# Strengthening of a Barrel-Shaped Roof using Textile Reinforced Concrete

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## Summary

When reconstructing the Zwickau School of Engineering for use as an IRS Office it became necessary to strengthen a reinforced concrete roof structure more than 100-years of age with textile reinforced concrete (TRC). Compared to other strengthening options, only TRC was able to meet the varied demands of monument and fire protection, the architect, as well as the construction company/contractor, while simultaneously meeting all static standards. The thin TRC layer, made of fine-grained concrete with embedded textile reinforcement, was applied to the roof structure in a total thickness of only 10 to 15 mm.

**Keywords:** Textile Reinforced Concrete; TRC; Strengthening; barrel-shaped roof; Zwickau

## 1. Introduction

Seldom buildings are used in the same manner consistently throughout their entire lives. The consequences are reconstruction or changes to the supporting structure. Renovation and reuse of existing historical buildings in particular not only require adjustments in terms of the structure's future use but often also compliance with specific aspects of monument conservation. The structural safety of the existing structure is to be assured without major consequences to the existing load-bearing system.

TRC is a new, effective and quite innovative strengthening composite material that can be utilized in building rehabilitation. It combines the advantageous material features of concrete with those of high-tech fibre substances. Reinforcement is provided by continuous high performing fibres consisting of either alkali-resistant glass (AR-glass) or carbon, rather than steel. This textile reinforcement permits a load-orientated arrangement of the strengthening when fibres are fabricated into a grid structure, thereby providing efficient use of these high quality component materials. In order to strengthen reinforced concrete components, one or more thin layers of textile reinforcement are embedded into special, fine-grained concrete and then subsequently applied to a constructive element/component (Fig. 1).

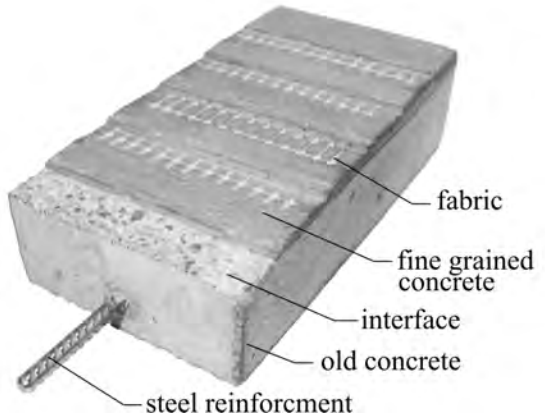


*Fig. 1: Principle of strengthening with textile-reinforced concrete*

This strengthening method does not require any concrete cover for the corrosion protection of the textile reinforcement. The component unit size is therefore only enlarged by mere millimetres. Compared to strengthening methods using concrete topping or shotcrete, the increase in dead-load is extremely small. The ductility and workability of TRC layers enables an easy

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application to curved surfaces, as well.

The use of TRC does not only decrease deflection, crack spacings and widths in the serviceability limit state significantly, the flexural capacity can be augmented by a factor of up to 2, as well. Experiments have already shown that even component resistance against shear forces, axial forces (especially in columns) and torsion can be augmented.

The following is a sample report on the use of this new strengthening system for a historical, barrel-shaped, reinforced concrete roof. Information concerning the building materials and the reinforcement design are shown at the beginning.

## 2. Strengthening of the barrel-shaped concrete roof

The school of engineering, which was built in 1903, was reconstructed within two years from 2007 to 2009 and will now house the IRS Office of Zwickau. The strengthened barrel-shaped concrete roof spans a column-free hall measuring approximately 16 m × 7 m. In total, eleven beams are aligned by a 80 mm thick monolithic reinforced concrete slab. Each of the beams is 200 mm wide and 250 mm high. Nine out of ten roof zones have a light opening in their mid-section. It is a curved and textured shell structure.

*Fig. 2: View of the old engineer's school of Zwickau prior to the start of reconstruction*

Concrete and steel quality, as well as the reinforcement configuration, were determined from a comprehensive material examination.

After checking the bearing capacity of the consistent construction in the first stepp calculation of the strengthening followed subsequently. The required textile reinforcement was determined using preset internal forces, the pre-load and pre-deformation of the existing concrete construction.

The used TRC consists of a standard fine-grained concrete mixture developed by the Collaborative Research Centre 528 and an orthogonal textile reinforcement structure which was produced by the Institute of Textile and Clothing Technology at the TU Dresden. The carbon roving's possess a fineness of 800 tex (4.000 filaments with a diameter 9 µm) and a cross-sectional area of 0.45 mm². The modular dimension is 7.2 mm in the warp direction and 14.4 mm in the fill direction. The tensile strength was assumed to be $f_{tu}$ = 1.600 N/mm² and the ultimate strain $e_u$ = 8 ‰.

The strengthening of the construction was carried out by experienced staff specially trained in strengthening reinforced concrete bearing structures. In order to provide a sufficient level of load-transmission, the splice, located between the existing and fine-grained concrete, was uncovered by sandblasting. Before that the existing plaster layers had been removed in order to expose the granular structure of the existing concrete. After pre-wetting the subsurface the first layer of fine grained concrete was applied using a wet-spray coating method. The thickness of the concrete layers was 3 mm. After that the textile reinforcement was worked into the existing concrete by slightly pressing and smoothing it with a trowel. This procedure was repeated until the required numbers of layers were applied to obtain the pre-determined strength levels. The end result was the provision of a strong TRC strengthening cover layer with a thickness of approximately 3 mm.

As shown in the example of this historical shell structure which was converted into a new IRS Office, a significant, economic increase in the ultimate load of existing structures can be achieved by using TRC, an easily produced and flexible strengthening system.