Experimentální Analýza Napětí 2011
Experimental Stress Analysis

Study of FGD Gypsum Mechanical Properties – Before and After Recycling

Andrea Hájková[1], Pavel Padevět[2], Tomáš Plachý[3], Hana Němcová[4] & Pavel Tesárek[5]

Abstract: Gypsum is one of materials, which can be 100 % recycled with the same financial costs as manufacturing of gypsum binders. Properties of the hardened gypsum is then dependent on many factors. The article compares some properties of the recycled gypsum made of gypsum blocks five years old with the original gypsum. Mechanical properties and parameters needed for the classification of the gypsum binder according to Czech standard ČSN 72 2301 were mainly compared.

Keywords: FGD Gypsum, Recycling, Mechanical Properties

1. Introduction

Recycling of building waste is current trend, as well as the production of building materials suitable for the process of recycling. An effective process of recycling of some building materials is nothing new. Therefore, it is very important to be careful and used quality materials.

Recycling of gypsum materials is theoretically very simple process. But if we are to achieve the best results of the consequence material for recycling – recycled gypsum, it is important to provide great depth individual steps of the process [1]. All these steps are possible to make also with regard to ecological and economic aspects. In some EU countries as well as in the wider world (e.g. USA, Japan), the technology has developed–so-called Recycling line (Fig. 1), which can effectively recycle waste gypsum and also undesirable substances (which contained a gypsum materials) in the form of various kinds of metals, paper, etc. [2]. Separated paper from the recycling line is collected in containers, which is then pressed into bales (Fig. 2). Prepared paper blocks are then exported to incinerators, redeemed or further farmers recycled with other paper waste [3].

There are several kinds of recycling lines and every company engaged in the disposal/recycling of waste gypsum based on their own know-how of recycling line. Therefore, we cannot describe in detail sub-processes during recycling, but the general principle of operation can be summed up in the recycling line diagrams in Fig. 3.

[1] *Ing. Andrea Hájková; Czech Technical University in Prague, Faculty of Civil Engineering, Department of Mechanics; Thákurova 7, 166 29 Prague 6, Czech Republic, andrea.hajkova@fsv.cvut.cz*
[2] *Ing. Pavel Padevět, Ph.D.; Czech Technical University in Prague, Faculty of Civil Engineering, Department of Mechanics; Thákurova 7, 166 29 Prague 6, Czech Republic, pavel.padevet@fsv.cvut.cz.*
[3] *Ing. Tomáš Plachý, Ph.D.; Czech Technical University in Prague, Faculty of Civil Engineering, Department of Mechanics; Thákurova 7, 166 29 Prague 6, Czech Republic, plachy@fsv.cvut.cz.*
[4] *Ing. Hana Němcová, DiS.; Czech Technical University in Prague, Faculty of Civil Engineering, Department of Mechanics; Thákurova 7, 166 29 Prague 6, Czech Republic, hana.nemcova@fsv.cvut.cz.*
[5] *Ing. Pavel Tesárek, Ph.D.; Czech Technical University in Prague, Faculty of Civil Engineering, Department of Mechanics; Thákurova 7, 166 29 Prague 6, Czech Republic, tesarek@fsv.cvut.cz.*

Fig. 1. Recycling line for waste plaster al. NWGR – UK, Adapted from http://www.nwgypsum.com

Fig. 2. The line for pressing waste paper. Taken from http://www.drywallrecycle.com

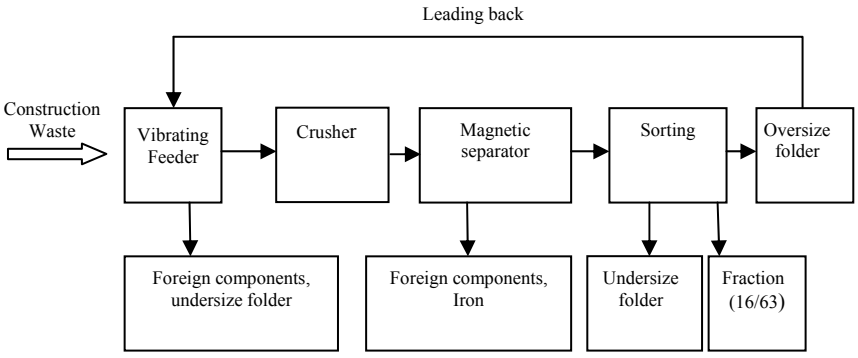

Fig. 3. Diagram of the combined recycling line for waste plaster

2. Recycling in laboratory conditions

Recycling of gypsum at laboratory conditions was realized at different specifications than production of calcined gypsum (natural or synthetic), where waste gypsum is added as secondary raw material. Dependence on the method of disposal cannot characterize the behaviour of impurities in waste gypsum and cannot accurately describe the outcome, because the waste is added at a rate of 3 to 15 % weight of the lot ready for calcination [4].

