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POSSIBILITIES OF REINFORCEMENT OF SUBTLE TRANSLUCENT CONCRETE PANEL

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Abstract. Textile-reinforced concrete not only has many advantages that lead to less consumption of primary resources, but also enables the creation of thin and subtle elements. The high performance of such elements allows us to create interesting architectural features, such as translucent concrete. This article focusses on the possibility of reinforcing translucent concrete panels.

Keywords: Concrete, light-transmitting concrete, textile-reinforced concrete, high-performance concrete.

1. Introduction

Concrete is one of the most used building materials, but due to its massive production, concrete has a huge impact on the environment (especially because of the cement and steel used as reinforcement). On the other hand, concrete offers many benefits (such as mechanical properties or the ability to maintain the stability of the internal environment) that make it almost irreplaceable in many cases. This is the reason why it is so important to optimise concrete [1].

There are several ways to improve concrete and reduce its environmental impact – for example, it is possible to partially replace cement using fly ash, silica fume, or slag, reduce the amount of water (that leads to higher strength which allows lower concrete thickness) or replace traditional steel reinforcement with alternative noncorrosive reinforcement that has a lower environmental impact. Furthermore, no concrete cover is required to protect the reinforcement, which also leads to a lower thickness of the concrete. Reducing the thickness of concrete has an impact on the reduction of used materials, lower load, which means smaller dimensions of the supporting structures, and easier handling [1].

Textile reinforced concrete (TRC) combines the above improvements. It is reinforced by technical textiles made of carbon, alkali-resistant AR-glass, basalt, or natural materials such as flax or hemp, which can be impregnated using a polymer matrix, e.g., epoxy resin. Technical textiles are in the form of orientated rovings and are embedded in a concrete matrix, which is usually high-performance fine-grained concrete [2–5].

Another material that combines the above improvements is fibre-reinforced concrete (FRC), where dispersed reinforcing fibres (made of steel, polymers or, for example, glass) instead of traditional reinforcement. These fibres can contribute to higher strength and ductility, but also to enhance fire resistance [5, 6].

Overall, there are many ways to improve concrete and thus reduce its environmental impact, but it is also possible to combine multiple functions (e.g., load bearing, acoustic, or lighting) in one material. For example, luminescent or acoustic concrete is being developed and light-transmitting concrete is already available (under the name of Litracon, Lucem, or Licrete). Light transmission is ensured by several elements – usually optical fibres, polymers, or glass [7–9].

Based on that, it was decided to explore the possibilities of light-transmitting concrete reinforcement using alternative reinforcement to reduce the thickness of concrete and thus reduce its environmental impact. Different types of rovings (carbon, AR-glass, and flax) were tested, and a plexiglass (or polymethyl methacrylate – PMMA) elements were chosen to ensure light transmission.

2. Preparation of samples

Translucent samples were made with dimensions of the samples $30 \times 150 \times 400$ mm for the flexural strength test. There were 4 groups of TRC, 6 samples in total, 4 samples were translucent, and 2 samples were opaque:

- U R (2×) carbon roving (Tenax STS40 F13 24K 1600tex) + plexiglass,
- U R ref (2× – opaque) carbon roving (Tenax STS40 F13 24K 1600tex),
- L R (1×) flax roving + plexiglass,
- ARG R (1×) AR glass roving (Cem-FIL® 5325) + plexiglass.

A fine-grained concrete mixture was used for the preparation of samples, which is described in the Table 1.

Reinforcement was prepared as impregnated rovings with epoxy resin. The used rovings are described in the Table 2.

	$[\mathbf{kg\,m^{-3}}]$
CEM I 42.5 R	650
Silica sand D_{max}=1.25 mm	1 200
Silica fume	75
Microsilica	235
Superplasticizer	18
Water	190

TABLE 1. Concrete mixture.

