17th International Conference
ENGINEERING MECHANICS 2011
Svratka, Czech Republic, 9 – 12 May 2011

RECYCLING OF FLUE GAS DESULPHURIZATION GYPSUM AT LABORATORY CONDITIONS

A. Hájková[*], P. Padevět[*], T. Plachý[*], P. Tesárek[*]

Abstract: *The main point of this research was to determine the practical and theoretical level of possibilities of the recycling gypsum binder and to characterize the recycling gypsum binder according to the only available Czech standard for gypsum binders – ČSN 72 2301. Therefore, the laboratory experiment of the recycling process was conducted and then the recycled gypsum binder was tested by the tests specified in this standard. Finally, comparison between starting compound, which was subjected to the process of recycling, with recycled gypsum binder was carried out. Specialty of the recycled gypsum in this case, which has undergone the process of recycling, is its age – 5 years, and also the fact that during this period it was exhibited as the gypsum block in the building envelope with no protective features and was exposed to exterior conditions as sun, wind, snow, rain etc.*

Keywords: ***Flue gas desulphurization gypsum, mechanical properties, recycling, compressive strength.***

1. Introduction

Recycling of building waste is nothing new today. In recent years beginning to emerge in the world different recycling processes of building waste, it is a way how environmentally friendly disposal with the building waste which was previously unthinkable (Ahmed and Ugai, 2010). If we talk about recycling of gypsum, we can say that the process is relatively efficient, recycled gypsum can be used as full-valued materials, not only in the building industry (Vranken and Laethem, 2000). The actual recycling is necessary to comply with certain criteria for the recycling process as well as ensure the quality of the feedstock (Wirsching, 1983). The gypsum binder classified according to ČSN 72 2301 as G-13 B III (ČSN 72 2301, 1978) was selected for the laboratory experiment of the recycled hardened gypsum. The binder was subjected to standard tests and was subsequently used for making the gypsum block that has been located in the building envelope without the protective elements for 5 years (a facade rendering, an insulation, etc.) – Fig. 1. After 5 years, the gypsum block was cut, crushed and used for production of a new recycled gypsum binder.

Fig. 1: The gypsum blocks (left – the interior side, right – the exterior side).

[*] Ing. Andrea Hájková, Ing. Pavel Padevět, Ph.D., Ing. Tomáš Plachý, Ph.D. and Ing. Pavel Tesárek, Ph.D.: Czech Technical University in Prague, Faculty of Civil Engineering, Department of Mechanics; Thákurova 7, 166 29 Prague 6 - Dejvice, Czech Republic, emails: andrea.hajkova@fsv.cvut.cz, pavel.padevet@fsv.cvut.cz, plachy@fsv.cvut.cz, tesarek@fsv.cvut.cz

2. Process of recycling

The recycling process was carried out in several points, which are summarized in Tab. 1, where they are listed with description of each applied process:

Tab. 1: Processes of gypsum recycling at laboratory conditions.

Processes	***Description***
Hard crushing	*Hard crushing of the gypsum block by the press machine WPM 100 kN*
Predrying	*Predrying in the laboratory conditions during the temperature 20 °C ± 1 °C*
Gentle crushing	*Crushing by the metal hammer (weight 3 kg) to elements < 1 cm*
Milling	*Milling on the equipment RETSCH PM 400 to elements < 2 mm*
Screening	*Elimination of elements > 2 mm*
Calcination	*Calcination proceeded during 10 days with the temperature 110 °C ± 3 °C in the drying machine by the amount of 500 g ± 100 g*

After the recycling processes, the recycled gypsum binder was placed in a container to prevent degradation of moisture and dirt. The isolated recycled gypsum binder was cooled to a laboratory temperature of 20 °C ± 1 °C. After reaching a laboratory temperature, the following tests were carried out on recycled gypsum binder according to the standard ČSN 72 2301:

- fineness of grinding,
- determining of the normal consistency,
- determining of the start and end of setting,
- compressive strength after 2 hours,
- bending strength after 2 hours.

Further parameters were determined too: cleanness of the recycled gypsum binder, bulk density and total open porosity. Based on described tests and additional parameters it was possible to compare the original gypsum binder and the recycled one according to the standard ČSN 72 2301.

3. Tests

3.1. Fineness of grinding

Fineness is the only test, which can affect the "end" feature recycled binders. Milling was carried out on a machine RETSCH PM 400 in a container of 500 ml – weight of every shot was 200 g ± 10 g, to achieve the desired fineness. Then the powdered gypsum binder was sifted through a sieve of a mesh diameter 2 mm. Particles remaining on the screen were removed from the gypsum binder. The result was similar grinding of these tested gypsum binders. Both mixtures can be classified in category III – finely ground – by the standard ČSN 72 2301.

