Fungicidal effects on cement composites with recycled glass from photovoltaic panels

K. Kučová, K. Máčalová, V. Václavík, T. Dvorský, M. Vašinková

INTRODUCTION

The service life of photovoltaic panels is estimated between 20-30 years. Most solar panels were installed at the end of the 20th century, which means we can expect an increase in the amount of photovoltaic panels to be disposed of in a few years [4]. Cement composites with recycled glass, as well as conventional cement composites, can suffer from biocorrosion. Biocorrosion is understood as a change in the properties of materials caused by the action of living organisms or their metabolites. The organisms involved in biocorrosion are called biodeteriogens, and they are mainly microorganisms that are known for their ability to biotransform and biominerize substances from the environment, in which they mechanically mix organic substances with mineral ones, through their metabolic activity on surface substrates [13] - bacteria, algae, cyanobacteria or microscopic fibrous fungi. However, they can also be plants such as lichens or bryophytes [14]. The biocorrosion of building materials is influenced by many factors that act not only on the cement composite but in interaction with metabolites of microorganisms. They also affect the viability of microbial consortia [15]. Although biocorrosion may not be visible, it can still negatively change the properties of cement composites, which in most cases leads to severe damage to the entire building structure as a whole. Therefore, it is important to identify not only the macroscopic but also the microscopic changes caused by the metabolic activity of microorganisms [14].

METHODS

Portland cement EN197-1 – CEM I 52.5 R, recycled glass from photovoltaic panels as a 100 % substitute for natural aggregates in 4 fractions (0/0.5 mm; 0.5/1 mm, 1/4 mm and 4/10 mm) and mixing water from the water supply system were used for the preparation of the cement composites. According to the determination of the optimal grain size curves, five new recipes (R1-R5) were selected for the preparation of concrete mixtures. The dried cement composites were then cut into test specimens measuring 40 x 40 x 8 mm (W x L x H). All parts were washed with ethanol to prevent the samples from drying out in the agar with inoculated micromycetes.

Crumbling

Once the beams were dried to a constant weight, they were crushed in a jaw crusher and ground in a ball mill into crumbling with a grain size of <1.5 mm. The prepared crumbling was sterilized for one hour at 180 °C before use.

Agar

The used cultivation medium was the same for the experiment on the test specimens and crumbling. It was Sabouraud Dextrose Agar with these main components: dextrose, mycological peptone, agar and distilled water, pH 5.6 ± 0.2, prepared in Erlenmeyer flasks in autoclave at 121 °C.

The following representatives of micromycetes were selected to research fungicidal effects in the biocorrosion process - *Aspergillus clavatus*, *Aspergillus niger*, *Cladosporium* sp., *Penicillium glabrum* and *Mucor* sp. Microscopic fungi represent a stable microbial component involved in biocorrosion together with other symbiotic microorganisms.

Experiment

Cement composite samples

The prepared and washed cement composites of recipes R0 – R5 were prepared in Petri dishes with a diameter of 90 mm and bathed in sterile agar to the height of the composite. Once the medium had cooled, the selected microscopic fungi were inoculated, and the Petri dish was sealed with parafilm to prevent contamination and drying of the medium. The samples prepared and secured in this way were moved to a place with sufficient sunlight and a constant temperature (24 °C), and the growth of biomass was checked and recorded at 7-day intervals. They were evaluated according to ČSN 72 4310 standard [22], determining the degree of fungal growth.

Crumbling

The sterilized crumblings of recipes R1-R5 were weighed into a Petri dish in the initial ratio of 1:9 to the cultivation medium, which made up 10 % of cement crumblings, then in the ratio of 2:8 (20 % cement crumblings) and also in the ratio of 4:6 (40 % cement crumblings). The weighed crumblings were supplemented with a medium in Petri dishes, and after solidification, the selected micromycetes were inoculated. The dishes prepared in this way were treated in the same way as the cement composite dishes – sealing with parafilm, transfer to the same place, and frequency evaluation of biomass growth.

RESULTS AND DISCUSSION

The degree of micromycetes growth : 0 - fungi do not grow; 1 - growth is negligible; 2 - growth is gradual (up to 25%); 3 - growth is intensive (up to 50%), 4 - growth is very intensive (up to 75%); 5 - growth is complete (100%).

