SINT SEBASTIAANSBRUG, DELFT. REUSE REQUIRES CREATIVE THINKING

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ABSTRACT

The Sint Sebastiaansbrug in Delft needed extension to both sides to facilitate a new tramway next to pedestrian, bicycle and car traffic. During the preparation for widening the bridge, major flaws in the construction and foundation were discovered, leading to acute rejection of the bridge.
Initially, a traditional design approach was used, consisting of demolishing the old bridge and building a new one. This resulting design exceeded the available budget by a high margin.
Subsequently, City of Rotterdam Engineering took the available budget as a starting point. Their intention was to reuse as many elements of the previous bridge as possible, even though many of the piles had shown insufficient bearing capacity.
Significant cost reductions were found in not demolishing the cantilever basement and the centre pillar in the water way. Both structures were extended to facilitate the new wider bridge. The extensions made use of new piles that at the same time relieved the old piles. The ramps on both banks of the channel were constructed on geosynthetic-reinforced piled embankments. The fill of the piled embankment consisted of municipal waste incineration ash, reducing the use of primary building material.
The bridge was built according to the new design within the available budget.

Keywords: reuse of piles, bridges, extended pile diameter, geosynthetic-reinforced piled embankments, reinforced soil

INTRODUCTION

The Saint Sebastian bridge in Delft was built in 1964. The bridge crosses the Delftse Schie with a fixed span of 12 m and a movable span of 12 m. In the middle of the waterway, both the fixed and movable bridge decks rest on a pier. The vertical clearance of the fixed part is 4.5 m. On both banks there was an approximately 80 m long access ramp, consisting of a concrete construction on piles. Each section of the access ramp had a span between the supporting structures of approximately 10 m.

Fig. 1. Panoramic overview of the old bridge

During the preparations for converting the bridge to accommodate a tram in 2006, a thorough inspection of the bridge was executed. The inspection conclusions were very unfavourable. Several supporting structures had settled considerably, causing structural damage to the upper structure (Fig. 2).

Adding bearing capacity to the failed foundation, repairing the structural damage and accommodating the tram on a wider bridge was studied in 2010 and was found unfeasible and the uncertainty profile associated with this solution was also considered to be too high.

Then, a conventional bridge replacement (demolishing the old bridge and building a new one) was evaluated. The resulting design required an estimated budget of 50 M euro, which exceeded the available budget by a high margin.

In 2016, the engineering department of the city of Rotterdam was hired to design a new bridge given an available budget of 25 M euro.

Fig. 2. Example of cracks in the concrete

DESIGN CONSTRAINTS

The main design objective was the available budget. Furthermore, the bridge had to accommodate pedestrian, bicycle, car and public transport traffic (tram and bus).
The design team tried to reuse as much as possible of the old structure to optimize the design for the budget. This led to preservation of the bridge elements most costly to replace.

DESIGN CHALLENGES

Demolishing and rebuilding the counterweight basement and the central pillar in the waterway were very expensive.
The concrete structure ramps on both sides of the channel were expensive to replace as well. One of the reasons for these high costs was the foundation pile type that was used to build the original ramps. These precast concrete piles had a toe with an extended diameter, to increase the pile bearing capacity. These wide pile toes had two disadvantages:

- The maximum pile-driving load was limited due to the relatively narrow pile shaft. Therefore, the contractor in 1964 was not able to install the pile sufficiently deep. This resulted in a lower bearing capacity than planned, and ultimately caused the damage to the bridge.
- The removal of the extended-toe-diameter piles is relative difficult, if not impossible. The relatively narrow pile shaft here again limits the pulling force that can be applied, and the wide foot acts as a kind of anchor. This gives high costs for the removal, and pieces will remain in the soil, giving hindrance for the installation of the new piles.

For these reasons (and relatively high production cost), this pile type is not applied anymore.

Fig. 3. Demolished access ramp on the south bank

DESIGN SOLUTIONS

The counterweight basement was reused and extended to both sides to accommodate the wider bridge and the larger counterweight. The hydraulic actuator of the bridge deck has been connected to a separate steel foundation pile to reduce the loads on the old concrete floor and piles of the counterweight basement.

