Structure-soil interaction during the construction of buried arch bridges

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1 INTRODUCTION

Buried arch bridges are built on both roads and railways, both as underbridges or overbridges. Due to low construction costs, great durability and endurance, they are favoured by contractors and investors. Buried arch bridges are built with spans from 2 m up to 40 m.

This text focuses on the structure-soil interaction of buried arch bridges under construction. The structure-soil interaction during the process of the construction is studied together with the impact of the construction phases on the distribution of internal forces. Methods of mitigating the unfavorable stresses which can lead to cracks development in the structure during the process of construction are proposed.

2 STRUCTURE-SOIL INTERACTION DURING CONSTRUCTION OF A BURIED ARCH BRIDGE

2.1 Modeling the compaction process

Good understanding of the soil-structure interaction during the construction of an ecological overbridge can help design structures which are cost-effective and durable.

The centre-line of the studied overbridge was optimized to the final phase of the backfilling, i.e. in the phase where it is finished. But nevertheless, the phases of the construction process, where the backfill is put in place and compacted, cannot be neglected.

The phases of the backfill placement and compaction process, as modeled in the geotechnical software PLAXIS, are illustrated in Fig. 1.
Figure 1. Definition of the construction phases of the backfill of an ecological overbridge (only the left half is plotted, the problem is symmetric).

Usually, the backfill is compacted in layers 300mm thick to achieve the best mechanical properties. For the numerical modelling, the compaction process is simplified to 13 phases.

The following figures (Figure 2-5) give an overview of deflections, bending moments and axial forces on the structure, which was optimized in the previous chapter, during the process placing the backfill. For better readability, every second phase of the backfill placement is not plotted; the horizontal axis represents the centre-line of the studied buried arch overbridge.

Figure 2. Vertical deflections of the buried arch bridge during the construction.
Natural hazards (optimisation of protection, interaction with structures)

Figure 3. Bending moments on the buried arch bridge during the construction.

Figure 4. Axial forces on the buried arch bridge during the construction.
The Figures 2-4 show, that in the initial phases of the compaction process (Phases 1 to 4), the structure is subjected only to minor stresses. The situation changes in Phases 5 to 9, where the backfill rises up the structure, but does not reach the top of it yet. In these phases, the structure is subjected to opposite loadings than is designed for in the final phase of the compaction process, i.e. the service life, while the prestressing due to horizontal forces in the arch is still negligible. In the final phases, the backfill reaches the top of the arch, the structures reaches the loading conditions which it is designed for.

It is obvious, that all the construction phases have to be considered in the design of a buried arch bridge. Special emphasis must be put on the phases, where the backfill rises up the structure, but does not reach the top of it yet.

2.2 Mitigation of the unfavorable stresses in the structure during the construction of a buried arch bridge

As noted in the previous paragraphs, in the phases of construction, where the backfilling has not reached the crown of the arch yet, considerable tensile stresses appear in bottom fibres of the arch in $\frac{1}{4}$ of the span and in top fibres at the restraint into the foundations. Bending reinforcement must be designed to cover these stresses.

There are two ways how to mitigate the tensile stresses during the process of backfilling:

- Leaving the structure in formwork during the entire compaction process
- Modification of the compaction process

To leave structure in the formwork during the entire compaction process is ineffective, slows down the compaction process and complicates the construction traffic on site, which leaves the only option to modify the compaction process to mitigate the tensile stresses in the structure during construction.

The modification of the construction process lies in putting an additional load at the crown of the arch in the decisive phase of the backfilling which causes tensile stresses the structure cannot sustain without developing cracks in concrete, see Figure 5.

Figure 5. Modification of the construction process of a buried arch bridge.
The load is made by soil put into a prepared compartment at the crown of the arch. The quantity of the soil can weighed to provide exact load to mitigate bending effect of the lateral load by increasing the horizontal force in the arch.

Commonly used buried arch bridges have massive haunches at the point where the arch reaches the foundations. The haunches have adverse effect on the internal forces because they:
- attract bending moments and
- reduce the prestressing effect of the axial force in the arch by the increased cross-sectional area

Thus further improvement of the behaviour of the structure can be achieved by reduction the cross-section of the haunch at the restraint of the arch to the foundations. The slimmer restraint attracts lesser bending moments and the prestressing from the force in the arch acts on a smaller cross-section thus having bigger impact on the reduction of tensile stresses.

Figure 6 shows bending moments during the construction of a buried with additional load put in phase 9 of the backfilling and weakened haunches at the foundations.

![Figure 6](image)

Figure 6. Reduction of bending moments by changing the compaction process and the dimensions of the haunch at the foundations.
3 CONCLUSIONS

This text was focused on the structure-soil interaction of buried arch bridges under construction. The structure-soil interaction during the process of the construction was studied together with the impact of the construction phases on the distribution of internal forces. Methods of mitigating the unfavorable stresses, which can lead to cracks development in the structure during the process of construction, are proposed: leaving the structure in formwork during the entire construction process, which is quite ineffective, or modification of the compaction process of the backfill.

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REFERENCES

