Thermal Energy storage capacity on different types of zeolites

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Abstract

In this study, the quality and thermal storage capacity of different types of zeolites have been analysed. The main objective of this work is to evaluate the thermal storage capacity of different types of zeolites exposed to hydrothermal control, resulting in an assessment of their thermal storage potential, based on the cationic exchange inside their cells.

Different lab experiments have been carried out, in which the behaviour of each sample has been evaluated under different conditions of drying (muffle, stove and desiccators) and operation, defining the thermal storage capacity for the different cases. A specific prototype has been designed for this purpose, which consists in different specific reactors for each zeolite type, including a sample storage chamber. “ThermaCAM SC660 Wes (TC)” results obtained for the different zeolites at different conditions, reveal high cationic exchange capacity for all types of zeolites. Drying and cooling conditions in the absence of humidity have been seen to influence results in a high extent, as well as the adequate design of the reactor, to provide effective air friction with the zeolite sample.

Keywords:Heat Transfer, Building Envelope, Thermal Comfort, Buildings, gaseous emissions, physical-chemical characterization, Thermal, CAM

1. Introduction

The need for energy saving in different fields of research has become increasingly important and has reached many different sectors. Among these ones, energy conservation in buildings is of high interest for all countries, including those situated in warm climates. This aim can be achieved not only by developing new building materials, but also with the implementation of new uses for existing materials from other applications, such as the case of the zeolites, presented in this research.

Another potential advantage is the zeolite avoids possible toxic pollutants of the heat systems and keep this heat, so the air wasted in these systems can be cleaner and of better quality.

2. Evaluation capacity of thermal storage

One of the best applications for these systems where residual energy is stored is the supply of peak energy demands in buildings. The mechanism involved consists in the activation of zeolites by using thermal energy waste of industrial processes and storing it in the absence of humidity (Mugnier and V. Goetz, 2011). This energy can also be stocked and transported where the heat is needed.

This study is the first part of a project where the capacity of thermal storage for zeolites has been evaluated by means of laboratory scale experiments.

2.1. Zeolite material: Mineral & synthetic

Nowadays, in the marketplace it can easily find the natural zeolite. It is a product that comes directly from the stone quarry and one of the common uses is for buildings and construction. In this study, the properties of this type of zeolite have been studied and compared with the synthetic zeolite type. On the contrary, the synthetic one is not commonly found in the market, so the production of this material would be increased if some

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application for the industry would be developed.

Materials selected include different sieves of both Natural Zeolite and Synthetic Zeolite. Natural Zeolite is a natural rock with high porosity and cation exchange capacity, selective absorption and reversible hydration. Synthetic Zeolites are a porous material with different properties and wide use in multiple sectors, such as an additive from water treatment plants, soil additives, cleaning products and even cosmetic synthesis. For the analysis, it is used and compared a mineral zeolite type and three synthetic zeolite types (4A,13x pellets and 13x spheres) (Zeochem).

The process that is searched in this research is to employ the cationic exchange for this kind of material to apply in thermal storage, using one of these two phases of the any zeolite material. The dry phase is named *activated*, because it is the one that you can use to extract the energy in heat form (S.Z. Xu , R.Z. Wang 2019).

The laboratory process to dry the material is divided in three steps. The first one consists in using the powerful laboratory muffle furnaces that are available for temperatures up to 1.000 °C in a small cell. After different tests to check the necessary strength to apply in any zeolites tested, it has been observed that in any case with less than 0,1 kg of sample, 40 minutes at 465ºC is enough energy to dehydrate completely the zeolite. The next step is to place the sample in oven at 110ºC for one day and it is finally stored in a vacuum desiccator for further analysis. The most important consideration in this process is the absence of air or humidity in the room. At this moment, the sample is ready for thermal heat capacity analysis in the reactor prototype.

2.2. Lab experiment: Reactor design

To check the thermal storage capacity of different types of zeolites, it´s needed to create different reactor prototypes. In this case, two reactors have been designed for both the natural and the synthetic zeolites. First of all, the design needs to be simulated by computer, and make it equal in flow proportionally for a both prototypes.

