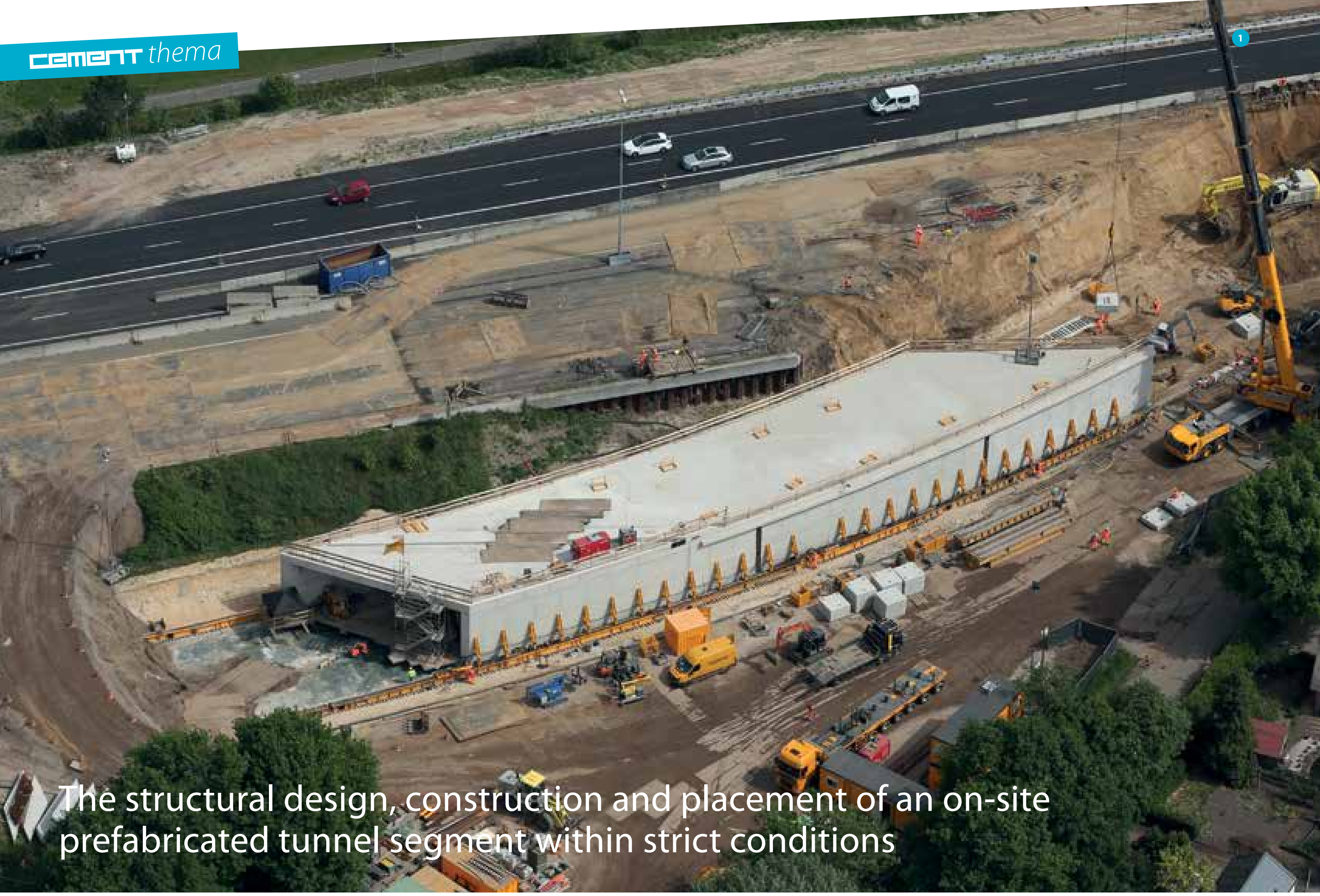

The structural design, construction and placement of an on-site prefabricated tunnel segment within strict conditions

Tunnel underneath highway A12 near Ede

In the Dutch highway A12, near Ede, a new tunnel structure crossing the existing highway was designed and built. This structure is commonly referred to as ODG A12 and provides the underpass junction for the Parklaan and hence an improved accessibility of the city of Ede. The structure consists of several tunnel segments. The largest segment, which provides the actual crossing, was prefabricated on-site and then was placed at its final destination in just one weekend.

