Assessment of structural Condition of an existing Railway Viaduct after excessive Deformations due to nearby tunnelling Works

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Summary

In the city of Delft, the existing two track railway viaduct will be replaced by a four track railway tunnel. In the central part of the project, where the preferred solution using diaphragm walls as tunnel walls in a top down building sequence was altered into a traditional cut and cover building pit with sheet pile walls; this due to the estimated risk of historic remains in the subsoil. The installation of these sheet pile walls and grout anchor piles induced considerable deformations of a part of the existing railway viaduct. After a first assessment of the viaduct and its foundation, local strengthening of the viaduct piers and slabs was performed. During this period, railway traffic could continue at reduced speed.

Afterwards a geotechnical investigation and some supplementary mitigating measures resulted in the removal of the temporary reduced speed limit. A complete monitoring scheme was defined, related to the possible risks during the remaining tunnelling works of the first phase in order to guarantee the necessary remaining lifetime of the viaduct. This article will focus on the definition of the load carrying capacity of the deformed viaduct, the design of the mitigating measures, the adapted execution process of the adjacent tunnelling works and the applied monitoring, set up as well as obtained results.

Keywords: load carrying capacity, monitoring, lifetime assessment

1. Causes of the encountered deformations

As the sheet piles were installed close to the inclined piles of pier 56, significant deformations were registered by the monitoring system, but as no alarm values were defined, no further actions were taken. Apart from this effect, the grout anchor piles, about one thousand pieces in a dense grid of 2 x 2,5 m were made by vibrating a thick walled casing into the soil. As the installation of the anchor piles neared the pier 56 of the viaduct, the existing deformations rose suddenly to an unallowable degree. Based on the known CPT-graphs, the contractor was not expecting any risk of liquefaction of the Pleistocene sand layer, however large deformations were registered. Monitoring results also showed a much wider settlement trough than originally anticipated.

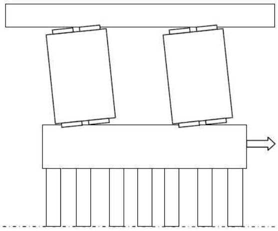

Fig. 1 : Schematic presentation of measured deformations

2. Effects of encountered deformations

The viaduct consists of a series of posttensioned cast in situ hyperstatic concrete slabs of approximately 50 metres of length. These slabs cover 4 spans of 12 to 13 metres. Each pier has two columns, articulated at both ends of the column, thus forming a perfectly hinged support. As the first slab was situated alongside the Bolwerk building pit, while the second slab was parallel to the diaphragm wall part, both slabs behaved otherwise, thus resulting in unallowable curvature of the rails and the formation of gaps

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between columns and slabs.

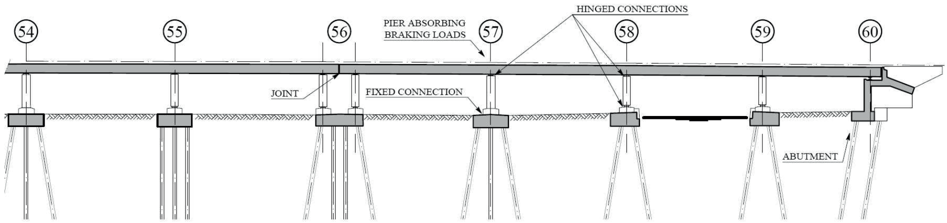

Fig. 2 : Elevation and structural system of the viaduct

3. Performed corrective measures

To ensure the equal partition of the mobile loads into both rotated columns, small steel strips were inserted in between upper and lower half of the supports showing gaps and external splitting reinforcement by means of threaded bars and steel profiles were installed. As serious doubts grew about the geotechnical stability of the pier when the speed of the passing trains should rise again, it was decided to create an extra bearing capacity by using the adjacent sheet pile wall as an extra pile. Through the formation of the gaps, the steel dowels at the supports had to cope with an unforeseen bending moment. Conservative design approaches resulted in plastified dowels, thus unabling to resist future higher horizontal forces due to increasing train speed. Therefore a bypass structure was implemented.

4. Assessment of the viaduct

As pier 56 showed serious deformations, the existing piles below this pier had to be investigated in order to define the allowable future deformations. The measured deformations of the bridge slab suggested a rotation of the piles around a centre point situated approximately at a pile toe depth. In this way, the piles were not subjected to significant bending. The calculated future deformations, caused by the excavation process in the nearby building pit were estimated to be allowable for the piles. The whole bridge structure (slabs, piers, dowels,..) was verified in case the allowable deformations, defined in the newly elaborated monitoring plan, would have occurred.

5. Anticipated mitigating measures and adapted excavation process

Every pier was equipped with a steel strut between the footing and the upper strutting frame of the nearby building pit. Hydraulic jacks could easily be inserted in order to push back the footing that displaced too much. A well defined excavation sequence made it possible to introduce the pre-stress force in the lower strutting frame of the building pit before most of the excavation took place.

Fig. 3 : Adapted excavation process

6. Conclusion

Although large deformations of the existing viaduct occurred during the first execution steps, the functionality of the viaduct could be maintained during the remaining execution works.