The sample is encapsulated in a cell and located in the middle position of a tube of about two meters length, according to the weight and volume of each zeolite type (S.Z. Xu,, Lemingtona 2018). Image 1 shows a ventilation equipment corresponding to the reactor diameter. The rest of the equipment is always the same in all experiments; with an air inlet and outlet where different temperatures and air speeds are recorded according to ambient conditions of outside temperature, pressure and humidity values. At the same time, temporal evolution is monitored by a thermographic (Hauer, 200) recording equipment of video and photographic model “ThermaCAM SC660 Wes (TC)” (accuracy ±1°C or ±1% of reading in a limited temperature range, ±2°C or ±2% of reading with thermal sensitivity NETD <30 mK @ +30°C), anemometers of air velocity / airflow transmitter Kimo instrument CTV 200 (accuracy air velocity from 0 to 3 m/s : ±3% of reading ±0,03 m/s / accuracy temperature ±0,5% of reading ±0,3°C), Kestrel 3000 environmental meter (accuracy ±3% of reading or ±0.1 m/s / ±1ºC) and a Fluke IR thermometer is use to check inside and outside ambient conditions of the prototype (Zhang, 2000) and verifications of the rest of equipment.

By means of these prototypes it has been possible to test different experimental conditions, as the reactor allows to control in real time different parameters as the ambient temperature and the air humidity, as the input sample it´s taken from a controlled flow of air through the first part of the reactor (Boer, R., et al. 2004) (Image 1).

2.3. Results Storage capacity

In the present figures (Figure 1, Figure 2, Figure 3 and Figure 4), the most representative results of the conducted experiments in the prototype reactor for the different zeolites types are shown. Red and blue lines show air temperature and air velocity evolution along the time, indicating the temperature and air velocity between the incoming air for ambient and the air once it passed through zeolite chamber (Núñez, 2001). In any cases the red line presents a high of temperature respect the blue one, checking the thermal storage capacity of the zeolites (S. Hongois, F. Kuznik 2014).

The amount to charge the zeolite cell reactor was near 1 kg in the case of the natural one, while for the synthetic zeolite less than 0,1 kg was necessary (Kakiuchi, et al. 2004). If the amount of the sample in the chamber would be reduced under these values, it would not work as outside air has almost the same temperature than the incoming ambient air.

By analyzing Figure 1, for the natural zeolite in stones form up to 8 cm size, it can be checked how this kind of zeolite works properly and the temperature of the whole reactor is seen to be increased by the heat conduction (Visscher et al. 2004). One of the objectives of this study consisted in collecting the heat coming from the chamber in the outside part of the reactor.

The comparisons of the results are shown in Figure 1 (5ºC for 6`), Figure 2 (10ºC for 20`), Figure 3 (8ºC for 25`) and Figure 4 (8ºC for 30`) for the different Zeolite types.

With regards to the synthetic zeolite, the results presented here are the most representative obtained from the analysis of three different types of Zeolite, comparing their morphology (Annerand Holl,2003) and structure.

From Figure 2 and Figure 3, it can be checked that for the Zeolite in Spheres 13x and Zeolite in Spheres 4A, in spite of having the same shape the behavior is improved when using the 13x molecular sieves. In the last case temperature is increased 8ºC for 25 minutes while for the 4A it increases up to 10ºC at the beginning, but the heating time is seen to be lower.

Finally, Figure 3 and Figure 4, show different shapes of the same zeolite type. It can be observed that in pellets shape, temperature is increased 8ºC for 30 minutes. This is the major time registered for all experiments developed and the results are replicable in different ambient condition for this kind of synthetic zeolite, but the air friction with sphere zeolite is bigger. Image 2 and Image 3 are the same picture with different camera lens. Image 2 shows, for the Zeolite 13x Sieves Pellets, that the reactor keeps cool, except in the chamber and the heated air is perfectly leaded up to the outside part of the prototype. When spheres type is employed, same results are obtained, but the air friction is better and more stable heat conduction to the outside part of the prototype.

