Algae as a part of microorganisms involved in biocorrosion of cement composites with total replacement of natural aggregates by photovoltaic glass

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INTRODUCTION

Biodeteriogen, or an organism involved in biocorrosion, causes undesirable changes in cement composites with its metabolites. The main organisms involved in biocorrosion are especially microorganisms - cyanobacteria, algae, micromycetes and bacteria, but they can also be lower plants - lichens or bryophytes. If the biodeteriogen damages composites with its metabolic products, it is dissimilation damage, while if the composite represents food for the biodeteriogen, it is assimilation damage. Like any other processes, the biocorrosion process is affected by several factors. Due to the involvement of microorganisms in this process, the most important factors include nutrients, temperature, humidity and pH. Nutrients for microorganisms are represented by inorganic and organic substances present in cement composites [5,6], humidity is essential for the existence and occurrence of microbial consortia on the surface of buildings, temperature affects the growth rate of biodeteriogens and pH value is associated with the present microbiota activity and its nutrient intake from the environment .The average lifespan of photovoltaic panels is estimated at 25 years which is why it is necessary to look for a solution focused on what to do with the resulting waste. Directive 2012/19 / EU of the European Parliament and of the Council on waste electrical and electronic equipment from 15 August 2018 [12] stipulates that at least 85% of materials from photovoltaic panels must be used and 80% of materials must be ready for re-use and recycled.

METHODS

This experiment was focused on the effect of microscopic algae on cement composites with total replacement of natural aggregate by recycled glass originating from photovoltaic panels at the end of the life cycle. The growth of selected species of algae was monitored on cement beams and cement crumbling.

Algae – *Pleurococcus****,*** *Trentepohlia* **and** *Stichococcus*

Algae of the genera were used in the experiment.

Preparation of cement composites with total replacement of natural aggregate

The cement composites were prepared on the basis of recycled glass from solar panels. The input components for the production of cement composites were as follows: photovoltaic glass as a total replacement of natural aggregate which consisted of 4 fractions (0/0.5 mm; 0.5/1 mm; 1/4 mm; 4/10 mm), Portland cement EN 197-1 - CEM I 52.5 R and mixing water from the water supply system. The R0 recipe was designed as a comparative one and contained total of natural aggregate. Based on the determined optimal curves of recycled glass grain size, 5 new recipes (R1-R5) for the production of concrete mixture were designed. The designed recipes contained different ratio of the individual fractions. Only two recipes contained all fractions (R3 and R5). The remaining three recipes (R1, R2 and R4) did not contain 1/4 mm fraction photovoltaic glass recyclate. The mixture was worked into beam moulds with dimension 40 x 40 x 160 mm (W x H x L), the mixture was left in the mould until the next day and then the mould was removed. The resulting beams were stored in an aqueous environment at 20 °C for 28 days, and then they were removed and dried to a constant weight. The treatment procedure of the test specimens was as follows:

- test specimens with dimension 40x40x8 mm were used for the 1st experiment, they were treated with ethanol to prevent drying of the medium with microorganisms, due to length of the experiment.
- crumbling (prepared by crushing hardened composites) was used for the 2nd experiment as a substitute for 10%, 20% and 40% of agar.

Cultivation medium

Algae Cultura Agar medium (HiMedia Laboratories, Mumbai, India) was used for algae cultivation with these main components: sodium nitrate, dipotassium phosphate, magnesium sulphate, ammonium, calcium and ferric chloride, agar and distilled water, pH 7±0.2. The medium was prepared in Erlenmeyer flasks and sterilized in a Sterimat Plus autoclave at 121 °C.

The course of experiment

The cut test specimens were prepared according to the recipes R0 - R5 and were placed in petri dishes (diameter 90 mm) and embedded with sterile cultivation medium to the level of the samples. Subsequently, after the medium had solidified, microscopic algae were inoculated and the petri dish prepared in this way was secured with a parafilm to prevent water leakage and a possible contamination from the environment. In the case of cement crumbling, a petri dish with 10%, 20% and 40% cement crumbling was prepared, and it was subsequently supplemented to 100% using the medium. After the medium had solidified, microscopic algae were inoculated and the petri dish prepared in this way was secured with a parafilm. The experiment with the prepared cement crumbling took place on samples prepared according to recipes R1-R5. All the prepared samples were placed in a laboratory with sufficient sunlight and the growth of algae was checked at intervals during 28 days. It was subsequently evaluated according to the ČSN 72 4310 standard.