Table 1 shows the growth of microscopic fungi on cement composites, which was very active. Complete growth – 5, 100% of the surface from the first 7-day period was observed in the representatives of *Aspergillus* (*A. niger*), *Penicillium* (*P. glabrum*) and *Zygomycetes* (*Mucor* sp.) genera in all types of recipes (R0 – R5). A slower start of growth was observed in *A. clavatus*, while in the recipe R5 it did not exceed the value of 3 – intensive growth up to 50 % of the surface. In *Cladosporium* genus stable growth was observed from day 14 up to the value of 4 – very intensive, up to 75 % of the surface. Overall, it can be said that the grain size fractions of the types of recipes did not significantly affect the growth of micromycetes.

Table 1 Fungi growth on cement composites for the duration of 7, 14, 21 and 28 days

Fungi species		A. clavatus				A. niger				Cladosporium sp.				P. glabrum				Mucor sp.			
Days		7	14	21	28	7	14	21	28	7	14	21	28	7	14	21	28	7	14	21	28
Recipe	R0	1	4	5	5	5	5	5	5	2	4	4	4	5	5	5	5	5	5	5	5
	R1	1	4	4	4	5	5	5	5	2	4	4	4	5	5	5	5	5	5	5	5
	R2	2	4	5	5	5	5	5	5	3	4	4	4	5	5	5	5	5	5	5	5
	R3	2	4	4	4	5	5	5	5	3	4	4	4	5	5	5	5	5	5	5	5
	R4	1	4	4	4	5	5	5	5	3	4	4	4	5	5	5	5	5	5	5	5
	R5	3	3	3	3	5	5	5	5	2	4	4	4	5	5	5	5	5	5	5	5

In the case of 10 % content of cement crumbling, immediate growth after 7 days is visible only in *P. glabrum*, although at the beginning, it is negligible and gradual – 1, 2. From the second period, after 14 days, the growth is complete – 5, 100% surface. The highest activity of biomass growth was not recorded in any other representatives; it only reached the value of 4 – growth up to 75 % of the surface, was very intensive, and was not in all types of recipes. In the case of *A. niger* and *Cladosporium* sp., a sudden increase in biomass growth was recorded after 21 days of checking – from the value of 0 to the growth value of 4 (very intensive), which can be explained by the longer interval of adaptation to the conditions in an isolated environment; this phenomenon was recorded for all recipe types (R1-R5). Table 2 shows the largest growth – 5, 100% of the surface, in biomass of *Cladosporium* genus in all recipes except for recipe R3, where the growth was very intensive. In *P. glabrum*, only negligible growth was observed in recipes R1, R2, R4 and R5, while in recipe R3 the growth was gradual, at the value of 2 to 25 % of the surface. In the other representatives – *A. clavatus*, *A. niger* and *Mucor* sp. the growth was zero, which may be due to the lack of nutrients or light.

Table 2 Fungi growth on 20 % share of crumbling for the duration of 7, 14, 21 and 28 days

Fungi species		A. clavatus				A. niger				Cladosporium sp.				P. glabrum				Mucor sp.			
Days		7	14	21	28	7	14	21	28	7	14	21	28	7	14	21	28	7	14	21	28
Recipe	R1	0	0	0	0	0	0	0	0	0	5	5	5	0	1	1	1	0	0	0	0
	R2	0	0	0	0	0	0	0	0	1	5	5	5	0	1	1	1	0	0	0	0
	R3	0	0	0	0	0	0	0	0	0	4	4	4	0	2	2	2	0	0	0	0
	R4	0	0	0	0	0	0	0	0	0	5	5	5	0	1	1	1	0	0	0	0
	R5	0	0	0	0	0	0	0	0	0	5	5	5	0	1	1	1	0	0	0	0

CONCLUSION

This research evaluated the fungicidal effects on cement beams and crumbling with 100 % replacement of natural aggregates with glass photovoltaic recyclate. Solid samples (cement composites) and cement crumblings were exposed to the effects of micromycetes – A. clavatus, A. niger, Cladosporium sp. P. glabrum and Mucor sp for the duration of 28 days, while the biomass growth was evaluated every 7 days. The conclusions drawn from this research are as follows:

- micromycete growth was more successful on solid samples;
- the intensity of biomass growth on cement composites was at the same level from day 14;
- in the case of 40 % share of cement crumbling, there was zero growth in all selected representatives due to the very low input of nutrients from the medium and high pH value > 11;
- in the case of cement crumbling in the ratio of 1:9, the representative of the genus *Penicillium* – *P. glabrum* was the most successful, value 5 – complete growth.

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