# Gärtnerplatz Bridge in Kassel

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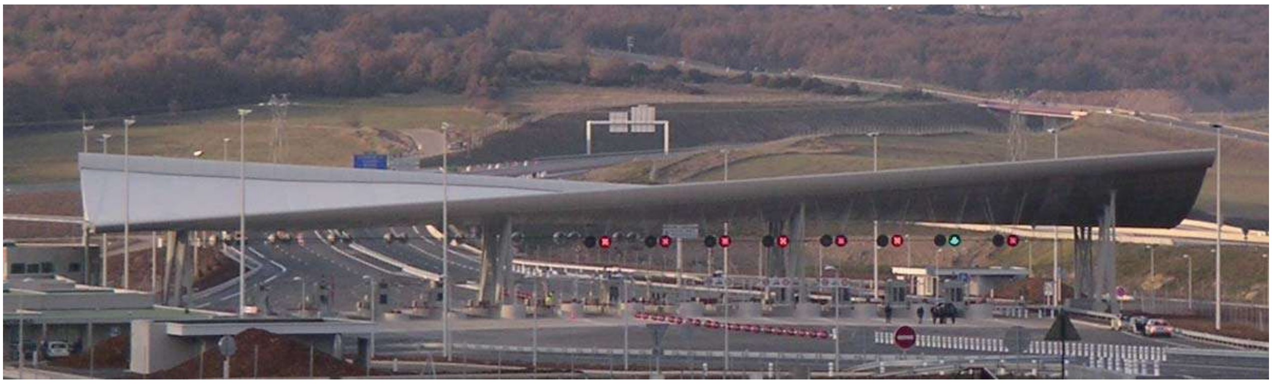
## General / History

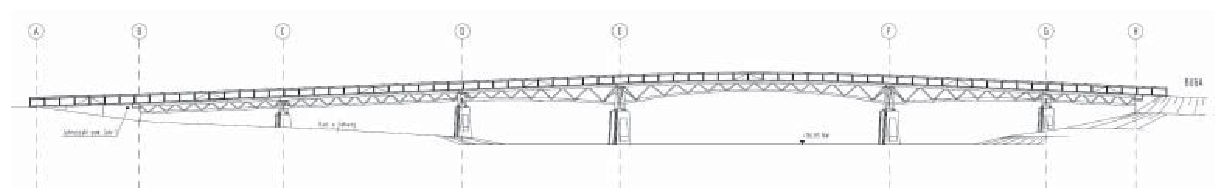
Experimental projects are under way around the world using the new technology of UHPC (Ultra High Performance Concrete).

One of these is a 98x28m concrete structure forming the toll station roof and spanning the A75 motorway, on the approach to the breathtaking new bridge near Millau in Southern France – the tallest bridge in the world – which was built in 2004. For this experimental but functional project, 54 separate curved precast sections were produced using UHPC technology, they were then bonded together with epoxy resin and post–tensioned with steel tendons.

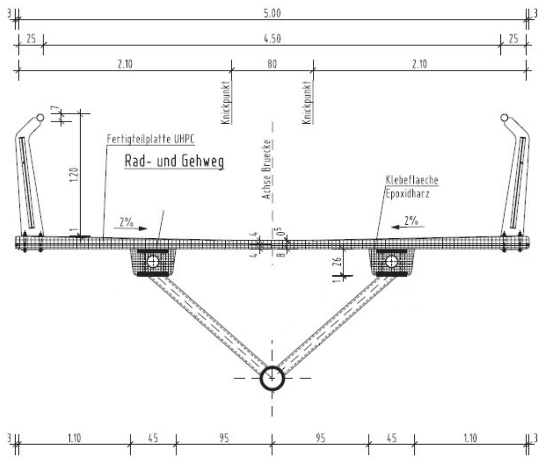


## Gärtnerplatz Bridge

UHPC is also being researched at several universities in Germany. Following some development projects, Kassel Uni–versity used their laboratory results to design and construct 4 small bridges and then the 136m long Gärtnerplatz Bridge.



*Longitudinal section of the bridge*




*Cross–section of the superstructure*

The Gärtnerplatz Bridge across the River Fulda in Kassel is the first large pedestrian and cycle bridge in Germany to use predominantly ultra high performance concrete (UHPC). For the first time in the world, the precast structural components made from this high–strength material with its extremely impermeable structure, were bonded together on site with an epoxy adhesive.

For official acceptance of this innovative individual project, extensive tests were carried out at Kassel University to de–termine the mechanical properties required for the design of the bonded joints and to assess their potential durability.

The operational behaviour and performance of this new hybrid bridge construction system with bonded joints under shear stress will now be recorded online by a comprehensive monitoring system for several years.

## UHPC

Ultra High Performance Concrete (UHPC) is a particularly impermeable fine or coarse grained concrete, practically free of capillary pores and with a compressive strength of 180 to 200 N/mm$^2$. This impermeability and homogeneity also continues to the surface of the units produced with the material. Its surface tensile strength is 6 to 8 N/mm$^2$, which is another good reason for joining the UHPC units together by adhesive bonding instead of with conventional mechanical fixings.

## Bonding of UHPC

Adhesive bonding is already commonly used in the so–called ‘segmental construction technique’ in which precast concrete segments are bonded together in situ, e.g. for bridges, but in these situations the segments are then post–tensioned together. In operation, the longitudinal tensile stresses are absorbed by the tensioning and any shear stres–ses in the vertical segment joints are absorbed by tongued and grooved type profiling of the individual segment faces. This technique has been in use for many years and has confirmed that adhesive bonding of concrete units is durable.