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1 View on the monolithic, on-site prefabricated tunnel segment from the air
credits photos: Rijkswaterstaat
2 The tunnel segment during the sliding operation
3 Typical cross section

ODG A12 is part of a metamorphosis of the highway section Veenendaal - Ede - Grijsoord. The highway was upgraded with additional fast lanes as well as several new structures such as bridges and viaducts, allowing an appropriate connection with the adjacent junctions (Grijsoord and Waterberg). Primary objectives for this upgrade were an increased traffic flow and improved traffic safety. In order to realize this upgrade existing structures needed to be modified (e.g. widening of bridges) and sound barriers were placed. Also the use of special asphalt mixtures exhibiting low sound emission properties contributed to a sustainable design solution.

The design of the new structure ODG A12 had to meet a variety of conditions, amongst others architectural requirements and limitation of traffic hindrance during construction and nuisance for the inhabitants and surrounding environment. In this respect it was chosen to apply a sliding operation of the full monolithic structure in order to limit hinder and maintain an operational highway as long as possible. Due to its geometry (15 m wide, 80 m long and approximately 6 m in height) this was a challenge.

The structural calculation models incorporate all subsequent stages of the building process and associated loads, as well as different soil parameters. The section dimensions were optimized to limit the dead weight to approximately 3800 tons. Within the models, soil pressures underneath the structures during the building sequence were carefully monitored in order to limit settlements.

Structural design and design considerations

The main design aspects that had to be taken into account, are:

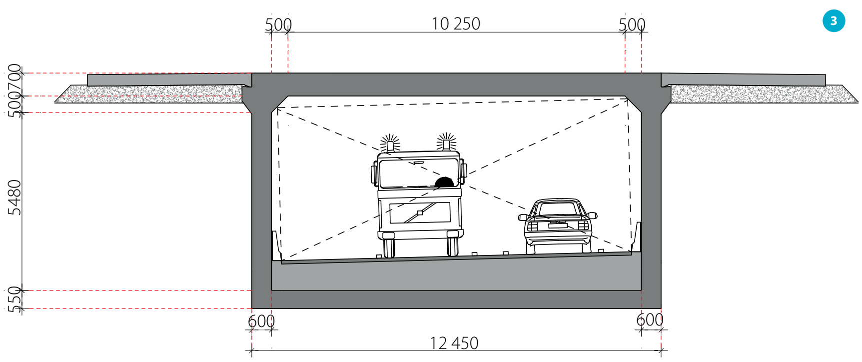
- the tunnel crosses the highway at an angle of 33⁰. This means that the tunnel segment length is large compared to the width of the highway (width of the highway is approx. 36 m, length of the tunnel segment is approx. 80 m);
- the road design for the tunnel is horizontally curved. In order to optimize driving comfort as well as material usage, it was chosen to adopt the same curvature for the complete length of the tunnel. This results in a constant cross section of the tunnel segments;
- soil parameters showed that a shallow foundation was possible;
- essential within this project was to limit traffic hindrance to an absolute minimum. This resulted in an additional requirement in terms of construction technology and intended building phases;
- the aesthetical appearance was mandatory and was derived from the aesthetical vision ‘Regenboogroute A12’, setting an extensive list of requirements. Masonry appearance of the structure was mandatory. At the inner side a finishing consisting of tiles and light armatures was required.

2

The entire structure is made of reinforced concrete (without prestressing). The strength class of the concrete used was C45/55. Figure 3 shows a typical cross-section.

The structure was modelled in Autodesk Revit. In close cooperation with the architects, solutions were designed to satisfy the aesthetical vision. Visuals were created, based on the Revit model, which have been used in several stages of the project, such as requesting the building permit and during meetings with inhabitants.

Figure 4 and photo 5 show an architects impression and a photo taken from approximately the same viewpoint.



