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APPLICATION OF ZEOLITE IN CONCRETE MIXTURES FOR RADIONUCLIDE BARRIERS

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ABSTRACT

Basic physical properties, mechanical properties, and water absorption of concrete suitable for engineering barriers against radionuclide movement in nuclear waste repositories are studied. At the mix design, natural zeolite is used to enhance the radionuclide sorption ability of concrete and the influence of its dosage on the engineering properties of concrete is analyzed.

Keywords: natural zeolite, radionuclides, basic physical properties, mechanical properties, water absorption

INTRODUCTION

Radionuclide transport from nuclear waste repositories into the natural environment is unacceptable. Therefore, the construction of rad-waste repositories is based on a multi-barrier system (Koťátková *et al*., 2017). Concrete, as a well known construction material with low cost and very good properties, is a good choice to be used as a secondary engineering barrier in the multi-barrier system. This particular part of the system is called secondary package. Such concrete package is multi-functional, as it can serve as a shielding and protection box for transport of the primary package of nuclear waste and also provide a mechanical barrier inside the repository (IAEA, 2001). Next to this, the protection can be enhanced by its ability to lower the radionuclide transport into the environment.

The radionuclide transport through a material can be limited by the use of sorption materials, such as natural zeolite. These materials offer sites for physical bonding of the hazardous ionic species. There are several mechanisms of radionuclide immobilization, the most prevailing is ion exchange (Koťátková *et al*., 2017). Natural zeolite has a very porous structure and contains poorly bonded ions, which very easily enter the process of ion exchange (Ahmadi and Shekarchi, 2010). Therefore, the work was aimed at incorporation of zeolite in concrete, while investigating the changes in its engineering properties.

MATERIALS

The composition of concrete mixtures is presented in Table 1. The concrete mixtures were composed of aggregate with maximum grain size 16 mm and the granulometric curve was complemented with fine grains of silica flour. For all studied mixtures, except from the reference, ordinary Portland cement CEM I 42.5 R was substituted by 20% of natural zeolite, which takes action in the hydration process due to its pozzolanity. Further addition of zeolite was dosed as a replacement of the fine inert silica flour by 33%, 66% and 100%. Water-cement ratio was not constant as the design was made to achieve a specified flow of 160 mm (according to the standard ČSN EN 206).

Table 1 - Composition of studied mixtures

	RZR	RZ1	RZ2	RZ3	RZ4
Portland cement CEM 42.5 R	400	320	320	320	320
Silica fume	-	-	-	-	-
Zeolite		80	120	160	200
Silica flour ST6	120	120	80	40	-
Aggregates 0-4 mm Dobříň	760	760	760	760	760
Aggregates 4-8 mm Zbraslav	455	455	455	455	455
Aggregates 8-16 mm Zbraslav	483	483	483	483	483
Superlasticizer - Stachesil 2000	6.9	6.9	6.9	6.9	6.9
Water	195	165	160	160	160

RESULTS AND DISCUSSION

The basic physical properties measured by water vacuum saturation method and pycnometry are given in Table 2. The table shows an increase of open porosity with the increasing amount of zeolite in the mixture. When omitting the reference mixture (which did not contain any zeolite), the differences were within 12% and 18% for water vacuum saturation method and pycnometry, respectively. In a comparison with the reference mixture the increase was almost by 50%. However, it should be noted, that the reference mixture did not contain any pozzolnic admixture and therefore the amount of cement was higher. Changes in bulk density and matrix density were in an agreement with the open porosity.

Table 2 - Basic physical propesrties of studied concrete mixtures

	Water vacuum saturation method			**Pycnometry and gravimetric method**		
	Bulk density [kgm^{-3}]	**Matrix density [kgm^{-3}]**	**Open porosity [%]**	**Bulk density [kgm^{-3}]**	**Matrix density [kgm^{-3}]**	**Open porosity [%]**
RZR	2 319	2 579	10.1	2 361	2 638	10.5
RZ1	2 111	2 514	16.0	2 166	2 595	16.5
RZ2	2 097	2 505	16.3	2 157	2 594	16.8
RZ3	2 046	2 456	16.7	2 152	2 595	17.1
RZ4	2 002	2 448	18.2	2 082	2 606	20.1

In the relation to open porosity, the mechanical properties slightly worsened, as it can be seen in Figures 1 and 2. Both compressive strength and three-point bending strength were decreasing with a rising amount of zeolite. Again, without taking the reference into account, the decrease of compressive strength was within 20%; in case of bending strength the drop was higher, by 40%, which can cause a significant loss of mechanical performance. In a comparison with the reference mixture, the loss of mechanical properties was also almost 50%.

