Textile reinforced concrete sandwich panels

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ABSTRACT

The main reason for the thickness of a concrete sandwich element is the requirement for the protective concrete cover for the steel reinforcement. By changing the steel reinforcement to non-corrosive textile fibre net this requirement could be strongly reduced. Use of textile reinforced concrete (TRC) makes it possible to produce much thinner and slimmer concrete facades in the future without changing their mechanical properties. This article presents selected results from Tekocrete project (Formas-BIC) concerning pilot production, modelling and full-scale testing of new light weight sandwich elements reinforced with AR glass and carbon fibre nets.

Keywords: concrete, sandwich element, textile reinforced concrete, AR glass, carbon fibre

1. INTRODUCTION

During the recent years the development of fibrous materials applied for civil engineering applications has been receiving a great attention by the textile, building material and construction sectors (RILEM Technical Committee 201-TRC, 2006; Hegger et al. 2007; Peled and Bentur, 2010, Malaga et al. 2011). Textile reinforcement in form of oriented or randomly distributed fibrous structure has been widely used for last decades in concrete applications. Technical textiles are normally used for apparel applications, packaging, sport and medical equipment but they can also offer new possibilities to construction sector. In combination with concrete they can contribute to a modern shaping of structures, non-corrosive reinforcement, innovative renovation and retrofitting and non load-bearing applications in façade elements.

The requirement for specific load bearing capacity of concrete sandwich elements is often over designed. This is mainly due to the use of an inner concrete- or steel structure, which supports the vertical forces from snow loads and dead weights. The concrete façades shall often manage only to resist the horizontal wind load and local stresses from the anchorages and connections of a façade into the load bearing structure behind. To secure the durability of a façade the concrete cover of the reinforcement is chosen to at least 30 mm. However, the deterioration of concrete is mainly caused by steel corrosion when the structure is exposed to humid and salty conditions. Thus, steel reinforcement might limit the service life of sandwich elements. By changing the current steel reinforcement into non-corrosive textile one, the requirement for concrete cover could be strongly reduced. A sandwich element with a thinner outer façade panel reduces not only the total weight but also the environmental impact from the manufacturing process, handling and transportation. Thinner outer layer in a sandwich element could also offer more room, if needed, for a larger insulation layer. Since the dead weight of the façades is more or less directly proportional to the concrete thickness, use of textile fibre reinforcement creates new possibilities for application of these new types of concrete elements for the repair of older buildings where light elements are to be preferred.

The goal of this project was to develop a technology for the production of different types of textile reinforced sandwich elements. In this project the main focus was on polymer fibres in form of bars and nets of carbon and alkali resistant glass. Additionally, non-conventional textiles have also been tested. The goal was to produce TRC sandwich elements with conventional methodology and construction concrete mixture; and, to decrease the thickness of the outer panel of the façade elements from 80 mm to 20-40 mm.

2. RESULTS AND DISCUSSION

Before the production of tests beams and two full-scale sandwich elements a FE-modelling was performed. The modelled sandwich elements were of the following dimensions: *l:* 5400 mm; *h*: 2700 mm; thickness façade panel: 40 mm; thickness insulation: 200 mm; thickness inner-panel: 120 mm. The anchorage of the façade panel to the inner panel was done by the 12 SPA-B-5 and 3 SPA 2-8. The distance for the anchors was 1200x1200 mm, and in the corners 300 mm. The concrete strength class was assumed to be C30/37. The modelling was done by use of the continuum shell elements and the anchoring with beam elements. The sandwich panel was calculated for concrete's weight and wind load perpendicular to façade. The results indicated that it is fully possible to produce TRC sandwich panels (Fig.1).

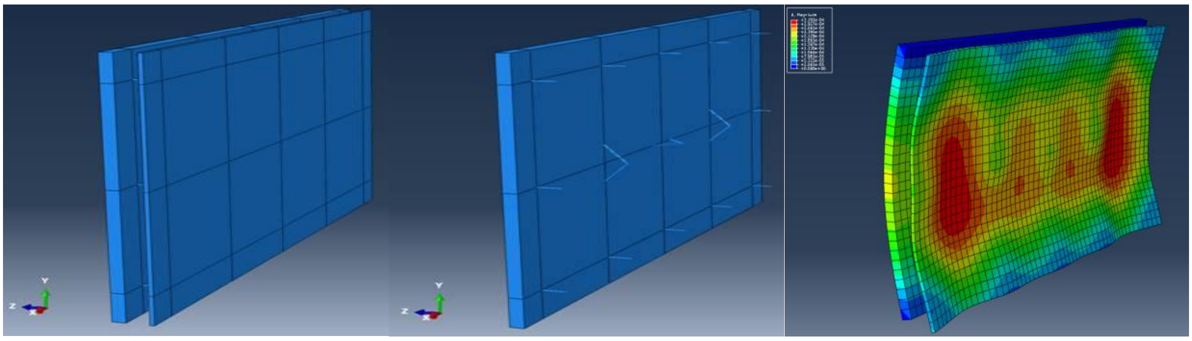

Figure 1 - FE-model of a sandwich element (left, middle) and the total deformation U for dimensioned wind W = 1.57 kN/m^2.

Load testing of concrete beams was performed in order to select the most promising textile reinforcements for full scale production (Fig. 2). Different types of reinforcement and their placement were tested. The bending strength was based on EN 14488-3. Two steel reinforced beams were cast with a height of 70 mm.