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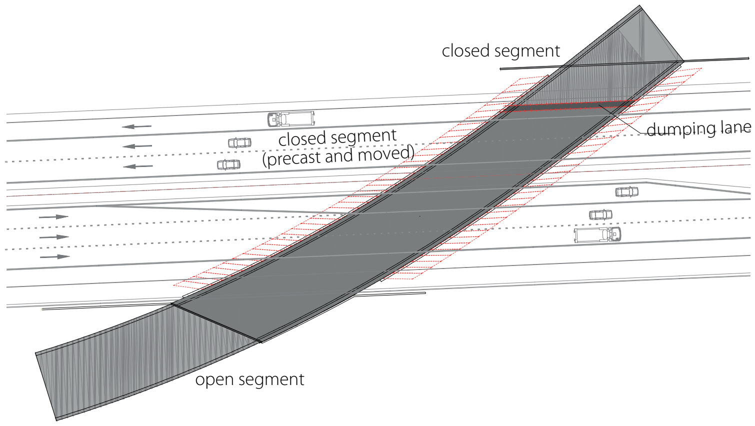

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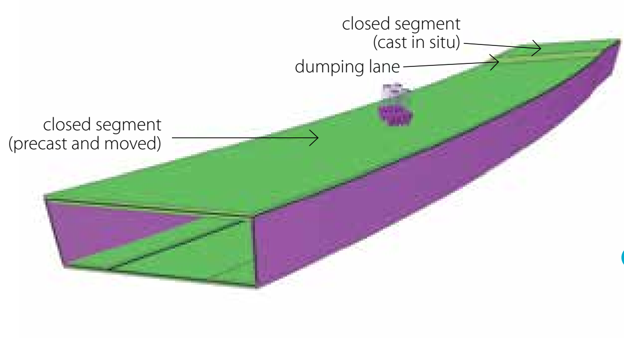

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4 Architectural impression
5 Built situation (under construction)
6 Plan view of the complete structure
7 3D-model of combined tunnel loaded by a tandem axle load
8 Distribution of principle moment m¹ [kNm/m¹]; (a) interior; (b) exterior

Construction phases and relation with structural design

In order to minimize traffic hindrance it was chosen to adopt the following building schedule:

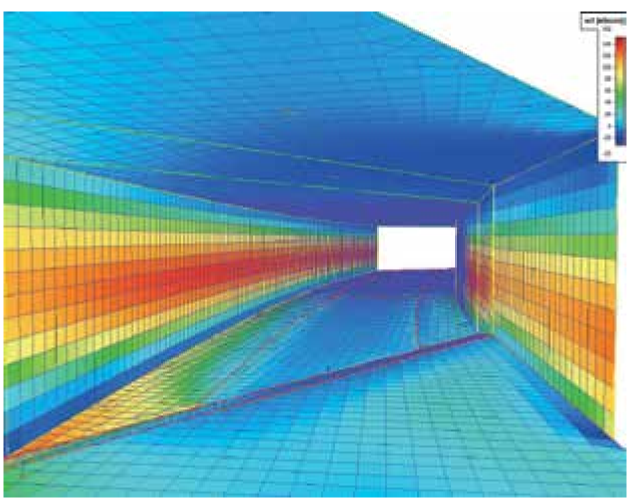
- Building of one tunnel segment at the final position;
- Prefabrication of the major part of the tunnel on-site at a temporarily position;
- Sliding of the prefabricate segment towards its final position;
- Building open tunnel segment.

In figure 6, a plan view of the complete structure is given.

In adopting this building sequence, the highway A12 could remain operational during the entire construction time (photo 1) with the exception of just one weekend. During this weekend tons of earth have been moved to create an opening in the soil body providing the space needed to position the tunnel. Also, at the crossing location, the existing road has been demolished and a new road has been built within this time span.

In the preliminary stages other design solutions, such as the use of (prestressed) concrete slabs combined with temporarily structures (e.g. sheet piles), have been considered. However, all alternatives appeared to be less preferable than the monolithic structure, as now built.