3. Tables, figures, equations, and lists

3.1. Figures

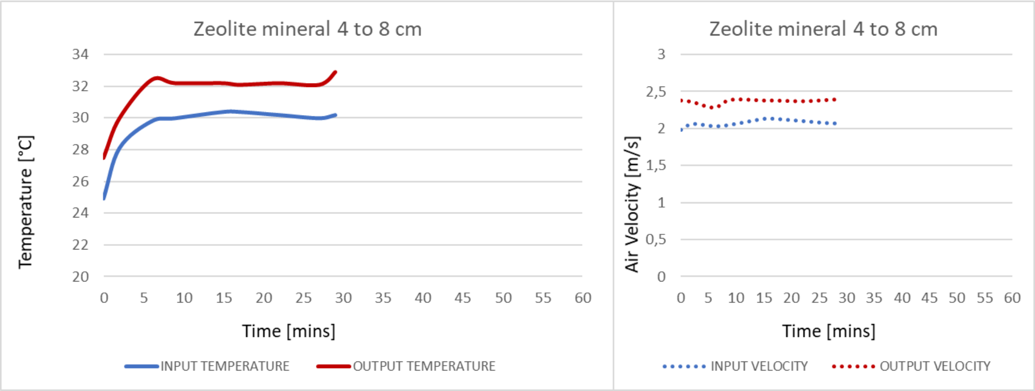


Figure 1: Zeolite mineral. 4 to 8 cm

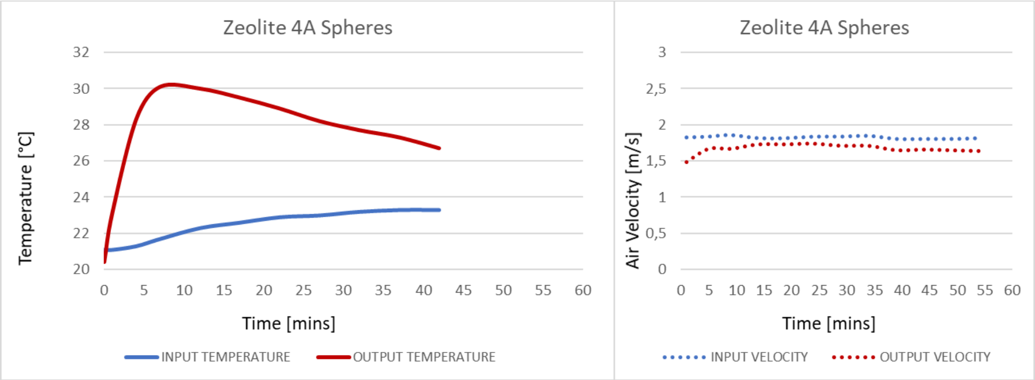
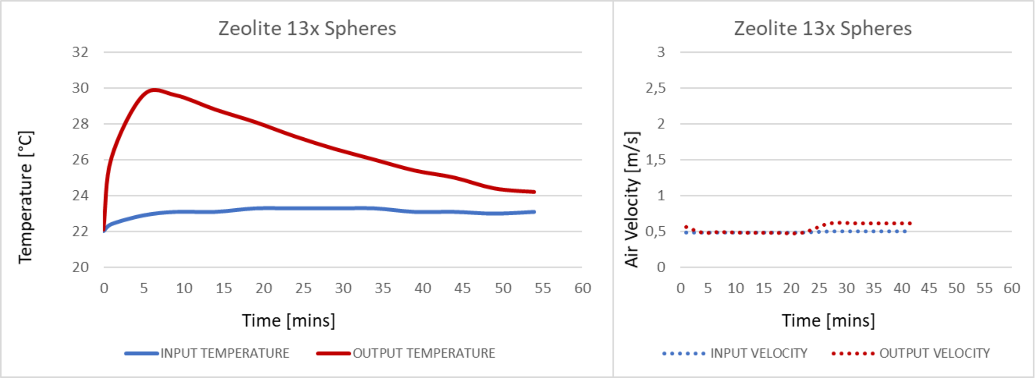
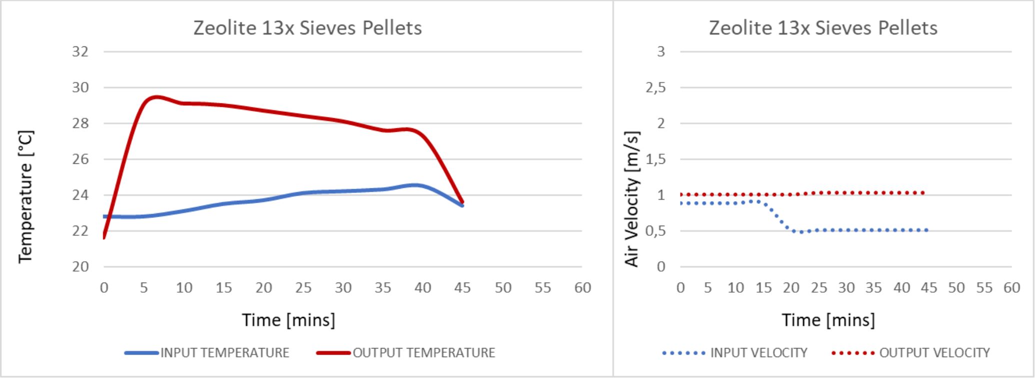


