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Using of TRC for research of crack evolution and the effect of autogenous healing

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Abstract. Cracks in the concrete part of substructure are a problem in terms of penetration of water into the building. The best way is to prevent their development or support autogenous healing of concrete as much as possible. It is suitable to create many small specimens for research of crack evolution in various boundary conditions. TRC is applicable material for this research due to its compact dimensions and the ability to create a lot of cracks in relatively small area of the specimen. There are two basic methods how to create cracks in this material, tensile and bending loading. Each method provides different crack shapes.

1. Introduction

Concrete structures almost always have cracks (figure 1). In the substructure of the buildings this problem is often solved by using of some admixtures which causes secondary hydration in concrete. Primary purpose of these admixtures is to support autogenous healing of concrete. If it doesn't work, then some remediation method is applied. The best way should be defend the structure from the moisture penetration. For making research focused on admixtures which causes secondary hydration in concrete, the biggest problem is to determine boundary conditions. It is also appropriate to evaluate suitable boundary conditions for support of the autogenous healing and then apply it to the real structure. Research like that requires creation of a large number of specimens saved in many different conditions. It is advantageous to create the smallest specimens with the largest number of cracks as possible. The way should be using textile reinforced concrete (TRC) with non-woven polypropylene fabric [1-12].

Figure 1. Moist cracks in substructure.

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2. Materials and methods

For research of the crack evolution two possibilities were considered. The first one is using standard test cubes with edge length 150 mm or 100 mm. The second one possibility is based on using of TRC with non-woven polypropylene fabric (figure 2).

Using of the cube specimens should be more similar to the situation in the real buildings than using of TRC. The biggest advantage is the possibility to use the same concrete mixture as used for real structure.

The largest aggregates which can be used for TRC production is 0.25 mm. Also the water-cement ratio is often higher than in the real structure and it is also necessary to use plasticizer for create the TRC specimens [4]. It is suitable to examine some trends of autogenous healing in concrete and then apply it to specimens made of the same mixture as it is used in the specific structure. Exception is a situation, where the examined structure is made from fiber-reinforced concrete (FRC) or textile reinforced concrete (TRC) – there should be used similar mixture.

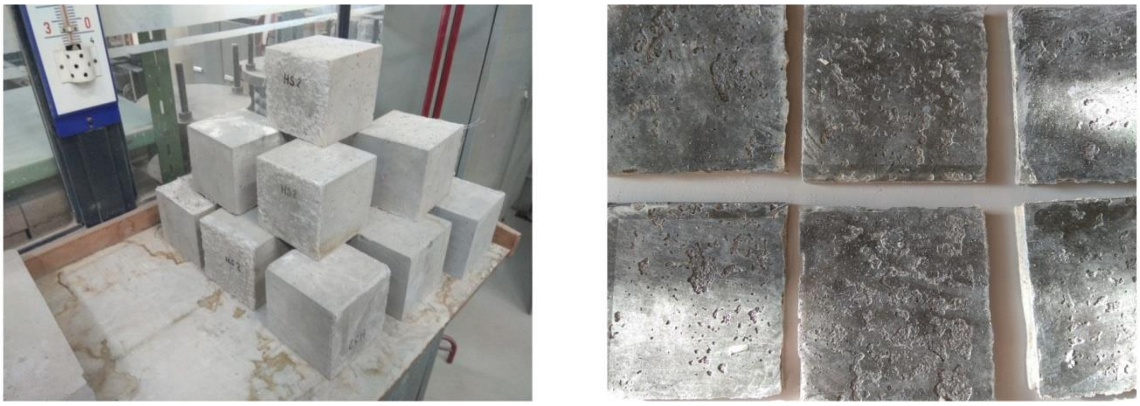

Figure 2. Test specimens: left – cube specimens; right – TRC specimens.

2.1. *Crack-creation in cube specimens*

Creation of the realistic cracks in the cube specimens is a problem, which can be solved for example by using of fiber reinforcement. It is suitable to use non-metallic fibers, polypropylene or PVA fibers are recommended. Thanks to the presence of fibers, the cracks should be created without complete destroying of the specimens.

This procedure allows to create just one crack in one test specimen (figure 3). Only external proportion of the crack can be measured, internal geometry of the crack is unknown. Cracks in the cube specimens are about 0.1 – 0.6 mm wide.

Figure 3. Cube specimens: left – storage of the specimens during the experiment; right – crack in the specimen, width of the crack is about 0.5 mm.