The central pillar in the channel was also reused. However, according to current design codes, the piles had insufficient bearing capacity and the pillar had to be widened as well. The wider bridge deck could be accommodated by extending the pillar to both sides. On each side of the central pillar, four steel tubular screw piles with grout-injection at the pile tip were installed for this purpose, as shown in Fig. 4. Above the new piles, concrete extensions to the central pillar were constructed. Grout jacks were placed between the pile heads and the concrete structure. The new piles were preloaded to pre-mobilize the geotechnical resistance of the piles and at the same time reduce the load on the old piles under the existing part of the central pillar. The load on these piles was reduced enough to comply with current (EuroCode, Dutch annex) design codes.

As a result, the old piles that previously showed insufficient bearing capacity, were able to handle the reduced load due to redistributing a large part of the load to the new piles.

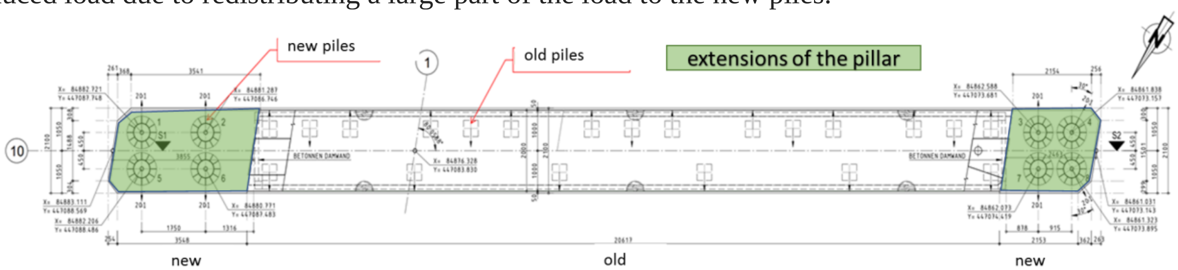

Fig. 4. Top view of the central pillar in the channel

The old piles underneath the failed supports were reused in the new construction. The damaged concrete access ramps were replaced by geosynthetic-reinforced piled embankments, designed following CUR226 (2016). The old piles underneath the supports of the old access ramps had been placed at a 2.5 m x 10 m centre to centre pile spacing. New precast concrete piles were added between the old pile rows to produce a grid of piles centre to centre pile spacing of 2.5 m x 2.5 m.

