piling. Inside the building, massive pillars were supported against piles using steal beams, which were inserted through the old structure. A field load test was performed on each pile and the rate of settlement was measured. Each pile was tested with Pt = 1.5 Pw. The test was carried out as a repeated load test.

4.1 Preliminary work

Before the actual strengthening work, some major empty cavities under all the walls were filled with concrete. Filling was made side by side with archeological digging. Archeological digging was carried out stage by stage ahead of piling work.

Photograph 2. The University building during the work in 1995.

4.2 The main entrance wall of the building

The strengthening work in the area of the main entrance started by casting concrete beams h x b = 2.0 x 0.5 m², both sides against the original stone and brick masonry of the cellar wall (Figure 2 and Photograph 3).

The stone and brick masonry wall of the main entrance was injected. Then reinforced concrete beams were cast and post-tensioned against the old structure.

Each post-tensioned anchorage consists of 7 plastic-sheathed greased strands (monostrand) SUP 1630/1860, As =140 mm².

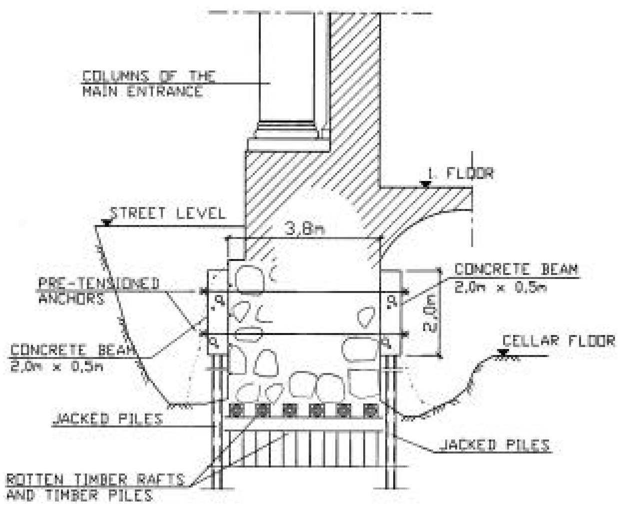

Figure 2. The principal of the work under the main entrance wall of the building.

At first stage the anchorage of seven wires was pulled to 1350 kN. Re-tightening of the anchorages were made nine months after original tensioning, to eliminate any fall in compressive force due to creep of the original masonry. At re-tightening, it was confirmed that each pre-stressed force of anchorage was at minimum 1050 kN as planned. At last the holes of the anchorages were injected with concrete mortar, and anchorage pieces were protected with concrete casting.

Jacked piles Ø 218 x 10 were made under the concrete beams of the external wall. Piles were filled with concrete. The permissible load for the piles was Pw = 500 kN and load test/end wedged action load was Pt = 750 kN. At both ends of the external wall were installed two jacked piles Ø 140 x 8. Before jacking the ends of the wall foundation, consisting of stone and brick masonry, was supported by concrete casting. At last, the steel wedges of the heads of the piles were covered with concrete casting to ensure long time resistance of the structure.

Photograph 3. Concrete beam h x b = 2,0 x 0,5 m² against the old cellar wall and pre-tensionend anchors.

4.3 Walls of the building

External and internal walls were strengthened by jacked piles Ø 218 x 10 against the foundations. Walls were supported by underneath concrete casting. Permissible load was Pw = 400 kN and test load for piles/wedged were Pt = 600 kN.

Under one internal wall, an old concrete structure was discovered during the work. The old structure was off-center to the wall above. That wall was strengthened also by jacked piles Ø 218 x 10 under the wall. To compensate the effect of the off-center piling, steel beams were installed through the wall. Those steel beams were supported by jacked piles Ø 140 x 8 on both sides of the structure. In above mentioned special case the permissible load for the piles Ø 218 x 10 was Pw = 500 kN and load test/end wedged action loads were Pt = 750 kN. The permissible loads for the piles Ø 140 x 8 were Pw = 105 kN, and load test/wedged load was Pt = 1.5 x Pw.

All the steel wedges of the heads of the piles were covered with concrete casting.

4.4 Internal pillars of the building

The pillars inside the building were strengthened by inserting steel beams through the old pillars, and under them were used jacked piles Ø 140 x 8. The old structure was supported by underneath concrete casting. The permissible load of piles was Pw = 92 kN and test load/ wedged force was Pt = 1.5 x Pw.

Steel wedges of the heads of the piles were covered with concrete casting.

5 OBSERVATIONS AND MEASUREMENTS

Movements of the old structures were closely followed by measurements over during the whole work period. The rate of settlements of each pile was measured during piling process.

During the course of the work the movements of the old structures were relatively small and no real deformations appeared. The columns and the wall under the main entrance, which was the most critical area, settled in average 2...3 mm during the piling process, but no cracks were observed. In other parts of the building settlements were smaller.

According to the post-work observations 1996-1997, the columns of the main entrance have not settled after finishing the work and any new deformations have not been found.

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