3.2. Determining the normal consistency

The amount of water in the mixture (water-gypsum ratio) is the basic criterion for determining of the gypsum binder properties (Chandara et al. 2009). In determining of the normal consistencies is necessary to follow the procedure set out in the standard and determine the appropriate ratio of water and mixture. For the original mixture, it was chosen water-gypsum ratio 1 : 0.627, for the recycled mixture water-gypsum ratio of 1 : 1.020. The dependence on a water standard spillage over the water-gypsum ratio is shown in Fig. 2. Results could be dependent on the spillage l_r [mm] and the water-gypsum ratio v [-] expressed by the equation of a line:

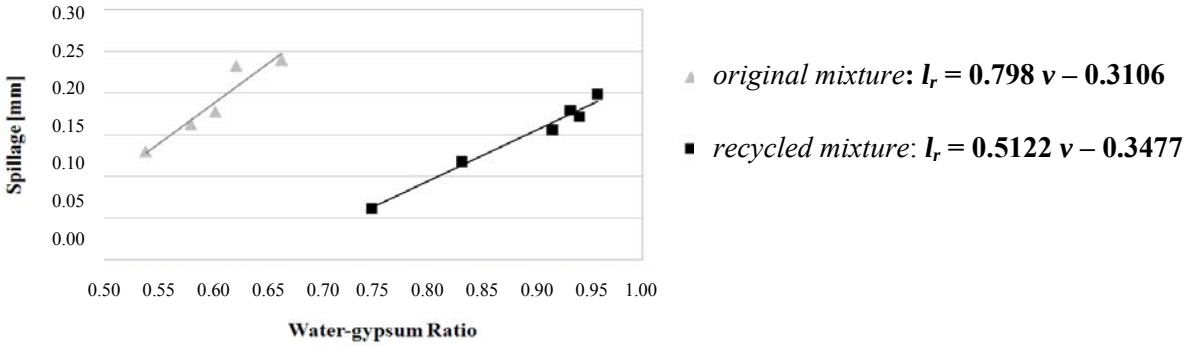

Fig. 2: The Dependence of the gypsum spillage on the water-gypsum ratio.

3.3. Determining of start and end of setting

For this test, it is always necessary to use a mixture of a normal consistency, therefore mixtures with the above-mentioned water-gypsum ratio. The Vicat device was used for determining of start and end of gypsum mixture setting. Results for the both compounds are listed in Tab. 2.

Tab. 2 shows the different values for beginning and for the overall setting time. The process of recycling accelerated values of the beginning and the end of solidification of the recycled gypsum binder approximately about ½ times.

Tab. 2: Determining the start and the end of setting.

Sample	***Measurement***	***Start of setting [min]***	***End of setting [min]***
Original binder	*1*	*9*	*14*
	2	*9*	*12*
	3	*9*	*13*
	Average	***9***	***13***
Recycled binder	*1*	*4.5*	*6*
	2	*4.5*	*8*
	3	*4.5*	*7*
	Average	***4.5***	***7***

3.4. Compressive strength after 2 hours

A compressive strength test was performed on the samples 40×40×160 mm. The samples were made from the original and the recycled gypsum binders. A pressure testing was performed 2 hours after mixing the gypsum with water at a laboratory temperature 20 °C ± 1 °C by the press machine WPM 100 kN. The calculated values are shown in Fig. 3:

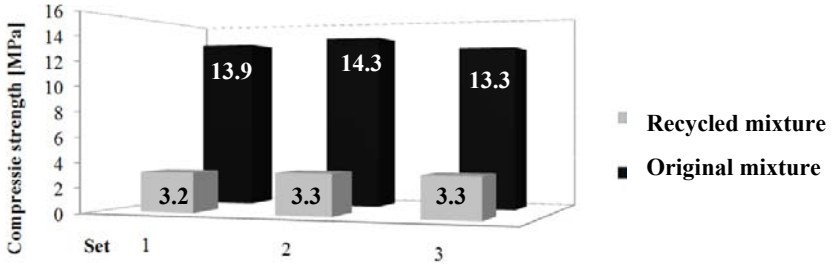

Fig. 3: Compressive strength.

In the Fig. 4 it can be seen a big drop in 2 hour compressive strength and it is approximately 76 %. Decrease in the compressive strength may be large due to almost double water ratio used for making the set of the samples from the recycled gypsum binder.

The bending strength is not a standard test for the classification of gypsum binders, but is an integral part of this experiment (as a completive mechanical parameter). Fig. 4 shows the results of the experiment. Presented values of the bending and compressive strengths showed effect of the recycling process, in this case – decreased significantly strength values.

