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RESEARCH ON CEMENT RECIPES FOR CCS APPLICATION***

1. INTRODUCTION

Nowadays, as the industry is going forward, we have to face the problem of anthropogenic carbon dioxide (CO_2) emissions into the atmosphere. Increased concentration of carbon dioxide has a devastating influence on the environment and may cause irreversible global climate changes.

Governments impose enormous penalties on countries, which do not comply with the regulations of utilizing devastating CO_2. There are different ways to cope with the problem. One of them is a CCS method (Carbon Capture and Storage) [1, 10].

CO_2 capture and storage is a technology capable of reducing CO_2 emissions from fossil fuel power plants and heavy industries by up to 90%.

There are three different ways of reducing emissions depending on when the CO_2 is captured:

1) during fuel combustion – oxy-combustion,
2) after the fuel has been burned – post-combustion,
3) before the fuel is burned – pre-combustion.

Once captured, and in order to be stored, the CO_2 is pressed and dehydrated. To make sure that it is safely and permanently stored, use is carefully selected structures that exist naturally underground. Usually, the CO_2 is piped into one of two types of natural storage reservoirs: deep saline formation or depleted oil and gas reservoirs. A rigorous monitoring system is always set up to ensure that CO_2 storage sites function as they should.

Despite the fact, that CO_2 is stored in perfectly tight formations closed by impermeable layer of cap rock, there exists a danger of possible gas exhalations through the sealing of

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injection well. This might be a result of improper choice of a slurry recipe that was used to seal the sequestration well.

The research concentrates on finding the best cement slurry recipe to be used as an effective sealing in CO_2 well sequestration technology [2–6].

2. RESEARCH

The research includes examinationson cement slurries of five different recipes most often used for sealing wells in Poland. These are:CEM I Kujawy 42.5R, CEM I Małogoszcz 42.5, Rejowiec HSR, Kujawy HSR and cement class G according to API regulations. First two of mentioned are Portland cements and the three others are cements class G according to API. Specifications of slurries prepared for the research are shown in Table 1.

Table 1

Specification of cements used in research

Component	Portland cement CEM I 42.5R	Cement class G API
SiO_2	21.6	21.22
Al_2O_3	4.94	4.23
Fe_2O_3	2.30	5.49
CaO	64.2	64.27
MgO	2.18	0.91
SO_3	3.18	2.16
Na_2O	0.13	0.53
K_2O	0.86	0.1
Cl^-	0.02	0.01

For each analyzed cement, cement powder was mixed with fresh water in a water-cement ratio of w/c = 0.5 and w/c = 0.6. All the cement slurries recipes were prepared in accordance with suitable API regulations.

The first stage of the research involved the measurements of:
– density (mud balance),
– fluidity (Ford's cup),
– filtration (filtration press),
– viscosity (twelve-ranged viscometer FANN),
– mathematical parameters of the slurries' rheological models (Rheosolution Software).

Cement slurries used for non-sequestration wells are not exposed to such a high concentration of carbon dioxide. The parameters of cement rock which is affected by acidic environment change with time. It means some additional factors should be taken into account while creating the recipe resistant to these changes. To compare the maintenance of cement slurries used in traditional conditions and in heightened CO_2 concentration conditions, a series of samples has been prepared. They were divided into two groups. The first group of samples was stored in fresh water environment to simulate the standard conditions in accordance with the norms. The second group consisted of samples which were stored in the environment of concentrated CO_2 [7–9].

Aggressive acidic environment for samples of cement rock was created with the use of pressure tanks of authors' own invention. The samples were stored in conditions of 95% CO_2 concentration for the period of 180 and 360 days under the pressure of 0.5 MPa. After taking the samples out of the tanks, flexural and compressive strength of each sample was measured with the use of specialized laboratory equipment.

3. LABORATORY ANALYSES

Laboratory analyses were focused on proving the following thesis: a proper selection of the cement slurry recipe prevents from CO_2 exhalations through a destroyed cement rock.