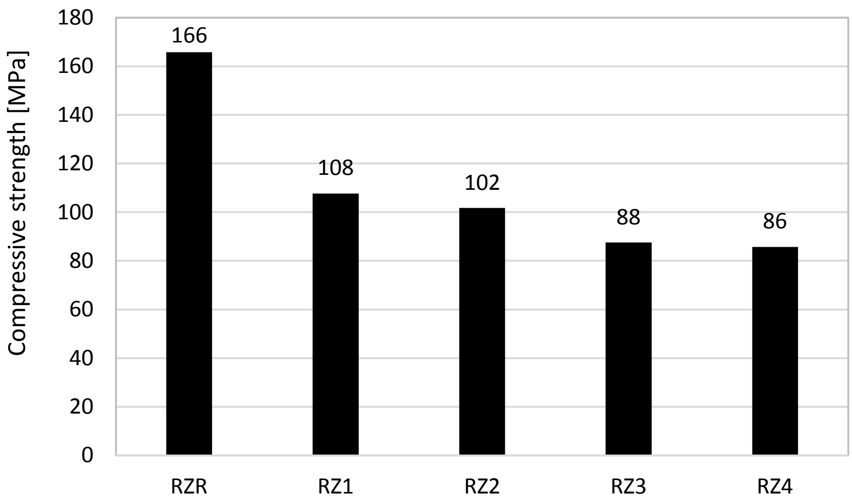

Fig. 1 - Compressive strength test results

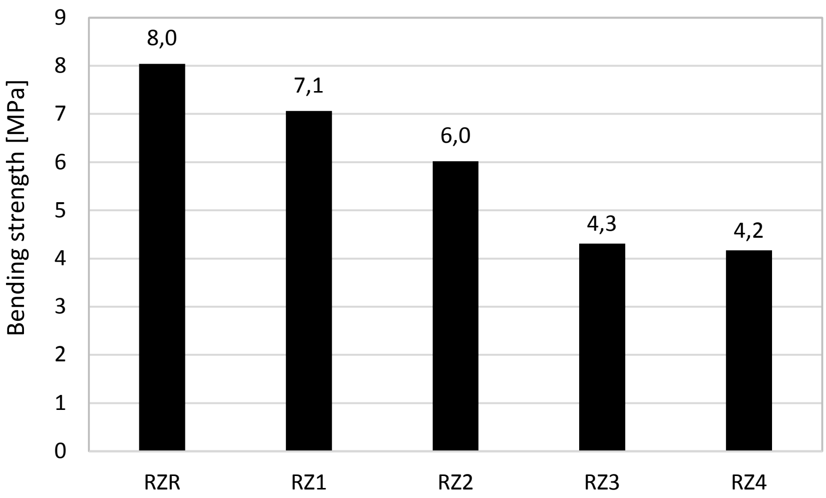

Fig. 2 - Three-point bending strength test results

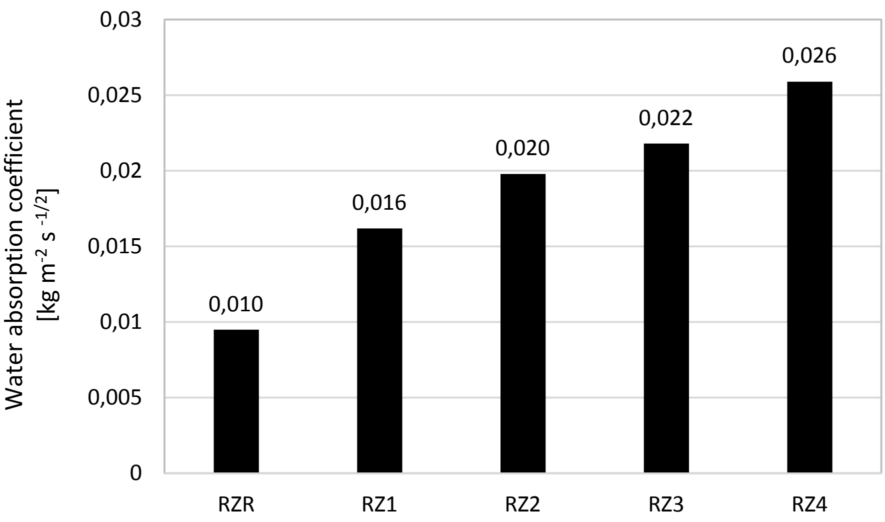

Fig. 3 - Values of water absorption coefficient

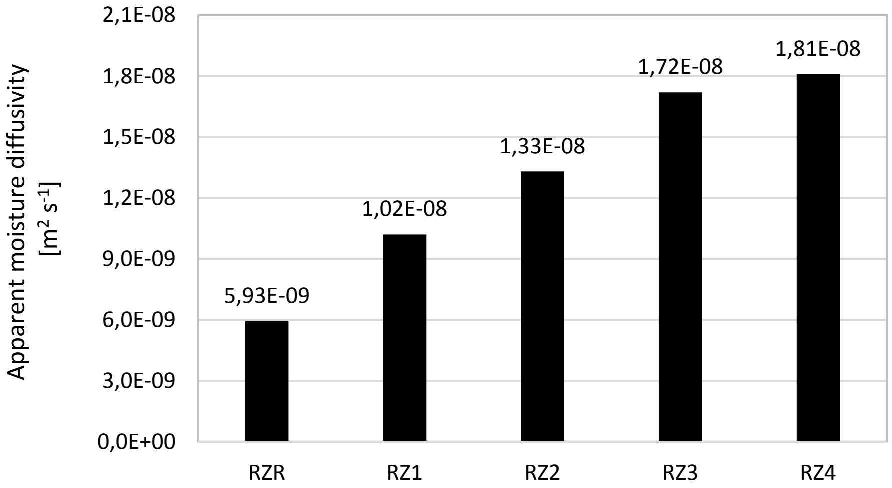

Fig. 4 - Values of apparent moisture diffusivity

Figures 3 and 4 present the results of water absorption experiment. Water absorption coefficient rose with zeolite addition, the increase was by 37% when comparing mixtures with no substitution and 100% substitution of silica flour by natural zeolite. In a comparison with the reference, the rise was by 63%. The experiment provided also the values of apparent moisture diffusivity, which went also up with the addition of zeolite. The increase was even more significant, being 44% when omitting the reference.

CONCLUSIONS

The effect of using natural zeolite in concrete suitable for engineering barriers against radionuclide movement in nuclear waste repositories was analyzed. The measurement of basic physical properties, mechanical properties, and water absorption showed an engineering properties loss caused by adding natural zeolite as a sorption material. Further experiments should be performed to balance the benefits related to the limitation of radionuclide transport and possible problems caused by worsening of functional properties.

ACKNOWLEDGMENT

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