Figure 2 – Casting of the beams (left) and set up for bending strength measurement (right).

The free distance between the supports *L* was 700 mm and the distance between the line-loads were *L*/3. The load was applied under displacement control with a rate of 0.15 mm/min. This means that the cracking did not occur instantaneously, despite a sharp reduction of load bearing capacity. During the test the deflection of the beams in the centre was recorded. The test results showed that only the epoxy-coated glass rods and carbon fibre nets increased the moment capacity of the concrete beams. For the other beams the crack moment was significantly higher than the maximum bearing capacity after the first cracking. The results showed that the thickness and the placement of the textile reinforcement were crucial for the function of the reinforcement. Steel reinforcement in the reference beams resulted in an equivalent bearing capacity and stiffness as for the epoxy-coated glass rod reinforcement. Both reinforcements took a large load relatively early, even at a small deformation. It is important to emphasize that the internal lever arm was much larger for the reference prism, which complicates a fully accurate comparison. The bond between concrete and reinforcement was very good for both cases. The carbon fibre reinforced beams had a much greater deformation before it became active. This indicates a slightly weaker bond between carbon fibre and concrete or a lower total stiffness (moment of inertia) of the reinforced element. Deformation (deflection) for the epoxy-coated glass rod was 1.9 mm. It can be compared to the typical limit for concrete beams and panels, which is $L/300 = 700/300 = 2.33$ mm. The resulted deformation for a moment of about 170 Nm, gave an acceptable value. Carbon fibre reinforcement had an average deflection of 4.7 mm. Although carbon fibre net showed lower value than the epoxy-coated fibreglass rod, which was mainly due to a different placement in the beams, it was selected for the full-scale experiments.

For the production of sandwich elements (Fig.3) two textile reinforcement concepts were selected: 6 mm thick fibre glass rods arranges in a net pattern and a carbon fibre net. The panels were of the following dimensions: *l*: 2000 mm; *h*: 2500 mm; thickness façade panel: 40 mm; thickness insulation: 150 mm; thickness inner-panel: 150 mm. The reinforcement was placed at the distance of 20 mm, in the middle of the façade panel. The casting with the glass fibre net was performed by a normal production procedure but the casting with the carbon fibre required ‘casting in layers’: a 20 mm bottom concrete layer was casted first, thereafter came reinforcement and textile anchoring covered by the second concrete layer.

Figure 3 – Preparation of the reinforcement (carbon fiber –left; glass fiber –right)

The sandwich elements were tested in a ‘wind chamber’. Figure 4 shows the experimental setup. The inner panel was attached to the load frame at three points on the top and three points on the low side. The facade panel was able to move freely but was sealed all around with elastic sealants alongside the frame. Three position sensors were mounted on an aluminium frame. The deformation was measured in relation to the corners of the façade panel. Wind load was applied in sequences: positive wind suction and negative wind pressure. Wind load was increased to the selected load and then held constantly for about 30s before the next load was applied. The maximum wind load was 4000 Pa. The results showed that the measured displacements were relatively small in both cases, see Figure 5.

Figure 4 – Sandwich element (left), mounting for the wind load testing (middle and left).

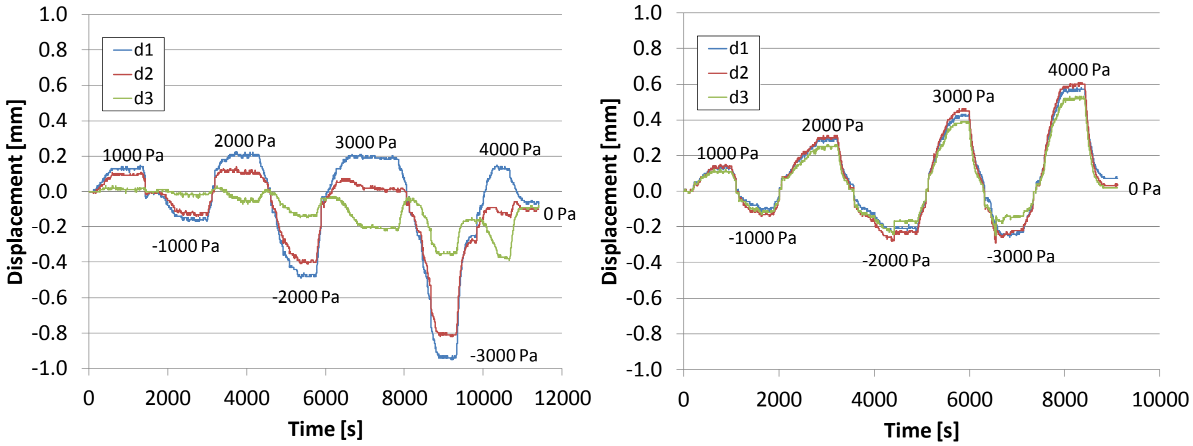

Figure 5 - Displacement vs. time for the respective gauges for carbon fibre reinforced element (left) and glass rod reinforced element (right).

3. CONCLUSIONS

By exchanging the steel reinforcement to non-corrosive textile fibre net or rods offers possibility for production of much thinner and slimmer TRC facade elements than by any conventional technique and without alteration of their mechanical properties.

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