Recycling at laboratory conditions was equivalent to 100 % recycling without the additions of the original gypsum in relation to the characterization of mechanical properties.

2.1. The material used for the laboratory recycling process

Flue gas desulphurization gypsum from power plant Počerady (Czech Republic), was chosen as an experiment material, this gypsum is characterized according to ČSN 72 2301 [5] as G-7 BIII. The material used for the recycling process had one unusual feature – has been issued for five years in the building envelope – Fig. 4. The gypsum blocks of dimensions 350 × 250 × 600 mm were made for this purpose. The production of the gypsum block was in compliance with ČSN 72 2301. The water/gypsum ratio 0.627 was chosen based on this standard. Used gypsum binders remain raw, with no added ingredients and additives, without reinforcement. The gypsum block was exposed to weather conditions. Within five years, the temperature and humidity of the blocks were measured and recorded.

Fig. 4. Gypsum blocks in the building envelope, the view from the outside

After five years, the block was removed from the building envelope; it was cut into thirds and specimens with dimensions of 40 × 40 × 160 mm were prepared from one third of the block. The compressive and flexural strength of the specimens were determined. The measured values were compared with values measured five years ago – Fig. 5 and 6. After measuring of the strengths, the specimens were recycled.

2.2. Process of recycling

The recycling process was carried out on samples from the 5 year's old gypsum block. Residues of the gypsum samples were crushed into smaller pieces in the press of WPM 20 kN. Subsequently, the gypsum grain diameter < 10 mm were inserted into the oven and pre-dried at 40 °C for 3 days. After three days, the pre-dried gypsum were subjected to grinding to an average grain size < 2 mm. The milling machine was used RETSCH PM 400. After milling, the powdered gypsum was sieved on a mesh screen 0.2 mm. Sieving minced gypsum was oversized to eliminate undesirable grain. Then it was just calcined in an oven at 110 °C for 7 days until there was no stabilization of weight loss.

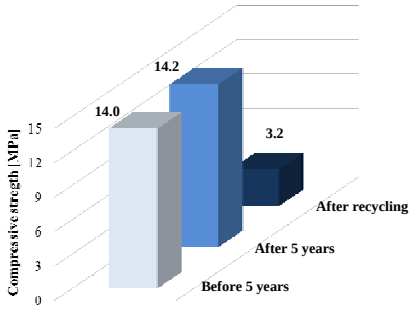

Fig. 5. Compressive strengths of tested gypsum samples

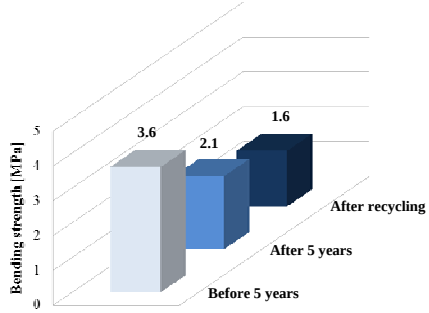

Fig. 6. Bending strengths of tested gypsum samples

After calcination, the recycled gypsum has been stored in polyethylene bags and insulated from the environment to prevent moisture degradation. The specimens 40 × 40 × 160 mm were made from the recycled materials. The fixed compressive and flexural strengths were compared with values before and after five years – Fig. 5 and 6. Compressive and bending strengths are basic mechanical parameters, which describe macromechanical properties of tested materials [6], [7].

Fig. 5 shows the same values of original gypsum samples, samples were tested before 5 years and now. Presented values of gypsum compressive strength in time (in our case five years) is interesting and our results showed resistance of gypsum against weather (rain, frost resistance, changing temperatures or values of relative humidity).

3. Properties of the recycled and non-recycled gypsum

Material properties of the recycled gypsum are not characterized only by the strength characteristics. The selected water/gypsum ratio, which was used in mixing gypsum binder used for casting of tested gypsum specimens, has influence to the final strength of the material. Material properties of gypsum binders are depanded on followed parameters: the fineness, purity of a gypsum binder, the temperature of the mixing water, the method and calcination temperature, the beginning and end of solidification, the quality of a material and the resulting density and total porosity.