It was decided to apply a sliding operation to move the tunnel segment to its final position. Performing a sliding operation involves the use of hydraulic jacks to lift the structure. To allow for the local jack loads, dowels were cast in with associated local reinforcement. Due to the horizontal curvature, the sliding operation was non-conventional. Since sliding was the preferred displacement technique, the total amount of dead weight should be limited. In the design of the concrete dimensions (e.g. wall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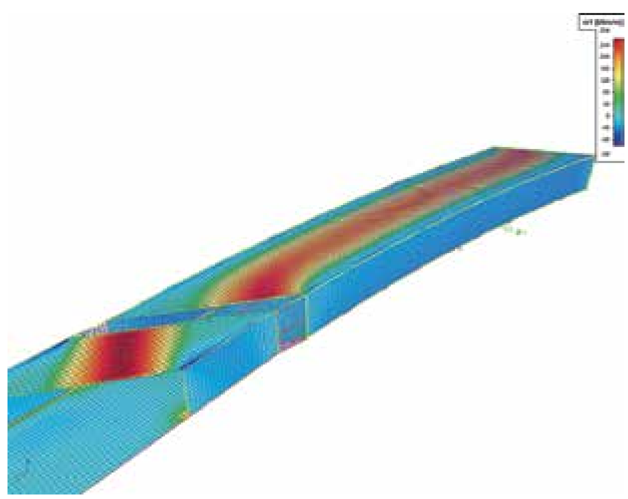
8b

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10

thicknesses, slab depths) this was taken into consideration at all times. It was chosen to adopt a phased casting sequence for the middle part of the floor slab since during the sliding operation the structure was loaded only by the dead weight. After positioning the tunnel segment, the final thickness of the floor slab was created by the second cast. The connection was realized by reinforcement at the interface. Soil compaction allows the ground underneath the floor to be fully mobilized.

Photo 1, 2, 9 and 10 show impressions of the sliding operation.

Calculation method

The structure was modelled in 3D SCIA Engineer. In total three models have been used:

- a shell model of the first tunnel segment (built at its final position);
- a shell model of the monolithic segment to be slided to its final position;
- combined model of the both closed tunnel segments at the final position.

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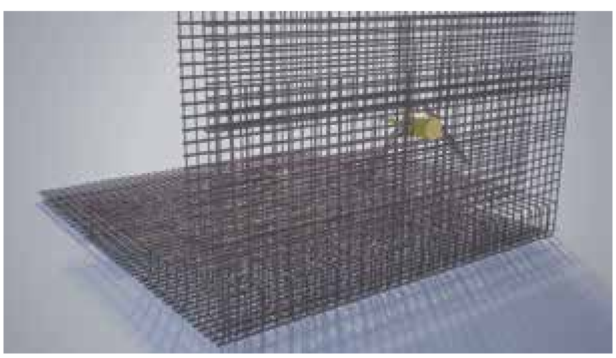

Figure 7 shows an impression of the shell model consisting of both tunnel segments. In between both segments a dumping lane of 2.5 m in width is used.

The building sequence is explicitly taken into account in the models. Based on the results in governing cross sections, amounts of necessary reinforcements are calculated taking into account both ULS and SLS. Within the models, occurring soil pressures underneath the structures during the building sequence were carefully monitored in order to limit settlements. Soil pressures of approximately 250 kN/m^2 were considered allowable.

Figure 8a and 8b show the distribution of the first principle moment in SLS-load combinations. The dumping lane allows for initial settlements of both segments without involving undesirable forces.

A special aspect within this project was the local load on the tunnel walls introduced due to the presence of the hydraulic jacks necessary for sliding. The sliding operation consist of several stages. First, the tunnel segment was lifted initially to obtain clearance between the bottom side of the floor and soil. These jacks are mounted on the steel sliding frame. All dead weight is transferred at the location of the dowels. Figure 11 indicates an impression of the 3D-Allplan model of the reinforcement at this dowel location. Additional reinforcement to prevent breakout is indicated as well. Since lots of jacks were present, the load per jack was relatively low and hence, only a few bars were necessary.

Project specifications / resumé

Heijmans acted as contractor to build this project but is also responsible for the maintenance over a period of 16 years. Wagemaker, in commission of Heijmans, was the structural engineer. The project was started in 2014 with the preliminary stages and has been completed in October 2016. ☒

9 View on the sliding tunnel segment from the side

10 Detail of jacks and sliding girders

11 3D reinforcement model (only one dowel is drawn)