Fire temperature influence on the textile reinforced concrete with non-woven polypropylene fabric

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Abstract. Textile reinforced concrete with non-woven polypropylene fabric has variable utilization for non-load bearing structures. One of the possible uses is production of facade panels or protective layers in the interior of buildings. For that reason it is important to determine fire resistance of this material. There was examined behaviour of specimens exposed to temperature in range 100 – 650°C for times from 5 to 60 minutes. Weight loss of the specimens caused by heating was also measured. Regardless to the relatively high moisture of material, the effect of spalling didn’t occur.

1. Introduction
Textile reinforced concrete (TRC) with non-woven polypropylene fabric has potential for using in non-load bearing structures. One of many possibilities of its utilization is using it as protective layers in technical parts of buildings. Architectural concrete is currently very favored and TRC should be used for creation of facade panels. [1] Advantage of this solution is that in case of any damage, panel can be exchanged for a new one. Simultaneously there should be used external thermal insulation placed under the panels.

Fire resistance of building’s facades is presently often discussed topic. Because of the technical requirements on the heat transfer during facade, using of external thermal insulation systems is mostly necessary. Separation distances between buildings are in the Czech Republic determined according to fire openness categorization of external walls. Because of this conservative approach separation distances are often bigger than it is necessary. This is primarily problem in the places with high density of urban structure. [2]

This is the main reason for the research of fire influence on TRC with non-woven polypropylene fabric.

2. Materials and methods

2.1. Test specimens
Test specimens were created by cutting up of one bigger slab to small specimens. This method of specimen’s creation was chosen due to gain the most similar material properties as possible. Dimensions of specimens are 50 x 50 mm (figure 1). Material of the specimens is made as two layered with one interlayer reinforced by alkali-resistant glass fabric. Main layers are reinforced by isotactic polypropylene fabric.
Specimens were divided into 6 sets contained 4 specimens. Sets were gradually exposed to the different temperatures. Initial moisture was also detected by gravimetric method. Another four specimens were weighted and then they were dried at temperature 115°C. Then they were weighted again, and initial moisture of the specimens was determined. This detail is important because of the possible concrete spalling. For classic concretes this effect is considered if the initial moisture is higher than 3% wt. The other specimens were also weighted before the experiment starts but weight decrease does not have to be caused just by water loss. Weight loss should be caused also by polypropylene fabric evaporation.

2.2. Choice of material heating temperatures

It is well known that exposing of the structures made from commonly used materials to the high temperatures has negative influence on their mechanical properties [3-9]. Properties of classic concrete are stable to 200°C, after that they are decreasing. This effect is caused by changes in the material (table 1).

| Temperature [°C] | Temperature effect on concrete                      |
|-----------------|------------------------------------------------------|
| 100             | Loss of evaporable water                            |
| 100-850         | Dehydration of hydrates                             |
| 400-600         | Dehydration of calcium hydroxide                    |
| 574             | Crystalline transformation of the quartz             |
| 600-900         | Decomposition of calcium carbonate                  |
| 1200-1500       | Melting of Portland cement                          |

Table 1. Temperature effects on the composition of concrete [10].

Used reinforcing fabric was made of 100% isotactic polypropylene. Standard properties of this type polypropylene were used: softening the material occurs between 140 – 150°C and melting of the material occurs between 160 – 170°C.

Specimens were exposed to the surrounding air temperature sizes 100°C, 150°C, 200°C, 350°C, 500°C and 650°C. These temperatures approximately match to the temperature of nominal temperature-time curve for external fire. This curve represents exposure of the facade to the fire from window or to the external fire (figure 2). Because of that, these temperatures are important for using TRC with non-woven polypropylene fabric as a facade panels.
Result of the experiment can be also applied for nominal temperature-time curve for slow heating during its first 30 minutes (figure 2). This curve can be used for elements with properties dependent on a high intensity of heating – for example external thermal insulation.

![Nominal temperature-time curves.](image)

**Figure 2.** Nominal temperature-time curves.

Measured results should be also applied for internal fire in residential buildings before the flashover starts. This phase is ended by achieved the air temperature range 400 – 700°C. Specific temperature depends on type of objects placed in the room. Temperatures after flashover are in the range 600 – 1200°C (figure 3). For undeveloped fire the temperature doesn’t increase so much as for fully developed fire.