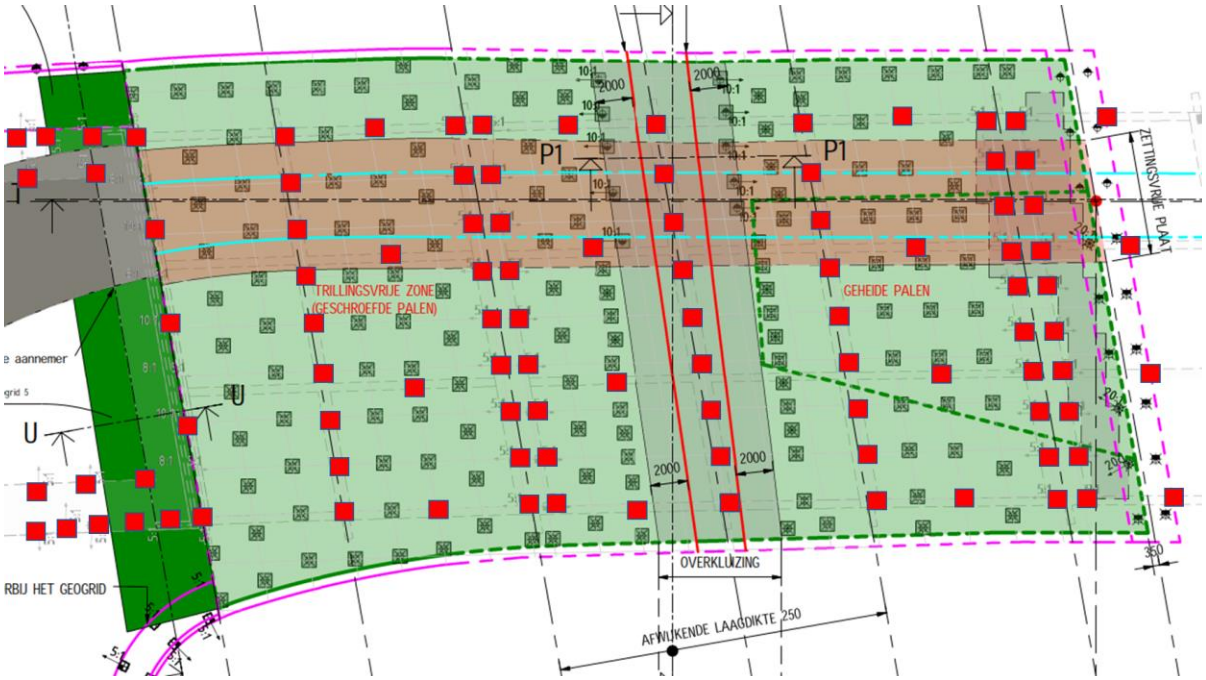

Fig. 5. Piling plan of the access ramp on the north bank with new piles (green) and old piles (red)

Due to limitations in available space, the piled embankments were designed with vertical slopes, using geogrid-reinforced soil, designed following CUR198 (2017).

SOLUTIONS DURING CONSTRUCTION

The bottom 0.80 m of the geosynthetic-reinforced piled embankment was filled with crushed demolition waste granulate. This material has a high frictional strength. Above this layer, sand is usually applied to fill the rest of the embankment, in the Netherlands. To reduce the amount of primary building material and costs, the contractor proposed to use an immobilised fly-ash mixture instead of sand. This mixture will finally harden to form a material like low-grade-concrete. The fly-ash mixture was premixed with sufficient water to allow for the required curing of the immobilising cement.
The immobilised fly-ash mixture has a high pH which conflicted with the chosen polyester geosynthetic reinforcement at the base of the embankment, near the pile heads. To address this conflict, a HDPE membrane was used to isolate the high pH material from the polyester reinforcement. This membrane was installed in the top of the embankment and along the sides of the reinforced wall, preventing rain entering the embankment. The geosynthetics used for the upper layers of the embankment consist of HDPE and PP, for which a high pH is not a problem.

The installation of the geogrids of the vertical slopes along the sides of the access ramps was executed without using a temporary support mould. The contractor used a system consisting of metal grids with internal stability (see Fig. 6).


Fig. 6. Temporary support of the vertical slope

Although installing the 45 degree tension bars through the geosynthetics was cumbersome, in the end the system worked well enough. It took however much more effort to make a more or less straight vertical wall using this system than with a temporary support wall.


Fig. 7. Vertical slope south bank, west side (not perfect but acceptable)

In the original plan, all piles within 20 m of surrounding buildings were planned to be screw-injection (vibration-less) piles. All other piles were planned to be driven prefabricated concrete piles.
However, the contractor proposed to install only prefabricated concrete piles with a push-in piling rig. The proposal of the contractor was accepted because it had also been considered in the design stage. At that time, it was only rejected due to the monopoly position in the Netherlands of the push-in piling company.

Fig. 8. Pile Pusher Pro (drukpaal.nl) piling rig

Piling with the pile-pusher (drukpaal.nl) generally worked well, but many obstacles in the soil were encountered. As a result, piling took more time than planned, but this would have been the case as well with regular pile driving. A significant advantage of the pile-pusher system is the continuous registration of the exerted penetration force. Each pile is documented with a CPT-like diagram. Failing piles could be recognised easily. Piles that did not reach the final depth could be evaluated quite easily for use in the construction because the push-in force is a good indication for the bearing capacity.

Fig. 9. Access ramp south bank (west side) final result

CONCLUSIONS AND RECOMMENDATIONS

In this project were, as far as the authors are aware of, for the first time old piles reused as part of the pile field for a geosynthetic-reinforced piled embankment with vertical slopes.

Other innovations were:

- reusing piled foundation with insufficient bearing capacity by transferring existing loads to newly installed extra piles, thus reducing the load on the old piles
- demolishing as few parts and reusing as many parts of the old bridge as possible

For such a complex project, the total delay was limited, and the full project was successfully delivered within budget.
Although reusing old structures comes with challenges regarding design codes, the potential benefits from an economical and environmental point of view are often considerable. Extending the lifetime of existing structures is the most economical option and is also the most environmentally friendly choice. Second best is reusing as many parts of old structures as possible. Within the constraints of this project, reusing and adapting the existing structures was possible and has been exploited to the fullest. In the end this has resulted in shorter building time, lower cost (25 M euro instead of 50 M euro) and much smaller impact on the environment (less primary building material used, less noise, less traffic diversions and waterway obstructions etc).

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