2.2. Crack-creation in TRC specimens

Creating of many cracks and micro-cracks is feature of textile reinforced concrete with non-woven polypropylene fabric. Thanks to this property, this material is not suitable for load-bearing structures [13,14]. But it is usable for protective layers, or for the research of the autogenous healing of cracks in concrete.

It means that there is a large number of cracks in relatively small test specimen compared with standard cube specimens.

There are two ways, how to create cracks. One way is to use tensile loading on the specimen. Problem of this process is that cracks are closed after unloading. The second way is to use bending moment. Cracks stay open after unloading, but the specimens are permanently deformed (figure 4).

Cracks created in the TRC specimens using the bending moment are about 0.03 – 0.15 mm wide. This method was chosen for testing of the crack evolution in different boundary conditions (figure 5).

It is suitable to create two-layer specimens due to better crack formation.

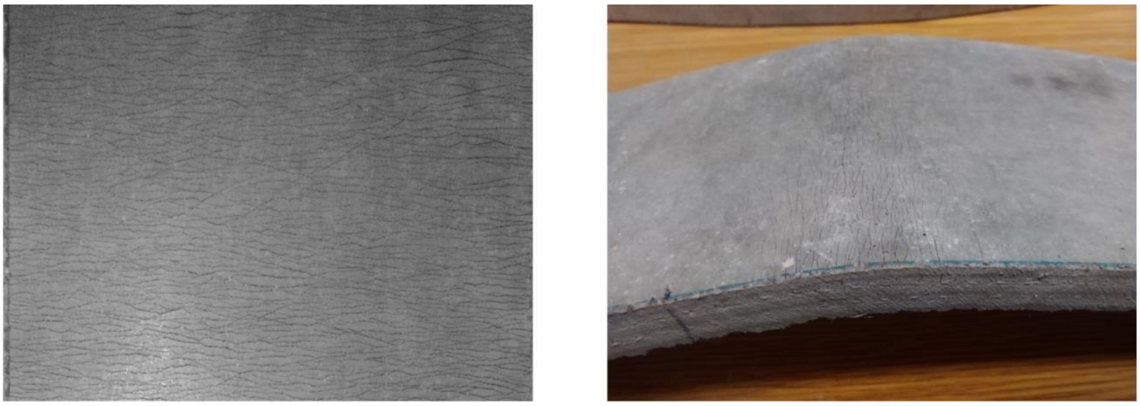

Figure 4. Cracks in the TRC: left – caused by tension; right – caused by bending moment.

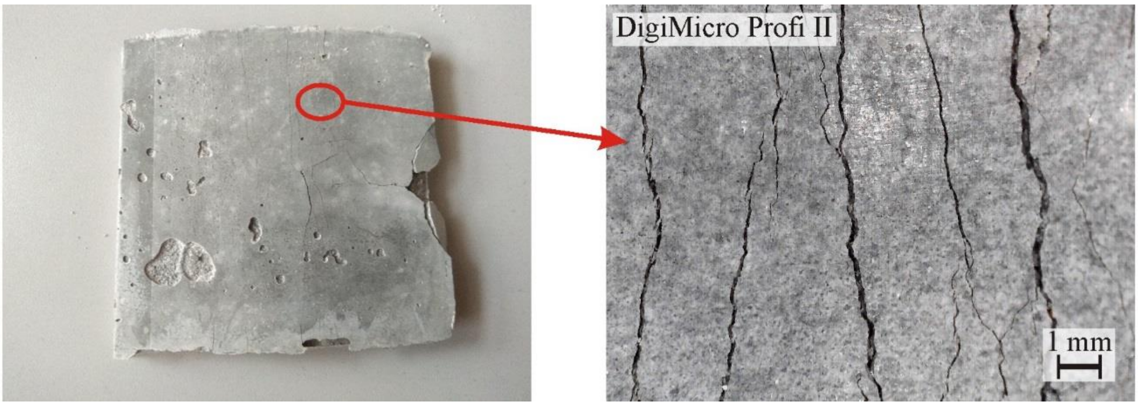

Figure 5. Cracks in the TRC test specimen, width of the cracks is about 0.04 – 0.15 mm.