Fibre type	**T** [tex]	**Tensile strength** [MPa]	**Elastic modulus** [GPa]
Carbon (Tenax STS40 F13 24K)	1 600	4 000	240
AR glass (Cem-FIL® 5325)	2 400	>1 000	72
Flax	1 680	N/S	N/S

TABLE 2. Material characteristics of used rovings [10, 11].

To ensure a 10 mm distance between the plexiglass elements (Figure 1), 10 mm wide wooden bars were placed between them. During the preparation of the translucent TRC samples, the rovings were impregnated with epoxy resin, placed in the space where the plexiglass elements are cut and then sprinkled with fine silica sand. After 24 hours, the hardened epoxy resin was able to keep the required distance between the plexiglass elements so the wooden bars could be removed and the same process could be repeated on the other side of the sample (Figure 2). The prepared inserts were placed into the mould and weighted down and then the concrete mixture was poured. All the samples were later demoulded and left in water until the day of testing.

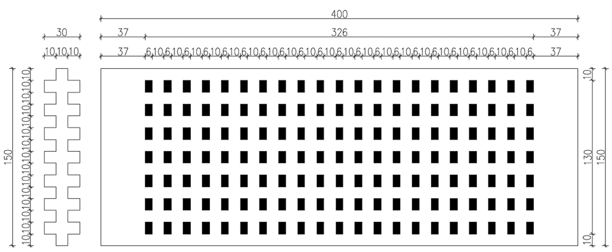

FIGURE 1. Scheme of translucent sample.

3. EXPERIMENT AND RESULTS

The compressive test according to CSN EN 12390-3 and the flexural strength test (three-point bending test) according to CSN EN 12390-5 both at the age of 28 days were performed to measure the mechanical properties of the concrete mixture. The translucent samples were prepared for the flexural strength test (four-point bending test) with constant loading speed of 1 mm min^{-1} which was partly according to CSN EN 12390-5.

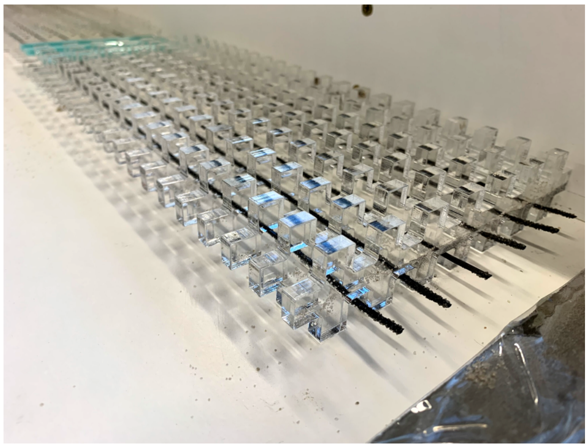

FIGURE 2. Elements with one layer of carbon rovings impregnated with epoxy resin and silica sand (right).

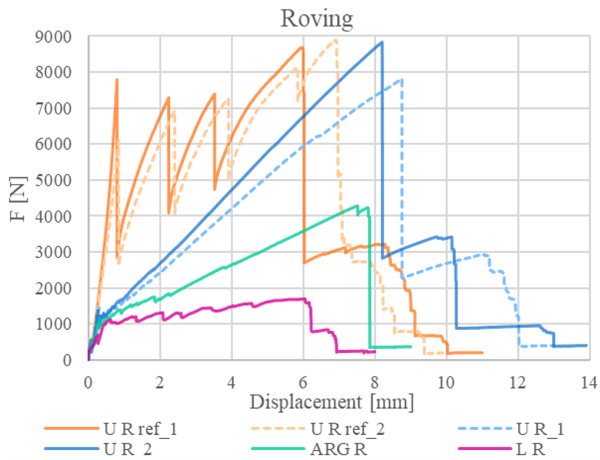

FIGURE 3. Force-displacement diagram of the translucent samples – rovings (right).

The average compressive strength on the cubes was 110.69 MPa, and the average flexural strength on the prisms was 17.24 MPa.

