A unique transparent structure for the new footbridge across a moat in Darmstadt, Germany

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Summary

The world's first footbridge made from a composite system of wood and Plexiglas® is standing in Darmstadt. As a result of this combination of materials, the structure appears light and largely transparent. It was developed by the Technical University of Darmstadt in cooperation with the manufacturer of Plexiglas®, Evonik Röhm GmbH.

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Figure 1: Palace moat bridge in Darmstadt

In the heart of Darmstadt right at the bell tower of the residential palace a footbridge has been constructed over the eastern palace moat with a unique load bearing structure. A significant portion of the structure is made of Plexiglas®, known in NAFTA as Acrylite®, which is transparent. The construction project described is part of a research cooperation between the Technical University of Darmstadt and Evonik Röhm GmbH.

The architectural design accommodates the height difference between the two bridge embankments by incorporating two "kinks" in the bottom chord of the support structure. The top chord is horizontal. Due to conditions set by heritage consultants it was not possible to transmit loads from the bridge to the existing structure. As a result the bridge is supported independently on two pairs of columns. Hence the static system of the bridge consists of a single-span girder with cantilevers at both ends. A 100 millimeter wide gap between the bridge and the existing structure ensures healthy clearance at both ends.

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The main girders of the bridge are positioned 4 meters apart from one another. Between them is a 1.6 meter wide footpath. In order to give the bridge structure more lightness and to avoid the impression of a transparent tunnel a one meter wide space between the main girders and the footpath was incorporated. In this way the risk of damage to the PMMA sheets could also be reduced. The lateral loads due to wind are transmitted to the bottom chord level through a horizontal Vierendeel truss. These steel I-beams also have the function of transferring the loads from the walkway to the main girders. The wind forces and all the stabilizing loads on the top chord are absorbed by a steel U-frame over the columns. The footpath is sheathed with vertical Siberian larch decking.

Figure 2: Transparent bridge

With this new structural system, the timber chords 2-150x200mm in the main girders withstand the tensile and compressive forces while the 70mm thick PMMA sheets act as webs between the two chords and resist the shear forces. This results in a mostly transparent support structure that appears quite filigraine and light. Each of the twin timber chords are bolted with the Plexiglas® between them. Due to the favorable ratio of the modulus of elasticity of glued laminated timber (larch) and PMMA, the flexural edge stresses that occur in the PMMA are lower than in the timber. At the point of support the load goes directly from the PMMA web into the supporting steel bearing plates. Teflon serves as the separating layer between the PMMA and steel in order to minimize stress peaks that arise.

PMMA is a highly transparent, thermoplastic material that is brittle and prone to stress cracking when unmodified. The mechanical properties are dependent on the load duration and the temperature, amongst other things. The microstructure is loosened by increasing temperature. The thermal expansion of PMMA is very high at 70×10^{-6} 1/K. Reactive forces arise due to the fixed connections to the timber. In the course of the approval process an expert opinion was furnished and various tests were carried out at the Technical University of Darmstadt. In addition to tests of the stability of PMMA sheets, many specimens were tested for bearing pressure in bolted connections. Since PMMA is a brittle material, it is very susceptible to the notch effect. The quality of the bore hole is of crucial importance.

The entire bridge was prefabricated at the factory of the wood construction company carrying out the work. The machining of the PMMA sheets such as sawing, drilling, etc. took place with tools specified by the manufacturer on a five-axis CNC machine also located there. Subsequently each of the four sheets were connected to the 26 meter long twin wood chords using bolts. Seven coats of varnish with a total thickness of one millimeter were applied to the timber as weather protection and flashing was installed on the upper side. The bridge was then transported to the Darmstadt palace in one piece with trailer trucks. With great public interest it was lifted into position within a short time that night and mounted on the steel columns that had been installed that same evening.

Technical data	
Length	26 m
Total width	4 m
Width of footpath	1.6 m
Height over ground	2 -3 m
Girder height	2.3 -3 m
Weight	28 t
Construction time	4 months
Inauguration	12 Oct 2007