In the aspect of the given thesis, the authors studied five popular types of cements used for sealing wells in Poland. The results of the mechanical resistivity research are shown in the graphs (Figs 1–5). The results for each cement are shown in separate charts. The charts compare change of bending and compressive stress with time for samples exposed to water and CO_2 rich environment.

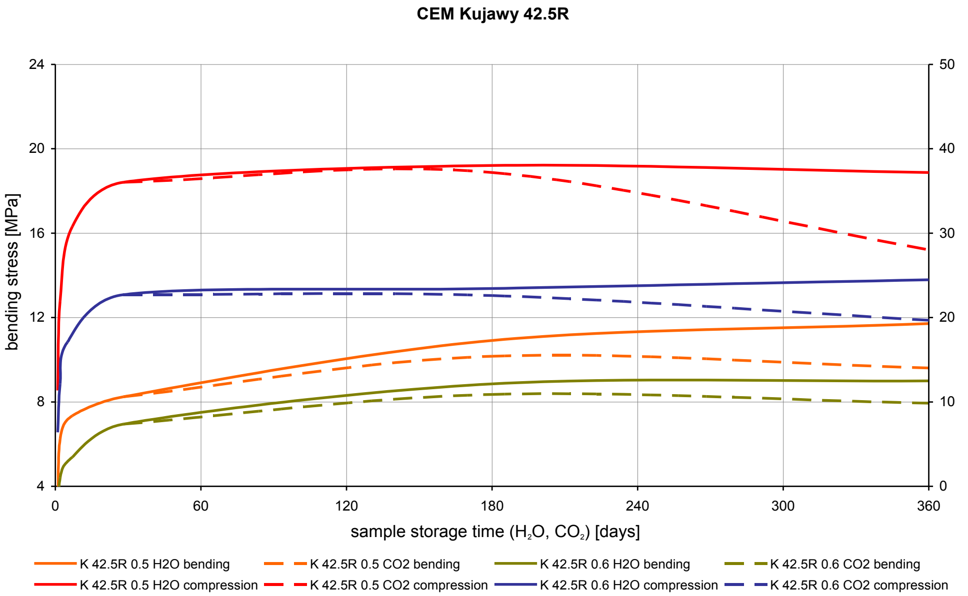

Fig. 1. Change in time of bending and compressive stress for samples of Portland cement CEM Kujawy 42.5R

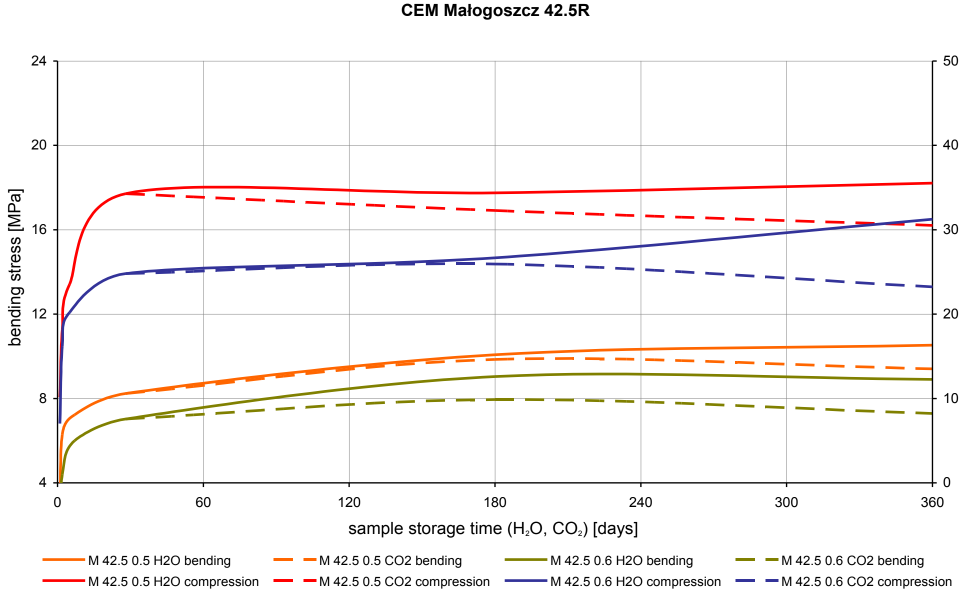

Fig. 2. Change in time of bending and compressive stress for samples of Portland cement CEM Małogoszcz 42.5R