The tensile and shear strengths of standard concrete are low by comparison with its compressive strength. The tensile strength is only about 1.5 to a maximum of 3 N/mm$^2$. Also, the surface zone of the concrete segment to a depth of up to a few millimetres is generally more porous and less strong than the rest of the concrete within the segment. It is therefore removed before bonding, e.g. by blast cleaning.

Unlike standard concrete, ultra high performance concrete has an extremely impermeable structure practically free of capillary pores. This means that gases or liquids harmful to concrete cannot penetrate – but adhesive materials also have limited penetration.

The tensile strength of UHPC without fibres is 6 to 8 N/mm$^2$ and up to 15 N/mm$^2$ with suitable steel fibres included. The flexural strength with steel fibres is up to 35 N/mm$^2$. The fibres also give the concrete ductility in the failure and post–failure range which is necessary for safe design and construction. The surface zone is just as strong and homogeneous (at least in standard heat treated UHPC segments) – and the surface is smooth or can be profiled.

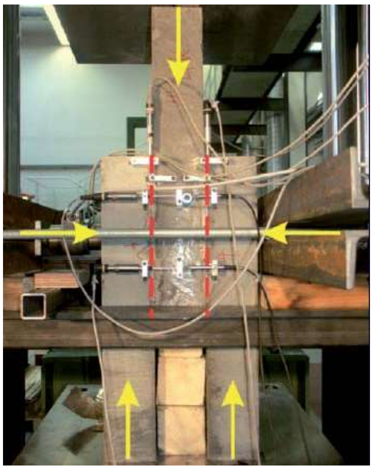
## Tests

The behaviour of adhesive bonds under different loads and climatic conditions was tested on various specimens and under shear/compressive stress on segments produced to scale.

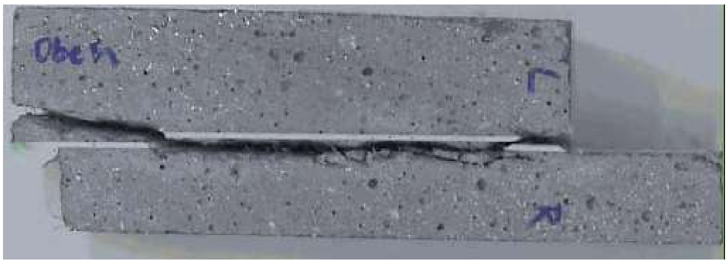
To test the durability of the bonded joints, UHPC prisms and beams were made at Kassel University. Their faces were bonded with Sikadur 30 at 10°C, 20°C and 30°C. These specimens were then tested to determine their tensile, flexural and shear strengths at the different setting times, joint thicknesses and designs, concrete finishes, curing methods and levels of freeze/thaw exposure. The flexural strength was always over 10 N/mm$^2$ and the shear strength always over 12 N/mm$^2$. The bond never failed, only the ductility of the concrete and then the fibres in the concrete were activated.

The durability at high temperature and humidity was also tested. Three bonded bending beams were subjected to 1 million dynamic load fluctuations and the deflection was measured. No fatigue was detected.


*Typical cracking adjacent to the bond in the test slab concrete*



*Configuration for testing of components to scale*




*Shear–tension test*

# Construction of the Bridge

*Gärtnerplatz Bridge shortly before completion*

The Gärtnerplatz Bridge in Kassel was completed in July 2007. The structure consists of a space frame in welded steel tube (steel grade S355J2G3). The precast lattice sections of the top chords (length 12 to 36 m, cross–section 30 x 45 cm) of prestressed UHPC were bolted to the frame with high–strength pretensioned bolts and grouted head plates. The newly–concreted top chord in the centre section was bent to align it with the curvature of the frame. The pre–assem–bled individual bridge segments between 12 and 36 m long were lifted into the bridge bearings. The top chords were then post–tensioned across their full length with internal unbonded tendons. The carriageway slabs measuring 5 x 2 m were first positioned loosely on the top chords and were then raised by mobile installation equipment. The bond faces previously blast cleaned at the precast plant were further abraded with a hand operated needle gun and cleaned with oil–free compressed air. The **Sikadur®–30** was then applied to excess on the approximately 40 cm wide top chords and the bonding and front faces of the slabs. The slabs were laid on top and vibrated until the required thickness of the joint (previously marked with spacers) was reached. An additional measure to ensure a fully homogeneous bond was to ensure that excess **Sikadur®–30** extruded evenly from the joint between the top chord and the slab. The homogeneity of the bond faces and the completed bond between the adhesive and the concrete was checked ultrasonically from the top of the carriageway slabs. Very little entrapped air was detected.

*View of the fresh bond between top chord and carriageway slab*

## Monitoring of the structure

The bridge performance will be monitored with a comprehensive system over the next few years to confirm the labo– ratory results and to learn more about construction with UHPC and bonded joints.

The bonded joints were fitted with strain gauges and creep extension meters and also bridged with optical fibres. Together these enable thermal and load related deformation, plus any changes in the joint condition to be identified, measured and monitored.

## Photos

*View of the fresh bond between top chord and carriageway slab*

*Lattice trusses with UHPC top chords*

*Lifting the 36 m span*

*Lattice truss installed*

*Superstructure soffit with slabs on top*

*Superstructure*

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