Figure 2: Zeolite 4A Spheres


Zeolite 13x Spheres

Zeolite 13x Spheres

Figure 3: Zeolite 13x Spheres


Zeolite 13x Sieves Pellets

Zeolite 13x Sieves Pellets

Figure4: Zeolite 13x Sieves Pellets

3.2. Images

Image 1: Lab experiment, reactor designs for different ambient condition

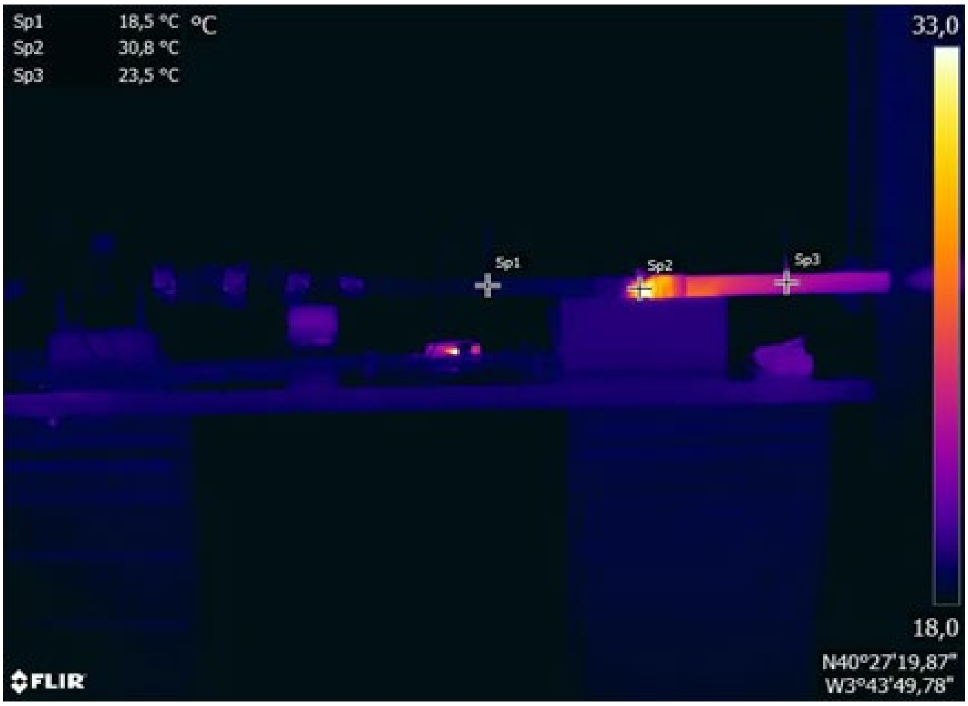


Image 2: IR vision for Zeolite 13x Sieves Pellets

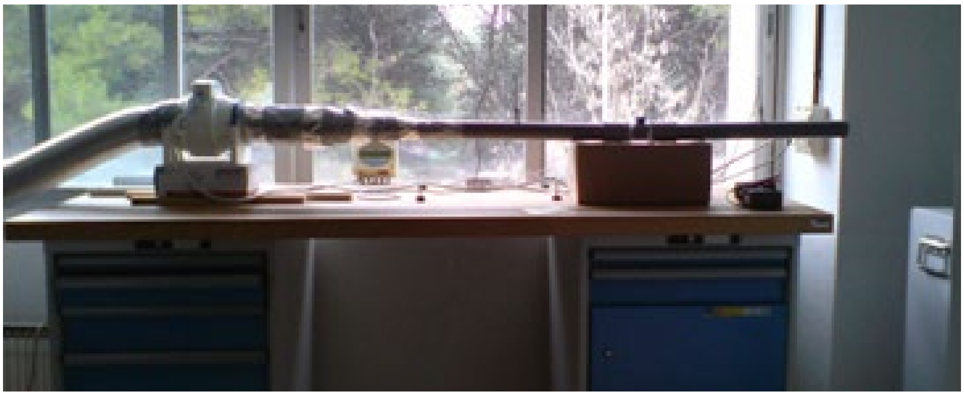


Image 3: Normal vision for Zeolite 13x Sieves Pellets

3. Conclusions

This study demonstrates that a high cationic exchange capacity for all types of zeolites is evaluated.

