Materials, Mechanics and Information Engineering

Edited by
Khanittha Wongseedakaew and Qi Luo

TRANS TECH PUBLICATIONS

Materials, Mechanics and Information Engineering

Selected, peer reviewed papers from the
2014 3rd International Conference on
Chemical, Mechanical and Materials Engineering
(CMME 2014),
October 24-25, 2014, Riga, Latvia

常州大学图书馆
藏书章

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Trans Tech Publications Ltd
Churerstrasse 20
CH-8808 Pfaffikon
Switzerland
http://www.ttp.net

Volume 729 of
Applied Mechanics and Materials
ISSN print 1660-9336
ISSN cd 1660-9336
ISSN web 1662-7482

Full text available online at *http://www.scientific.net*

***Distributed** worldwide by*

Trans Tech Publications Ltd
Churerstrasse 20
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Switzerland

Fax: +41 (44) 922 10 33
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and in the Americas by

Trans Tech Publications Inc.
PO Box 699, May Street
Enfield, NH 03748
USA

Phone: +1 (603) 632-7377
Fax: +1 (603) 632-5611
e-mail: sales-usa@ttp.net

printed in Germany

Applied Mechanics and Materials

ISSN: 1660-9336, ISSN/ISO: Applied Mechanics and Materials

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Aims and Scope:

Applied Mechanics and Materials is a book series specialized in the rapid publication of proceedings of international conferences, workshops and symposia as well as state-of-the-art volumes on topics of current interest in all areas of mechanics and topics related to materials science.

Internet:

The periodical is available in full text via www.scientifc.net

Subscription Information:

Irregular: approx. 80-100 volumes per year. First volume in 2015: Vol. 695

The subscription rate for web access is EUR 1089.00 per year.
Standing order price for print copies: 20% discount off list price plus postage charges.

ISSN print 1660-9336
ISSN cd 1660-9336
ISSN web 1662-7482

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Preface

2014 3rd International Conference on Chemical, Mechanical and Materials Engineering (CMME 2014), will be held on October 24-25, 2014, Riga, Latvia.

2013 2nd International Conference on Chemical, Mechanical and Materials Engineering (CMME 2013) has been held on January 20-21, 2013, Melbourne, Australia, which has been indexed by EI Compendex after three months.

CMME 2014 will be the most comprehensive conference focused on the various aspects of advances in Chemical, Mechanical and Materials Engineering. This Conference provides a chance for academic and industry professionals to discuss recent progress in the area of Chemical, Mechanical and Materials Engineering.

Chemical engineering is the branch of engineering that applies the physical sciences (e.g., chemistry and physics) and/or life sciences (e.g., biology, microbiology and biochemistry) together with mathematics and economics to processes that convert raw materials or chemicals into more useful or valuable forms. In addition, modern chemical engineers are also concerned with pioneering valuable materials and related techniques – which are often essential to related fields such as nanotechnology, fuel cells and biomedical engineering. Within chemical engineering, two broad subgroups include 1) design, manufacture, and operation of plants and machinery in industrial chemical and related processes ("chemical process engineers"); and 2) development of new or adapted substances for products ranging from foods and beverages to cosmetics to cleaners to pharmaceutical ingredients, among many other products ("chemical product engineers").

Mechanical engineering is a discipline of engineering that applies the principles of engineering, physics and materials science for analysis, design, manufacturing, and maintenance of mechanical systems. It is the branch of engineering that involves the production and usage of heat and mechanical power for the design, production, and operation of machines and tools. It is one of the oldest and broadest engineering disciplines. The engineering field requires an understanding of core concepts including mechanics, kinematics, thermodynamics, materials science, structural analysis, and electricity. Mechanical engineers use these core principles along with tools like computer-aided engineering and product lifecycle management to design and analyze manufacturing plants, industrial equipment and machinery, heating and cooling systems, transport systems, aircraft, watercraft, robotics, medical devices, and others.

Materials science is an interdisciplinary field applying the properties of matter to various areas of science and engineering. This scientific field investigates the relationship between the structure of materials at atomic or molecular scales and their macroscopic properties. It incorporates elements of applied physics and chemistry. With significant media attention focused on nanoscience and nanotechnology in recent years, materials science has been propelled to the forefront at many universities. It is also an important part of forensic engineering and failure analysis. Materials science also deals with fundamental properties and characteristics of materials.

We would like to thank the organization staff, the members of the program committees and reviewers.