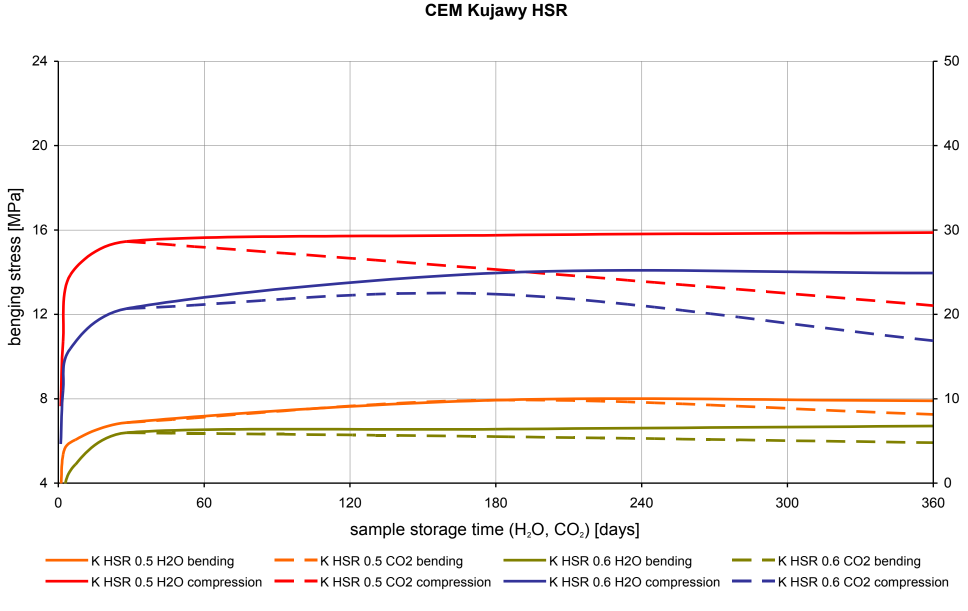

Fig. 3. Change in time of bending and compressive stress for samples of cement class G CEM Kujawy HSR