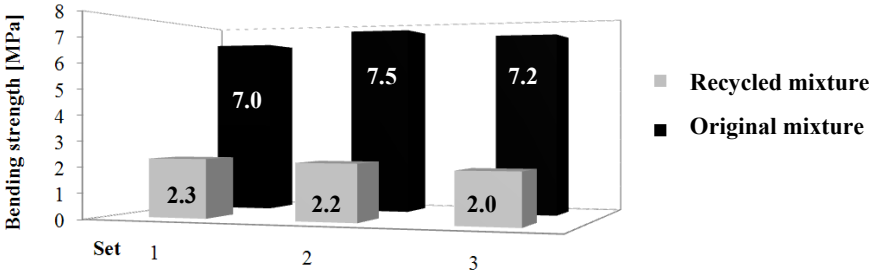

Fig. 4: Bending strength.

3.5. Cleanliness of the recycled gypsum binder

Purity of the recycled gypsum mixture was calculated after calcination process. During calcination the weight loss of the gypsum binder were measued, calcination was stopped, when the weight was stabilized. Weight was stable after 10 days of drying at temperature 110 °C. For the known values of molecular masses of individual molecules and the values of purity of the original gypsum binder mixture specified by the manufacturer, it was mathematically determined the resulting purity of the recycled gypsum binder (Thormark, 2001). The original gypsum binder reached 98 % of purity (indicated by the manufacturer), our measured value of purity for the recycled gypsum binder was 96.6 ± 1.8 °C %.

3.6. Bulk density and total open porosity

Bulk density of the gypsum samples was calculated from the weight and the volume of the tested samples; the resulting value of recycled gypsum binder is 850 kg/m^3 and it is different from the value of the original gypsum binder – 1170 kg/m^3. Total open porosity was determined using the known matrix density of the original mixture. This value is 54 % for the original gypsum binder and 66 % for the recycled gypsum binder.

4. Conclusions

From the obtained dates of the laboratory experiments on the recycled gypsum binder (Table 3) according to ČSN 72 2301 was ones classified as the gypsum binder G-3 AIII, the original gypsum binder was classified as the gypsum binder G-13 BIII. Furthermore, we can say that quality of the recycled gypsum binder is affected by recycling, calcination, the selected grinding fineness and quality of the feedstock (Hájková, A., 2010). Recycled materials can be considered as full-valued with a wide range of application and despite the fact that there was a significant decrease in strength.

Tab. 3: Measured data according to the standard ČSN 72 230.

Description	***Water-gypsum ratio***	***Absolute setting-up***	***Fineness of grinding***	***Compressive strength after 2 hours [MPa]***	***Bulk density [kg/m^3]***	***Total open porosity [%]***
Original binder	*0.627*	*Normal setting-up*	*Finely ground*	*13.8*	*1170*	*54*
Recycled binder	*1.020*	*Quick setting-up*	*Finely ground*	*3.3*	*850*	*66*

Acknowledgement

This project was supported by CTU in Prague under the project Advanced experimental methods SGS10/136/OHK1/2T/11.

References

ČSN 72 2301 (1978) Sádrová pojiva. Klasifikace. Všeobecné technické požadavky. Zkušební metody. Prague: Czechoslovak standardization institutions, pp. 17.

Hájková, A. (2010) Energosádra a možnosti její recyklace s ohledem na mechanické vlastnosti, Prague, Thesis, Czech Technical University in Prague, pp. 93.

Wirshing, F. (1983) Calcium Sulfate, In: Ullmanns Encyclopedia of Industrial Chemistry, Volume 6, Weinhein, Wiley-VCH Verlag, pp. 90 – 94.

Vranken, K. C., Laethem, B. (2000) Recycling Options for Gypsum from Construction and Demolition Waste, Waste Management Series, Volume 1, Waste Materials in Construction Wascon 2000 - Proceedings of the International Conference on the Science and Engineering of Recycling for Environmental Protection, Harrogate, England 31 May, pp. 325 – 331.

Ahmed, A., Ugai, K. (2010) Environmental Effects on Durability of Soil Stabilized with Recycled Gypsum, Cold Regions Science and Technology, 2010 (Accepted manuscript).

Thormark, C. (2001) Conservation of Energy and Natural Resources by Recycling Building Waste, Resources, Conservation and Recycling, Volume 33, Issue 2, pp. 113 – 130.

Chandara, Ch., Azizli, K. A. M., Ahmad, Z. A., Sakai, E. (2009) Use of Waste Gypsum to Replace Natural Gypsum as Set Retarders in Portland Cement, Waste Management, Volume 29, Issue 5, pp. 1975 – 1679.