

## Upside Down: Historic Tram Goes Underground – an Infrastructure Challenge on the Way to a Modern City

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## 1 Abstract

To deal with the high volume of traffic in the historic city center of Karlsruhe (Germany), the track system of the historic surface tram is moved underground.

First, seven underground stations are built, which are then connected by using a tunnel boring machine for excavation of the tracks. While the traffic continues on the surface, the new underground stations are being built in sections using the dig-and-cast construction method. Due to the high ground water level bore piles and diaphragm walls of reinforced concrete / concrete cut-off wall are used as excavation pit shoring. A grouted sealing blanket made using jet grouting processes serves as horizontal blanket.

The cover is made while the traffic continues overhead, to this end traffic routing of road and tram traffic is altered in several stages of construction. The subsequent removal of the soil is realized via this newly created tunnel system – this way no truck traffic has to pass through the city center.

The construction is a challenge to permit a limitation of the deformations in relation to the settlement of the immediately adjacent historic buildings and also in the logistics of the construction while keeping the traffic above ground running.

**Keywords:** cut-and-cover design, diaphragm walls, glass-fiber-reinforced plastic (GRP), jet grout bottom, support slab, micro-piles, special foundations, TBM (tunneling machine), water-tight constructions, waterproof construction

## 2 Introduction

Karlsruhe is the third largest city in the state of Baden-Wuerttemberg, Germany, with approximately 300,000 inhabitants. To the west, the city is framed by the river Rhine, resulting in a water table

that is strongly dependent on the water levels of the river. The planned baroque city Karlsruhe dates from 1715 with roads emanating like sunrays from the castle and initially developed solely in a southerly direction. Because of the resulting fan-shaped layout, Karlsruhe has been nicknamed Fan City.