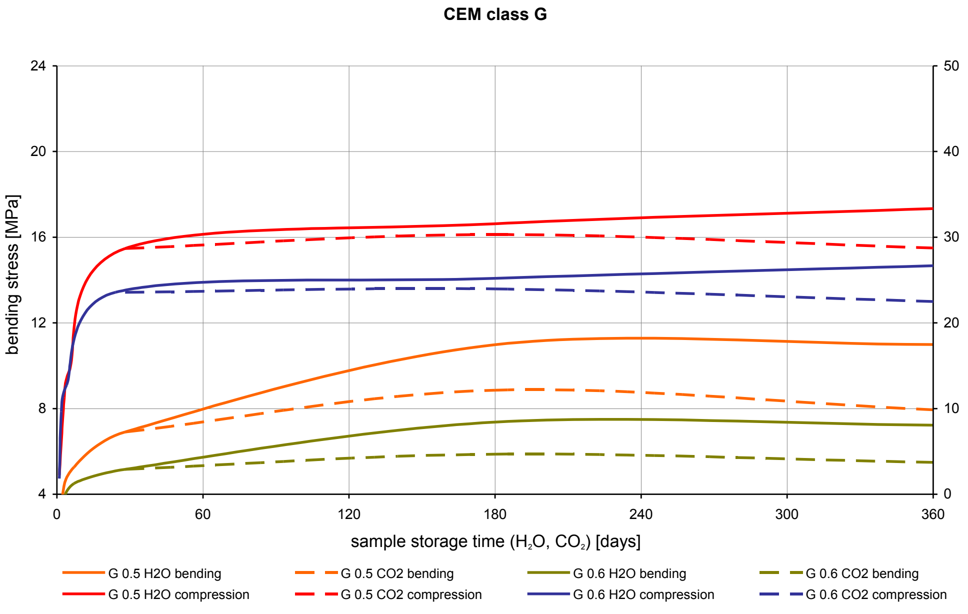

Fig. 4. Change in time of bending and compressive stress for samples of cement class G according to API regulations

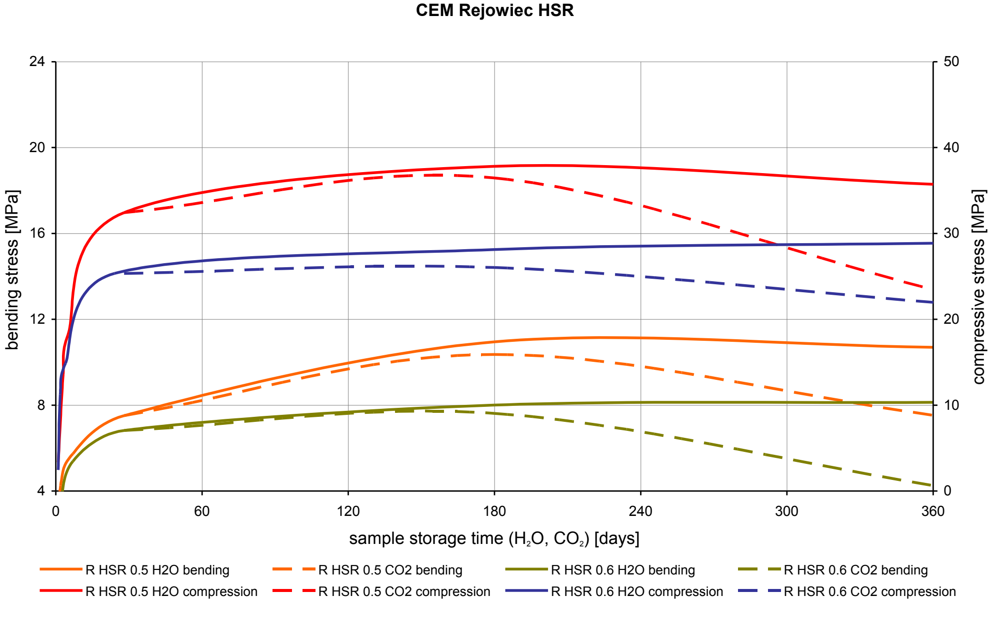

Fig. 5. Change in time of bending and compressive stress for samples of cement class G CEM Rejowiec HSR

4. CONCLUSIONS

Having compared all the results, the authors came to the following conclusions:

1. The acidic CO_2 environment leads todeterioration of the cement rock strength.
2. After a period of 180 days a decrease of sample strengths was insignificant while after the period of 360 days it reached up to 50% of the initial sample strength.
3. Both research on compressive stress and bending stress proved that CO_2 rich environment has a negative influence on cement rock strength.
4. The influence of the water-cement ratio (w/c) on a decrease of cement rock strength is an individual attribute of each cement
5. Cements CEM Małogoszcz 42.5R, CEM Kujawy HSR and cement class G according to API have slighter drop of strength for smaller w/c ratio (w/c = 0.5).
6. Cements CEM Kujawy 42.5R and CEM Rejowiec HSR have slighter drop of strength for bigger w/c ratio (w/c = 0.6).
7. Among all the researched cements CEM Rejowiec HSR is the least resistant to the corrosive environment of CO_2.
8. Out of all the cement samples stored in CO_2 rich environment CEM Kujawy 42.5R is of the best mechanical strength.

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