Natural zeolite needs more mass to take advantage of the cationic exchange's energy and the reactor system loses part of this energy by heat conduction.

In the heat test, the Zeolite 13 x test has the best results of the empirical campaing rising its temperature at 8 degrees Celsius for 25 minutes and during this time the rising is close to this 8ºC in every moment. In addition, the Zeolite 13 x spheres has a better result of material degradation.

The micro calorimetry experiments reveal that the energy level is maintained over more than seven charge/discharge cycles without any degradation of quality and reliability.

The reactor design is the key for a good air friction and to a proper energy saving produced by the zeolite.

Zeolite 13x exhibits the best results for all experimental tests carried out, keeping its temperature for a long time and the sphere shape can provide an effective air friction. Thus, Zeolite 13x Spheres has been selected to be employed in scaling up projects.

4. Acknowledgments

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5. References

European Commission (2018): SET-Plan ACTION n°3.2 Implementation Plan – Europe to become a global role model in integrated, innovative solutions for the planning, deployment, and replication of Positive Energy Districts. European Commission, Brussels.

IEA-EBC (2018): IEA Energy in Buildings and Communities Programme Strategic Plan 2019-2024. International Energy Agency, Paris.

S.Z. Xu,, Lemingtona, R.Z. Wang,, L.W. Wang, J. Zhub. A zeolite 13X/magnesium sulfate–water sorption thermal energy storage device for domestic heating. Energy Conversion and Management 171 (2018) 98–109

S.Z. Xu , R.Z. Wang , L.W. Wang , J. Zhu Performance characterizations and thermodynamic analysis of magnesium sulfate-impregnated zeolite 13X and activated alumina composite sorbents for thermal energy storage.. Energy 167 (2019) 889-901

S. Hongois, F. Kuznik, Ph. Stevens, J.-J. Roux Developement and characterisation of a new MgSO4-zeolite composite for long-term thermal energy storage.. HAL Id: hal-00683965 on 9 Jun 2014

Anner, N and S. Holl, Solicon as energy carrier – facts and perspectives, Proceedings of ECOS, Copenhagen, June/July 2003.

Boer, R., et al. Solid Sorption Cooling with Integrated Storage: The SWEAT Prototype. in Proc. International Conference on Heat Powered Cycles, HPC 2004. 2004. Larnaca, Cyprus. http://www.ecn.nl/docs/library/report/2004/rx04080.pdf

HauerA., Thermochemical Energy Storage in Open Sorption Systems – Temperature Lift, Coefficient of Performance and Energy Density. TERRASTOCK 2000, Proceedings of the 8th International Conference on Thermal Energy Storage, Stuttgart Germany, August 2000.

KakiuchiH., et al. Novel zeolite adsorbents and their application for AHP and Desiccant system, Presented at the IEA-Annex 17 Meeting in Beijing, 2004

Mugnier D. and GoetzV.Energy storage comparison of sorption systems for cooling and refrigeration. Solar Energy, Vol. 71 No. 1, pp. 47-55, 2001.

NúñezT., CharakterisierunguzndBewertung von AdsorbentienfürWärmetransformationsanwendungen, PhD Dissertation, University of Freiburg, 2001 www.freidok.uni-freiburg.de/volltexte/335/pdf/DissertationNunez.pdf

Visscher K., et al. (2004) ECN Report ECN-C--04-074: Compactechemischeseizoenopslag van zonnewarmte; Eindrapportage, ECN, Petten, Holland.http://www.ecn.nl/library/reports/2004/c04074.html. ECN-C--04-074.

Zeochen, www.zeochem.comTSDS-0014/V1/PKH230713. Access August 2020

ZhangL. Z., Design and testing of an automobile waste heat adsorption cooling system. Applied Thermal Engineering 20 (2000) 103-114.