Sample	**Spill test** [mm]	**Flexural strength** $\mathbf{f_{cf}}$ [MPa]	**Average flexural strength** $\mathbf{f_{cf,avg}}$ [MPa]
U R ref_1	300	18.31	18.00
U R ref_2	300	17.70	
U R_1	300	18.22	18.79
U R_2	300	19.36	
ARG R	300	8.42	8.42
L R	300	3.35	3.35

TABLE 3. Results of the four-point bending test.

In Figure 3 force-displacement curves of the translucent TRC samples are presented. The translucent TRC samples achieve high flexural strengths. The highest strength is achieved by the carbon-reinforced

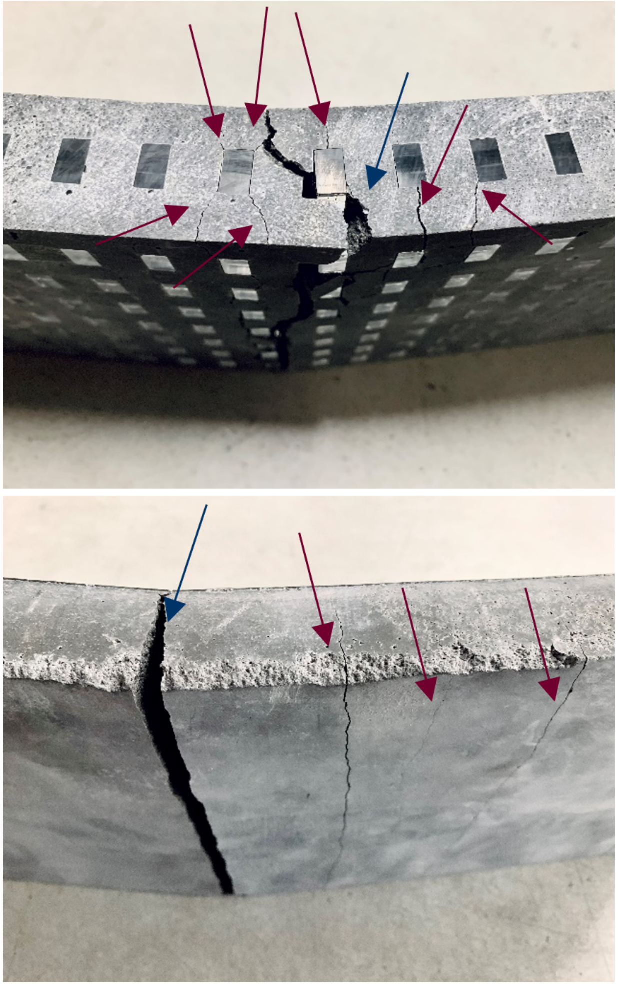

Figure 4. Number of cracks after four-point bending test: translucent TRC sample (left), opaque TRC sample (right).

samples, the flexural strength of the translucent samples is even higher than the opaque samples with the same reinforcement – 18.79 MPa and 18.00 MPa (see Table 3). It might be caused by the microcracks which cause that rovings must bear a certain amount of load from the very beginning of loading and can adapt to it (see Figure 4. The flexural strength of glass roving is 2 times lower than carbon roving (18.79 MPa and 8.42 MPa), and the flexural strength of flax roving is even 5.5 times lower than carbon roving (18.79 MPa and 3.35 MPa). After the maximum load, the samples with carbon and flax roving can carry about 4 % of the maximum load, unlike the samples with glass roving, which collapsed immediately.

4. Conclusions

All translucent samples achieved optimistic results. The highest average flexural strength had samples reinforced with carbon roving (18.79 MPa, which is even slightly more than opaque samples with the same reinforcement – 18.00 MPa), followed by glass roving (8.42 MPa, which is 2 times lower) and flax roving (3.35 MPa, which is 5.5 times lower). The samples with rovings also show ductility behaviour. In summary, all rovings could be used in certain applications of translucent concrete.

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