RESULTS AND DISCUSSION

The degree of algae 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 most intensive growth in the genus of *Trentepohlia*, however it did not exceed the value of 3 - intensive growth up to 50% of the surface, namely in recipes R1 and R2. The same growth trend was observed in recipes R3 and R4: 2 - gradual, up to 25% of the surface throughout the entire measurement period. The lowest growth activity was observed in the R0 recipe. The genera of *Pleurococcus* and *Stichococcus* showed only increase to the value of 1 - negligible in all recipes R0 - R5.

Algae species		*Pleurococcus*				*Stichococcus*				*Trentepohlia*			
Days		7	14	21	28	7	14	21	28	7	14	21	28
Recipe	R0	1	1	1	1	0	1	1	1	1	1	1	1
	R1	1	1	1	1	1	1	1	1	1	3	3	3
	R2	1	1	1	1	1	1	1	1	2	3	3	3
	R3	1	1	1	1	0	0	1	1	2	2	2	2
	R4	1	1	1	1	0	1	1	1	2	2	2	2
	R5	0	0	1	1	1	1	1	1	2	2	3	3

Table 1 Biocorrosion rate on beam samples with total replacement of natural aggregate with photovoltaic glass during 7, 14, 21 and 28 days

Table 2 Biocorrosion rate on cement crumbling samples with total replacement of natural aggregate with photovoltaic glass in 10% representation of the sample during 7, 14, 21 and 28 days

Algae species		*Pleurococcus*				*Stichococcus*				*Trentepohlia*			
Days		7	14	21	28	7	14	21	28	7	14	21	28
Recipe	R1	1	1	1	1	0	0	0	0	1	1	1	1
	R2	1	2	2	2	0	0	0	0	1	1	1	1
	R3	2	2	2	2	0	0	0	1	1	1	1	1
	R4	2	2	3	3	0	1	1	1	0	0	1	1
	R5	2	2	2	2	0	0	0	0	0	0	1	1

Algae species		*Pleurococcus*				*Stichococcus*				*Trentepohlia*			
Days		7	14	21	28	7	14	21	28	7	14	21	28
Recipe	R1	0	1	1	1	0	0	0	0	0	0	0	0
	R2	1	1	1	1	0	0	0	0	0	0	0	0
	R3	1	1	1	1	0	0	0	0	0	0	0	0
	R4	1	1	1	1	0	0	0	0	0	0	0	0
	R5	0	1	1	1	0	0	0	0	0	0	0	0

Table 3 Biocorrosion rate on cement crumbling samples with total replacement of natural aggregate with photovoltaic glass in 20% representation of the sample during 7, 14, 21 and 28 days

Tables 2-3 show the growth intensity of algae biomass in the ratios of 1:9, 2:8 of the crumbling to medium sample. Overall, *Pleurococcus* was the most successful in all two ratios, however, the growth activity did not exceed the level of 3 - intensive growth, up to 50% of the surface; the species of *Stichococcus* showed an absolute absence of growth in all ratios and in the species of *Trentepohlia* the growth was insignificant, mainly at 10% of the crumbling to medium ratio. In case of the highest share of crumbling - 40%, the growth was the lowest overall, which is attributed to a very small amount of nutrients present in the medium. The composition of recipes R1-R5 had no significant effect on the support or inhibition of the growth of microscopic algae.

CONCLUSION

This experiment was focused on the biocorrosion of cement composites - beams and crumbling, with total replacement of natural aggregate with photovoltaic glass in four different grain fractions. Three species of microscopic algae - *Pleurococcus, Stichococcus* and *Trentepohlia* - were used in this experiment because they were identified as part of the biofilm involved in biocorrosion. Based on the presented results, we can draw the following conclusions:

- the growth of microscopic algae was quantitatively small;
- low abundance was caused by the absence of symbiotizing microbiots from the point of view of growth support of selected algae representatives;
- growth quality was also affected by the high pH value of the samples (pH>11);
- weak growth of the used algae was also affected by the high level of recycled glass present in the samples, mainly in the experiment with crumbling, which affected the content of nutrients available for algae nutrition.

Acknowledgement:

- Grant of SGS No. SP2021/21, Faculty of Mining and Geology, VSB – Technical University of Ostrava, Czech Republic.
- Grant of SGS No. SP2021/11, Faculty of Mining and Geology, VSB – Technical University of Ostrava, Czech Republic.
- Moravian-Silesian Region – grant number RRC/10/2018 and RRC/02/2020.