2.3. Comparison of the use of test specimens

Using of each type of the test specimens has its own advantages and disadvantages (table 1). Cube specimens can be produced from the same concrete mixture as like as the real structure. Permeability test can be simply done alike it is applied on classic cube specimens. But only one crack can be made in one specimen. Also there is a greater storage requirement for the cubes than storage requirement for TRC specimens. Manipulation with the cube specimens is harder due to their greater weight.

For creation of the TRC specimens the concrete mixture is completely different than used in the real structure. It means that comparison with cube specimens is recommended. But there are a large number of cracks in one specimen and manipulation with the specimens is easy. These specimens are good choice for research of the trends for crack-healing in concrete.

Table 1. Comparison of the use of test specimens.

Cube specimens	TRC specimens
+ The same mixture as in the structure	− Different mixture than in the structure
− Greater storage space requirement	+ Less storage space requirement
− One crack in one specimen	+ Many cracks in one specimen
− Problem with crack-creation	+ Easy crack creation
− Bigger cracks (0.1 – 0.6 mm)	+ Smaller cracks (0.05 – 0.15 mm)
− Complicated manipulation with specimens	+ Easy manipulation with specimens
− Consumption of more material	+ Consumption of less material
+ Easy testing of the permeability	− Hard testing of the permeability

3. Production possibilities of the TRC specimens

For the specimens the edge length was chosen as 100 mm. There are two ways, how to create specimens with these dimensions.

The first one possibility is to create a larger slab and cut it up to smaller specimens (figure 6).

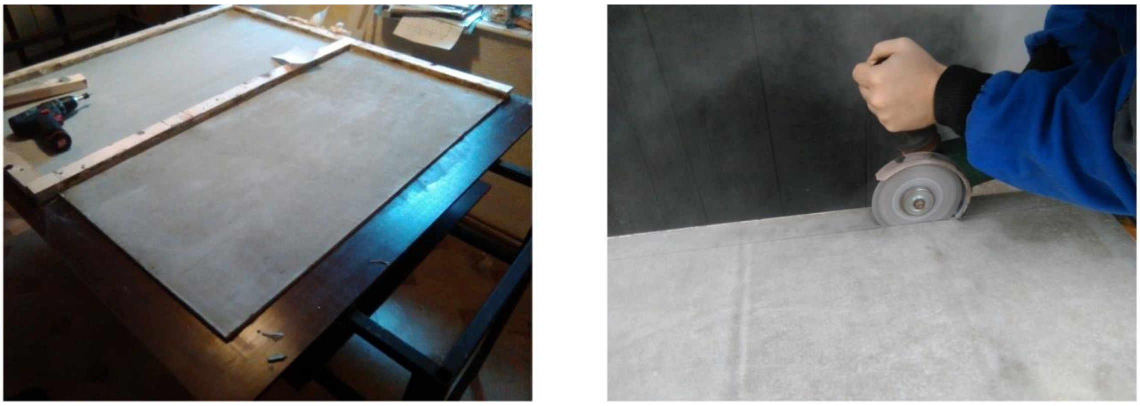

Figure 6. TRC slabs: left – bigger slab; right – cutting of the slab on the specimens.

The second one possibility is to create specimens with exact edge length (figure 7). Smaller space storage requirement during curing compared with bigger slabs is advantage of this method.

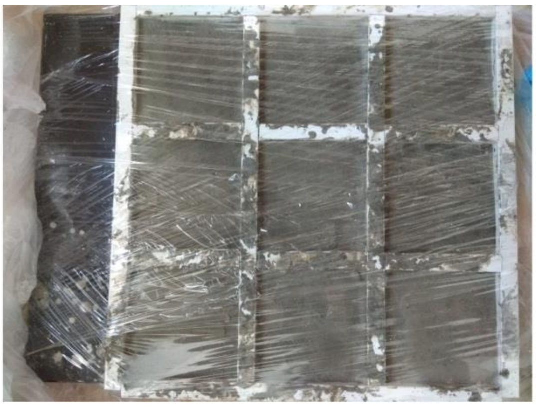

Figure 7. Curing of the test specimens in the formwork.

The main difference between these methods of creation is in the quality of the edges. Edges of specimens cut up from bigger slab are more equal than are on the specimens made with exact length (figure 8). For the crack research this detail is not important.