They have worked very hard in reviewing papers and making valuable suggestions for the authors to improve their work. Special thanks go to the organizing committee, program committee members, and TTP Publisher. Finally, the conference would not have been a success without the support of the authors. We would like to acknowledge and thank all authors who submitted their research work to the conference, whether the submission made it to the proceedings or not.

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CHAPTER 1:

Materials Science and Materials Engineering

Applied Mechanics and Materials Vol. 729 (2015) pp 3-8
© (2015) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMM.729.3

Submitted: 06.11.2014
Accepted: 07.11.2014

Lightweight Gypsum- based Material, Foamed by Lime Dust and Acid Agent

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Keywords: Lightweight gypsum; Foamed gypsum; Acid agent; Lime dust; Aluminium sulphate

Abstract. Lightweight gypsum materials foamed by the help of stone dust were investigated. Lightweight material prepared from the gypsum as a main binder and foamed by stone dust and acid agent. The materials with the bulk density are 607 kg/m^3, compressive strength about 1.3 MPa and thermal conductivity was prepared. Basic physical, mechanical and thermal properties were investigated.

Introduction

Lightweight gypsum based material has attracted much attention for scientific research due to its relatively small weight per unit volume under normal conditions. Gypsum has been used as a construction material since ancient times. Due to its easy fabrication features, environmental friendliness, aesthetics, low price, etc and also especially due to its excellent fire resistance property gypsum plasterboard is used extensively for interior walls or ceilings..The significance of gypsum gradually increases from the beginning of the 20th century, because raw gypsum is used as a setting retarder in Portland cement production and because the gypsum binder can be made from several waste products from various industrial sources, such as from the fertilizers production (phosphogypsum) [1] and particularly from the fuel gas desulfurization of coal power plants (FGD gypsum) [2]. Energy consumption of the gypsum production is significantly lower comparing to the cement and lime production because it can be made from waste products, gypsum is generally recognized as an environmental friendly material. However, in spite of its advantages, the current application of gypsum in building is relatively narrow. One of the interesting ways for extending of gypsum application possibilities is development of lightweight gypsum based materials.

There are several methods to prepare such kind of light weight gypsum material. Lightweight gypsum can be produced either as gypsum foamed by chemical additives [3, 4] or using light aggregates [5, 6]. Colak et al. reported the lightweight gypsum prepared by both foaming methods. For gas generating method he used either sulfate salts (aluminium sulfate or potassium alum) together with $CaCO_3$ or ammonium bicarbonate. Hernandez Olivares et al. [7] prepared the lightweight gypsum composite with 20 % of cork granulate and 2% of glass fiber. Gutierrez Gonzalez et al. [8] used the gypsum polyurethane foam waste to improve the thermal properties of the gypsum. Jimenez Rivero et al. [9] tested gypsum composite with ground waste rubber from pipe foam insulation.

Therefore, in this paper we study the gypsum based material foamed by CO_2, which is result of the following reaction:

$$Al_2(SO_4)_3 + 3CaCO_3 + 6H_2O \rightarrow 2Al(OH)_3 + 3CaSO_4 + 3H2O + 3CO_2 \quad (1)$$

Liquid acid agent prepared from aluminum sulfate and citric acid was used as the foaming agent and as a source of calcium carbonate $CaCO_3$ waste stone dust was used. By using of the waste stone dust we tried to find the most environmental solution, because accumulation of the waste stone dust from the cutting and polishing of the stones (especially marble) became the serious problem in many countries.

Materials and Sample Preparation

As a gypsum binder the commercional available β-hemihydrate $CaSO_4.1/2\ H_2O$ (producer Gypstrend, Czech Republic) was used. Amount of $CaSO_4.1/2\ H_2O$ in the gypsum was 80 - 95 %, its loose bulk density was 670-860 kg m^{-3}, retained on sieve 0,2 mm 0,6 - 6 %, initial setting time 8 min, final setting time T 16 min, compressive strength after 2 h 2,7 - 2,9 MPa.

