LARGE-SIZE FACADE ELEMENTS OF TEXTILE REINFORCED CONCRETE

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ABSTRACT: This contribution describes an example for fair-faced concrete elements. However, applications of textile reinforced concrete in building industry are seldom up to now. In Germany one needs approval (single case or general) for using TRC in structural buildings.

1 INTRODUCTION

In architecture, the renaissance of fair-faced concrete construction and the demand for light and filigree but nevertheless sustainable structures presently leads to an increased demand for thin-walled façade elements of textile reinforced concrete. Construction and building are described at the example of the object “House Rheinlanddamm Dortmund“ which was erected in 2002/2003, see Fig. 1 and 2.

2 OBJECT

The object “House Rheinlanddamm“ is an office building with 6 complete stories and a building height of about 21 m which was erected applying a conventional steel reinforced concrete construction method. According to the design of the architecture firm, the building should get a rear-ventilated façade of large-size, textile reinforced glass fiber concrete elements. The company Fydro B.V. from the Netherlands was ordered to manufacture these elements with a size of up to 7 m².

3 FACADE ELEMENTS

For the production of the textile reinforced façade elements, the purely mineral concrete matrix, developed by the manufacturer and used standardizedly, was applied which ensures an approved high durability of the textile reinforced concrete. In order to yield the necessary bearing strength, the 25 mm thick façade elements were reinforced with alkali-resistant (AR) glass fiber fabrics and with continuous AR endless rovings on both sides. Additionally, AR short fibers were introduced to increase the crack prevention. Due to the partly very large dimensions of the slabs of up to 2,100 x 3,500 mm a machine-production on a continuously operating equipment was no longer possible. Instead, the elements had to be manufactured in formworks as a single-part production. Nevertheless, to render the production widely efficient, the matrix was modified in that it practically featured the flowability of a self-compacting concrete (SCC). To yield the finely structured surface stipulated by the architect, the production of the elements was made on an especially developed fleece inserted into the
formwork which, on the one hand, created the micro surface structure and by which, on the other hand, simultaneously a curing of the concrete was made. The color, a warm grey, defined by the architect, was tuned adding iron oxide pigments. For this purpose, numerous pre-tests had to be conducted in the laboratory.

4 FIXING AND CONSTRUCTION

For the invisible fixing of the façade elements undercut anchors FZP 11 x 21 M6 of the Fischer company were used. Due to the necessary high precision the undercut bores and the insertion of the anchors were made in the production plant. Position and number of the anchors were adapted to the results of the static calculation. Owing to the thickness of the slabs and the resulting possible anchoring depth, the number of anchors – depending on the respective high position of the element and its positioning in a normal-, edge- or corner area – could be limited to an average of 4 to 5 pcs./m², thus reducing the assembly costs to a minimum. The assembly of the façade elements was made on a standardized aluminum substructure of U-brackets and extruded U-profiles and T-shaped suspension girders. The fixing of the U-brackets at the load carrying structure was made with MKT-anchors M10 as fixed point and with Fischer SXS 10 x 60 as moving point. The U-profiles slotted at the front and inserted into the brackets were fixed with stainless steel bolts. The façade elements with the factory mounted T-profiles were fitted into the U-profiles. To yield a restraint-free bearing, all bores in the T-profiles were made as slotted holes.

5 ASSEMBLY

The 3,000 m² large façade was assembled in 2002/2003. Altogether more than 1,200 elements with dimensions ranging from 850 x 3,500 to 2,100 x 3,500 mm were assembled. Special hoisting devices had to be employed due to the slab thickness of 25 mm and a grammage of 50 kg/m², respectively, so that, on the one hand, the elements and the load bearing structure were not unduly stressed under assembly and, on the other hand, a problem-free fitting of the elements into the substructure was ensured, see Fig. 3 and 4.

6 STATICS AND MATERIAL CHARACTERISTICS

As up to the present date, there are no standardized design procedures for glass fiber concretes and textile reinforced concretes, the static calculation of the elements was made applying the Finite Element Method on the basis of the previously determined material characteristics. In the calculation the following material properties of the textile reinforced concrete were taken as a basis:

- Proportional limit (LOP): > 7,5 MPa
- Flexural strength (MOR): > 12,0 MPa
- Young’s modulus: 20,000 MPa
- Thermal dilatation: 1,5 x 10⁻⁵
From these test values, permissible design values were determined and defined for the decisive calculation values under consideration of the usual safety standards. The load bearing capacity of the undercut anchor, which is the decisive characteristic for the dimensioning, was restricted to about 0.52 kN because of the test results.

By means of the permissive values, first the necessary standardized verifications of the flexural stresses and the anchoring strengths depending on the stiffness ratio between substructure and glass fiber concrete elements was made. The permissive deflections of the slabs were here limited to L/300 in the middle of the field and to L/200 at the cantilevers. In a complementary calculation, the failure case was simulated removing the most heavily loaded anchor from the calculation model in order to be able to prove that the calculatively remaining anchors are capable to absorb the arising forces and to conduct them into the substructure. Fig. 5 exemplarily demonstrate the bending moments $m_r$ and $m_s$ as well as the deformations for a slab with the dimensions length $x$ width = 3,490 x 1,040 mm and a fixing by means of 8 anchors.

7 APPROVAL IN INDIVIDUAL CASE

Due to the existing situation regarding the building laws and the still missing material and design standards for textile reinforced concrete an Approval in Individual Case according to the federal building regulations of North Rhine-Westphalia (LBO-NRW) was necessary. The basis for the grant of the Approval in Individual Case were the results of extensive tests of the construction, conducted by the Materials Testing Institute University of Stuttgart (MPA Stuttgart, Otto-Graf-Institute (FMPA)). Within the framework of these investigations the material characteristics as well as the total structure consisting of façade elements and the substructure were tested in a 1:1-test up to failure (Fig. 6). As expected the total structure failed in all building member tests due to exceeding the maximum anchor force, whereas the anchors always failed in the places expected. With reference to the calculative wind suction loads to be taken into account, safety distances of $\gamma \geq 6$ compared to the failure load resulted from the building member tests.

8 OUTLOOK

The completed project „House Rheinlanddamm Dortmund“ showed that façades can be realized with large-size textile reinforced glass fiber concrete elements. In the meantime, the company Fydro B.V. has realized further projects in Mettmann and Arnhem, see Fig. 7 to 11. Still this year, façades of textile reinforced concrete will be erected in Frankfurt, Hamburg und Heidelberg where each façade is produced object-related and thus represents a unicum.
Fig. 1  Façade “House Rheinlanddamm”

Fig. 2  Façade “House Rheinlanddamm”
Fig. 3  Façade “House Rheinlanddamm”

Fig. 4  Façade of “House Rheinlanddamm”
Bending moment $m_r$ as a result of wind suction

Bending moment $m_s$ as a result of wind suction

Deformation of the elements as a result of wind suction

Fig. 5 Results of a Finite Element calculation
Fig. 6  Façade element mounted into a façade testing facility
Fig. 7 Parking garage in Arnheim
Fig. 8  Parking garage in Arnheim

Fig. 9  Parking garage in Arnheim
Fig. 10  Vocational College Mettmann

Fig. 11  Vocational College Mettmann