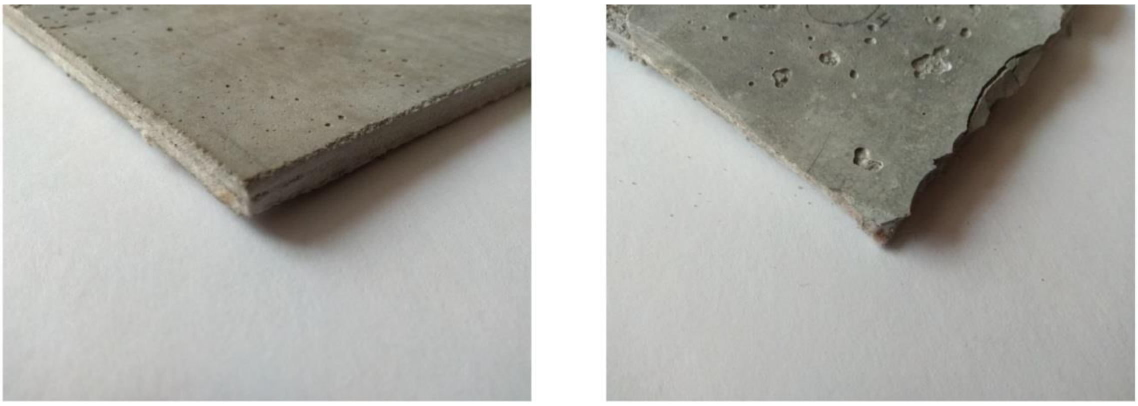

Figure 8. Difference in the quality of the specimen's edges: specimen cut up from bigger slab; right – specimens made with exact length.

4. Results and discussion

Specimens for research of the evolution of cracks in concrete and autogenous healing were made from TRC with non-woven polypropylene fabric. The specimens were squared with edge length 100 mm. These dimensions were chosen due to relatively small storage space requirements and small material consumption for the creation.

There are two ways how to create cracks in the specimens. The first one is using tensile loading which ensures that the specimen stays flat. But there should be a problem for crack research after unloading, because TRC with non-woven polypropylene fabric has a tendency to reclose cracks in the specimen. This property is more useful for elements in real structure than for research of the cracks. The second way is to load the specimen by bending moment. After unloading the specimen stays deformed but the cracks stay open, which is necessary property for the crack research.

Cracks in the specimens used for the autogenous healing research were created using bending moment to prevent their reclosing. Because of the small width of the cracks, digital microscope for the control and crack-width measuring was used (figure 9).

This method allows to investigate a large number of cracks in concrete specimens, which were saved in different boundary conditions.

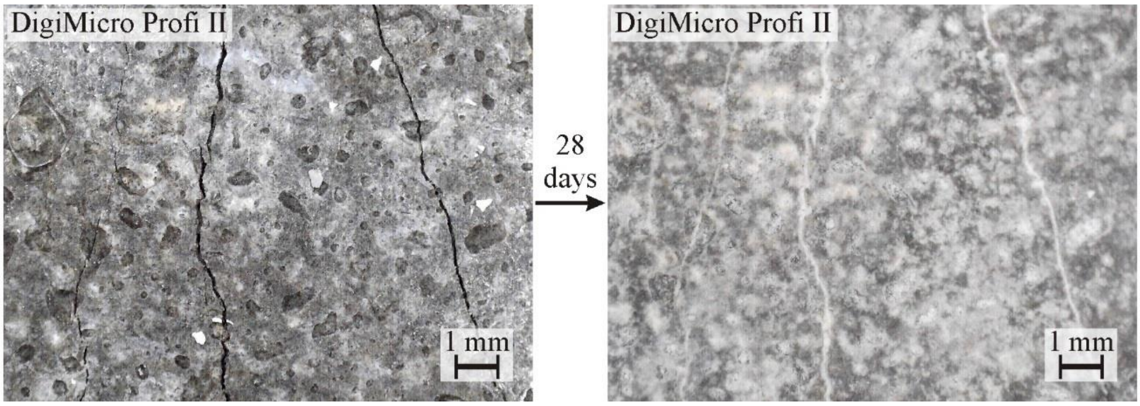

Figure 9. Research of the crack evolution using TRC specimen.

5. Conclusion

Using TRC with non-woven polypropylene fabric specimens is good choice for research and description of the trends of the crack evolution and autogenous healing process in concrete. Huge advantage of this material is that it is possible to examine a large number of cracks in relatively small specimens. It means, that there is less amount of consumed material for the specimens creation, small space storage requirements and last but not least small specimens are more ecological terms to waste disposal then classic cube specimens.

Acknowledgements

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