Tunneling underneath historical buildings of Delft

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Summary

In the city of Delft, the existing two track railway viaduct will be replaced by a 2,4 km four track railway tunnel. The tunnel runs through the historic city centre and replaces a railway flyover, which divides the town in two parts. The alignment of the tunnel is projected below two structures of historic value. One of these structures is a still functioning windmill, called The Rose, built in the 16^{th} century. The other structure is a medieval tower, The Beguine Tower, which was part of the fortification wall that surrounded the city of Delft at that time. To pass below both structures with the tunnel works, two different execution methods were defined.

Below both structures temporary reinforced concrete slabs were cast, and after hardening of these slabs the subjacent foundations were separated from the structures above, which – in the mean time - were taken over by an alternative foundation. Then, the historical buildings were moved in such a way, the diaphragm walls and future tunnel deck could be built at that location. Finally, both the mill and the tower were replaced back to their original location, but now on top of the new tunnel deck. Then, the top down construction process of the remaining tunnel works took place.

The article will focus upon execution techniques, allowed deformation criteria and the design models applied.

Keywords: historical structures, execution techniques

1. Introduction

Both structures were founded on shallow foundations, but in 1950 the foundation of the mill was upgraded by adding 3 meter deep large diameter casings at the canal side of the mill tower. In order to place these buildings on top of the newly constructed tunnel roof slab, it was necessary to separate them from their existing foundations. Therefore, a temporary alternative foundation had to be implemented.

2. Windmill the Rose

A temporary foundation of 45 piles was defined. The pile base level was chosen in order to avoid any bearing capacity reduction of the pile base due to later diaphragm wall installation. Reduction of shaft bearing capacity was investigated through a series of load scenarios. As these piles where located at the outside as well as at the inside of the mill and its attached buildings, the temporary foundation slab had to pass "through" the bearing walls of the structure. Therefore, at regular spacing, holes were cut through the masonry. The temporary foundation slab had to be verified for a wide variety of load scenarios such as : wet concrete of secondary slab as weight on primary slab; concrete slab supported by piles; concrete slab supported by tunnel roof slab; concrete slab during initial loading of the piles and concrete slab during diaphragm wall installation. In order to enable concrete works of the future tunnel roof slab, a working height of at least 2 metres between lower level deck and lower level of the temporary foundation slab had to be created. Therefore, the Mill and attached buildings had to be temporarily lifted by 1,00 m. As the Mill received a monumental

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status, only minor aesthetic damage was tolerated. This minor aesthetic damage was translated into an allowable crack width of 1 mm. FEM calculations of the masonry of the structure showed that a angular rotation of 1/1000 would result into a crack width of 1 mm. After hardening of the concrete deck and stiffener beams, the Mill could be lowered till it reached the tunnel roof level. As the tunnel roof will gradually receive the load of the Mill, the deck will show bending deformation. During this process of load exchange, the temporary foundation slab below the Mill had to stay as

Fig. 1 : masonry mesh from finite lement model seen from different viewpoints

straight as possible (= the initial criterion of maximum differential deformation of 4 mm between two adjacent prisms had to be maintained). As a consequence, the Mill had to be lowered by using about 90 hydraulic jacks, equally spread along the stiffener beams in order to induce as much as possible an homogeneously distributed linear load on each stiffener beam.

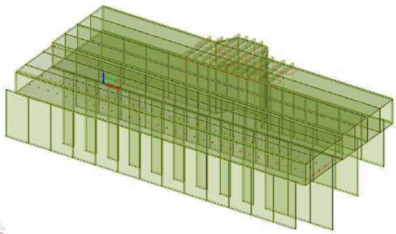

Fig. 2 : 3D model of tunnel at cross section the Mill

At the cross section comprising the Mill, the usually implemented two dimensional approach couldn't be maintained. The spacing between the stiffener beams upon the roof was variable and the span between the diaphragm walls of the eastern tube varied as the diaphragm walls followed the footprint of the Mill. These facts necessitated a three dimensional model of the deck and stiffener beams. Moreover, to define the behavior of the eastern tunnel tube, loaded by the Mill, during the excavation and construction of the western tube and adjacent parking lot, a complete three dimensional model was created.

3. The Beguine Tower

Compared to the Mill, the problem of the Beguine Tower was rather easy to solve. Steel skidding beams were positioned at both sides of the Tower on top of sand / cement –mixture shallow foundations. Upon these skidding beams, cross beams were placed, and subsequently the new foundation slab was attached to these cross beams by means of threaded bars. Finally the existing parts of the foundation below the new foundation slab could be separated from the tower by using concrete sawing. At first, Tower and foundation slab were lifted and then translated for about 18 meters by using horizontally installed jacks. After realizing the diaphragm walls and tunnel deck at the original location of the Tower, the Tower could be moved to its original position.

4. Conclusion

Both heritage buildings were temporarily displaced in order to facilitate the construction of the eastern tunnel tube. The execution methods as well as the defined criteria and allowable deformations showed to be correctly chosen as, at least at the moment of finalization of this article, no damages were reported. Figure 3 gives an impression of the actual state of the Mill execution process.

Fig. 3 : Rebar installation below the Mill