Refurbishment of the concrete-glass windows of Aachen City Hall

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Summary:

Textile-reinforced concrete, an innovative composite material, creates new opportunities for the refurbishment of historic buildings. For example, particular filigree components, such as the historic concrete glass windows of the Aachen City Hall, would benefit from the corrosion-resistant carbon textile reinforcement. The 60 years old windows had to be repaired because of the corroded steel reinforcement and concrete spalling. Therefore, the glass pieces embedded in the concrete were separated and reinstalled in reconstructed concrete-glass windows. The steel reinforcement was replaced by carbon reinforcement. Thus, the historic monuments protection authorities' terms were respected while avoiding future corrosion damage.

Keywords: refurbishment, architecture, textile reinforced concrete, carbon reinforcement, high-strength concrete

1. Inducement

The gothic Aachen City Hall is adjacent to the Aachen Cathedral, the most distinctive building in the imperial city of Aachen. It is one of the most important medieval state buildings in Germany. Erected on the foundations of the King's Hall of Charlemagne from the 8th century, this palace was built for the coronation ceremonies of German kings. The palace has been adapted and restored gradually to comply with contemporary requirements or demands. In 2014, the City of Aachen celebrates the 1200th anniversary of Charlemagne's death, for which parts of the old City Hall were refurbished.

The focus of the renovation work is on the Marien tower (fig. 1), the main apse of the former Kingdom Hall. Particularly striking features of this structure are the spire and the concrete-glass windows, which should reflect the appearance of the quarry stone walls.

The windows vary in appearance and size, and consist of glass stones embedded in a 3,5 cm thick concrete layer. The distance between the rows of glass stones is about 2,5 cm, reinforced with 5-mm diameter horizontal steel bars. The windows are surrounded by a steel frame, which is required to anchor the windows in the wall and served as lost formwork. Due to the small concrete cover (around 1,5 cm), concrete spalling occurred and the corroded reinforcements surfaced (fig. 2). Consequently, the refurbishment of the historic windows was essential.

Fig. 1: Aachen City Hall and Marien Tower

The regulatory constraints of the historic monuments protection authority for the refurbishment of the concrete and glass window were to maintain the appearance of the original window. Identical glass stones were to be used, reusing those already used in the old windows. In addition, the positions of the glass stones in the windows were required to remain the same. As a consequence, the thickness of the concrete layer (3,5 cm) could not be changed. Thus, the thin concrete cover must be maintained. This excludes a reapplication of the steel reinforcement, which would not be sustainable.

2. Solution

The refurbishment of the historic concrete-glass windows of Aachen City Hall was an extraordinary challenge. The use innovative carbon reinforcement contributed significantly to the solution of the problem. With the use of epoxy-impregnated carbon textiles and a high performance concrete, a corrosion-resistant solution was found.

As textile reinforcement, a scrim of carbon filaments was used. The cross-sectional area of the textile reinforcement mesh is 110 mm²/m, with 4,18 mm² per roving. To increase the ultimate stress of the roving, the fabric was impregnated with epoxy. By doing so, stresses of more than 3000 N/mm² can be achieved, corresponding to a tensile force of 12,5 kN per roving. In addition, the handling and robustness of the reinforcement is increased.

As concrete, a composition with a maximum grain diameter of 5 mm was utilized. The concrete has a compressive strength of 87 N/mm² and a bending tensile strength of 10,6 N/mm². The high material strength is particularly suitable for components that have to remain uncracked in use.

Fig. 2 shows a sectional view of a window segment. All required components for the production of a concrete-glass window are shown.

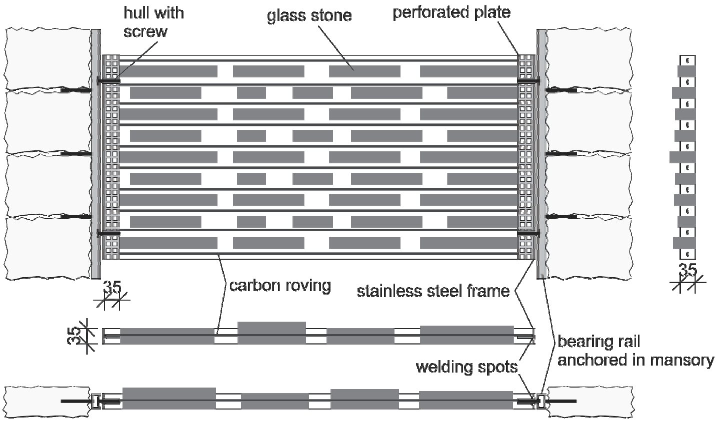

Fig. 2: Sectional view of a concrete-glass window

Bending tests showed that the glass stones are the decisive component for the structural behaviour in the service state. The glass failed due to compressive stress before cracking occurred in the concrete. Subsequently, the test load was almost doubled to a breaking moment of 2,5 kNm/m, which corresponds to a wind load of about 14 kN/m².

In addition, due to high aesthetic quality of the concrete (fig. 3, right), the executed solution (fig. 3, left) also impressed the historic monuments protection authority and critical monument conservators.

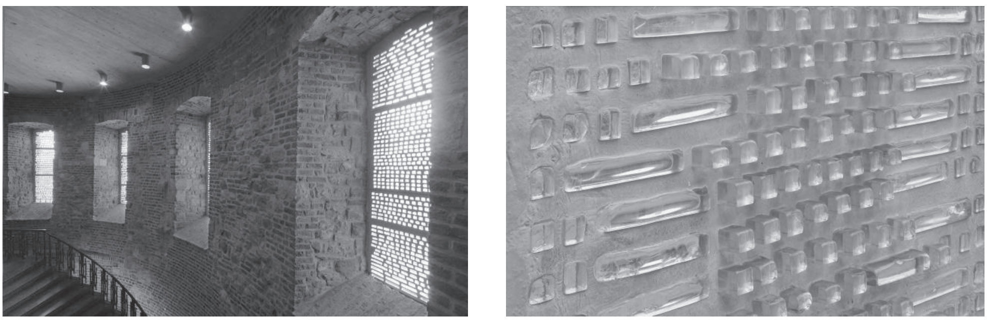

Fig. 3: View of the refurbished windows