3.1. Water/gypsum ratio

Water/gypsum ratio, which was used for the tested gypsum samples, was different for recycled and non-recycled gypsum binders. It was determined in accordance with the standard ČSN 72 2301 (a gypsum mixture with normal consistency). The normal consistency was determined by overflow tests described in the standard. The resulting value of the water/gypsum ratio was set 1.02 for the recycled gypsum binder (the original water/gypsum ratio used for manufacturing of the gypsum block was 0.627).

3.2. Fineness

Recycled materials were subjected to a norm sieve with a mesh size of 0.2 mm. Grains larger than 0.2 mm was eliminated.

3.3. The purity of gypsum

The purity of gypsum was determined based on the known values – molecular weight of molecules, and the weight loss during the calcination process. The resulting value of gypsum

purity was 96.559 %. The original purity of the gypsum binder specified by the manufacturer was 94 – 98 %.

3.4. Temperature of mixing water

The temperature of mixing water was 20 °C ± 1 °C, this value was the same as during manufacturing of the gypsum block.

3.5. Beginning and end of solidification

The test was conducted in accordance with the standard ČSN 72 2301 Vicat using the device. The results are shown in Table 1. Table 1 shows the large differences in measured values. A beginning of solidification is two times lower for the recycled gypsum in comparison with the original gypsum mixture. The recycling process also two times accelerated a setting time.

Table 1. Beginning and end of solidification

Samples	Measurement	Beginning of solidification [min]	Setting time [min]
Before recycling	1	9	14
	2	9	12
	3	9	13
	Average	**9**	**13**
After recycling	1	4.5	6
	2	4.5	8
	3	4.5	7
	Average	**4.5**	**7**

3.6. The quality of input material

The original material (FGD gypsum) chosen for the experiment was characterized by ČSN 72 2301 as G-7 BIII. (The recycled gypsum binder was made from gypsum blocks which were placed for a period of five years in a building envelope. We can say that for recycling was elected the unpolluted raw gypsum.

3.7. Bulk density and total porosity

The measured values of density and total porosity are shown in Table 2. The table shows differences in values of hardened gypsum produced of the gypsum binder before and after the recycling process.

Table 2. Density and total porosity

Sample	Bulk density [kg/m^3]	Total porosity [%]
Before recycling	1220	52
After recycling	850	66

4. Conclusion

The laboratory experiment with 100 % recycling of waste gypsum was realized. We can say that, for measuring of same characteristics after the Czech standard ČSN 72 2301 the gypsum binder before and after recycling, there is a depreciation of utility properties of the recycled

gypsum binder. On the other hand, our laboratory calcination is different from real calcination processes, which are used at building industry.

If we look at the recycled gypsum binder as a new material, despite the decline in strengths, we can state, that this material can be used in wide variety of industries. It is also necessary to specify the precise terms of recycling detail and focus on the technical characteristics of the recycled gypsum binder, e.g. obsolete standard ČSN 72 2301, hence the scale used for qualifying recycled binders are inaccurate.

Acknowledgements

This work has been supported by grant CTU under No. SGS10/136/OHK1/2T/11 – Advanced experimental methods.

References

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

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

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

[4] Shater M.A., Mosalamy F.H., El-Sheikh R., El-Didamony H., Mechanism of the hydration of tricalcium aluminate and gypsum of 1:3 mole ratio at low water / solid ratio and in suspension, Thermochimica Acta, Volume 69, Issue 3, pp. 379-388, 1983.

[5] ČSN 72 2301, Sádrová pojiva. Klasifikace. Všeobecné technické požadavaky. Zkušební metody. (Czechoslovak standardization institutions, Prague), pp. 17, 1978.

[6] Melzerová L., Kuklík P., Variability of Strength for Beams from the Glued Laminated Timber, in Proceeding of Experimental Stress Analysis 2010. Olomouc: Palacky University, 2010, p. 257-260. ISBN 978-80-244-2533-7.

[7] Padevět P., Zobal O., Change of Material Properties of the Cement Paste CEM I, in Proceeding of Experimental Stress Analysis 2010. Olomouc: Palacky University, 2010, p. 307-310. ISBN 978-80-244-2533-7.

[8] Plachý T, Padevět P, Polák M., Comparison of static and dynamic modulus of elasticity on concrete specimens. in Proceeding of Experimental Stress Analysis 2009. Liberec: Technical University, 2009, p. 201-206. ISBN 978-80-7372-483-2.

[9] Tesárek P., Plachý T., Hájková A., Padevět P., Polák M., Time Evolution of "Grey Gypsum" Mechanical Properties, in Proceeding of Latest Trends on Engineering Mechanics, Structures, Engineering Geology. Athens: WSEAS, 2010, p. 413-417. ISBN 978-960-474-203-5.