![Temperature development in the fire zone for fully developed and undeveloped fire.](image)

**Figure 3.** Temperature development in the fire zone for fully developed and undeveloped fire.

2.3. Material heating process

Four specimens from one set were heated by air flow of the specific loading temperature from the bottom side (figure 4). After the specific temperature was achieved the time was measured and gradually the specimens were displaced outside the heat source. The first specimen was exposed to the temperature for 5 minutes; the second one specimen was exposed to the temperature for 10 minutes; the third specimen was exposed to the heating for 30 minutes and heating of the last specimen was ended by 60 minutes after the experiment starts. After chilling of the heated specimens they were weighted again and weight loss was determined.

For finding out of the visual changes the digital microscope was used. Width of the cracks on the specimen’s surface was measured also by using the digital microscope.
3. Results and discussion
The weight loss caused by heating process was determined for all the specimens (table 2). It is impossible to reliably determine how big weight loss was caused by water loss due to polypropylene fabric evaporation.

Table 2. Weight development of the specimens before and after heating on the specific temperature.

| No. | T [°C] | Weight [g] | Weight loss [%] | No. | T [°C] | Weight [g] | Weight loss [%] |
|-----|--------|------------|-----------------|-----|--------|------------|-----------------|
|     |        | Before     | After           |     |        | Before     | After           |
| 1   | 100    | 31.14      | 30.56           | 13  | 350    | 28.16      | 27.92           |
| 2   |        | 32.36      | 30.12           | 14  |        | 30.18      | 29.98           |
| 3   |        | 29.88      | 28.12           | 15  |        | 35.98      | 34.02           |
| 4   |        | 30.10      | 27.98           | 16  |        | 29.92      | 28.14           |
| 5   | 150    | 28.12      | 27.94           | 17  |        | 36.14      | 32.00           |
| 6   |        | 30.14      | 28.08           | 18  | 500    | 28.14      | 25.86           |
| 7   |        | 27.86      | 26.12           | 19  |        | 30.28      | 28.06           |
| 8   |        | 27.14      | 25.68           | 20  |        | 39.82      | 33.92           |
| 9   | 200    | 34.16      | 34.02           | 21  |        | 31.96      | 29.96           |
| 10  |        | 34.44      | 31.88           | 22  | 650    | 32.12      | 29.88           |
| 11  |        | 31.78      | 29.62           | 23  |        | 31.88      | 28.02           |
| 12  |        | 30.02      | 28.06           | 24  |        | 31.28      | 28.02           |

In ordinary concretes loaded by fire the effect of spalling of surface layers can appear when the moisture is higher than 3% wt. Initial moisture was detected for 4 specimens of that reason. Average moisture of these 4 specimens was 9.1% wt. There is an assumption that all of the specimens had similar initial moisture. Nevertheless, the spalling effect wasn’t occurred for any of the specimens.

Both surfaces of the specimens were photographically documented before and after heating (figure 5).
Figure 5. Surface of the specimens: left – before heating, right – after heating.
For temperatures up to 200°C weren’t significant changes on the surface even after 60 minutes. Just development of the microcracks till the width 0.02 mm was occurred. Fibers of the polypropylene fabric are still intact in the pores.

Surface of the specimens heated on 350°C for 5 and 10 minutes was as like as for the lower temperature – just with small microcracks. For exposure times 30 and 60 minutes the cracks on the surfaces are wider – about 0.1 mm width.

Surface of the specimens heated on 500°C and 650°C was cracked with cracks 0.1 mm wide after 5 minutes. For longer exposure time the width of the cracks wasn’t change. It can be said that for higher temperatures the exposure time haven’t influence on the cracks width (figure 6).

For specimens heated on 650°C a smoke has appeared during first 15 minutes. After that there was no other smoke effect till ending of the heating.

Figure 6. Surfaces of the specimens for different temperatures; DigiMicro Profi II.
4. Conclusion

Fire resistance of TRC with non-woven polypropylene fabric was examined. Chosen temperatures were between 100 – 650°C for exposure times 5 min, 10 min, 30 min and 60 min. There was significant crack development on the surfaces of the specimens exposed to temperatures higher than 200°C. Nevertheless, spalling of the surface layers didn’t occur even though initial moisture of the specimens was about 9.1% wt.

Next step should be to research properties of bigger specimens for longer exposure time.

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