Liquid foaming agent was prepared from aluminum sulfate and citric acid dissolved in the water. The citric acid is added mainly as a retarder of setting and serves for the stabilization of the liquid acid agent also. The amount of acid agent is given in dry solid state as a ratio of citric acid: aluminium sulfate = 1:2

Stone dust is waste from the stone cutting and polishing from the local stonemason (town Beroun, Czech Republic). Composition of the dust is approximately 50 % of marble and 50 % of granite. It was taken in the form of sludge which was dried and then ground to the maximal particle size 100 μm. The dust contained approximately 15 % of $CaCO_3$, 20 % of CaO and 50 % of SiO_2. Particle size distribution of the dust is on the Fig. 1

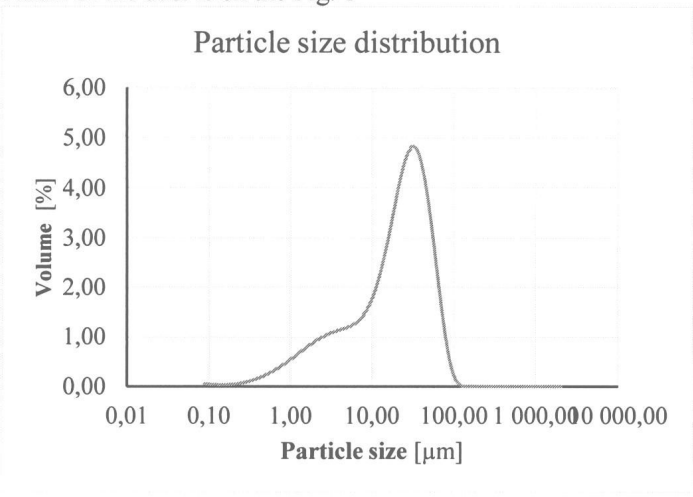

Fig.1 Particle size distribution of stone dust

As the paste preparation, firstly, gypsum and dust powder in dry state were mixed thoroughly together. After mixing of the dry components the dry composition was added into the measured amount of acid agent and water. Then it was mixed by laboratory mixer for 30s at low speed (14 rev/min), wiped off and mixed again for another 30 s at the same low speed. From all mixers three test prisms (160 ×40× 40) were prepared. The test pieces were not compacted; only the surface was leveled by knife. The specimens were dried at the temperature of 50^0C to constant mass after demolding.

Experimental Methods

The bulk density, flexural strength, compressive strength and thermal conductivity of studied gypsum were done.

The bulk density, ρ_V, was determined by weighing and size measurement of test prisms.

The measurement of bending strength was performed according to the European standard ČSN EN 13279-2 [9] on the 40 x 40 x 160 mm prism. The experiment was performed as a common three-point bending test. The measurements were done at the time of 7 days after mixing.

Compressive strength was determined in accordance with the European standard ČSN EN 13279-2 [9] on the halves of the specimens left over after the bending tests. The compressive strength was calculated as the ratio of the ultimate force and load area 1600 mm2.

Thermal conductivity and specific heat capacity were measured using the impulse method (apparatus Isomet 2104, Applied Precision, Ltd., Slovakia). The measurement was based on the analysis of the temperature response of the analyzed material to heat flow impulses. 70 x 70 x 70 mm samples were used.

Design and compositions of the mixture

In order to achieve the mixture with the target minimum bulk density the sequential optimization was utilized, using the computer code SOVA 1.0. [10]

Our target was to achieve as low as possible bulk density with the reasonable mechanical properties, using maximal possible dust. For that the complex point criterion was formulated. As an optimal values of the material the bulk density ρ_V = 600-700 kg.m^{-3}, R_c = 2-2,5 MPa, amount of dust = 12-15 % (from the gypsum mass) were determined. The principles of the criterions are given in the Table 3. The amount of points was used as an optimization property with the target to achieve maximal points.

Table 1 Complex point criterions for optimization

Property		Value					
Bulk density	[kg.m^{-3}]	< 600	600 - 650	650 - 700	700-750	750 - 850	> 850
Points		**2**	**1**	**0**	**-1**	**-2**	**-3**
Compressive strength	[MPa]	< 1	1-1,5	1,5 - 2	2 - 2,5	>2,5	
Points		**-2**	**-1**	**0**	**1**	**2**	
Amount of dust	[%]	< 8	8 - 10	10 - 12	12 - 15	> 15	
Points		**-2**	**-1**	**0**	**1**	**2**	

First reference composition G was prepared from gypsum without dust and acid agent. After that twelve mixtures from lightweight gypsum (GD1 to GD8) were successively prepared according to the computer code design. The first four compositions created the first trial (GD1 to GD4) of the optimization. At first those mixtures were prepared and their bulk density and strength were determined. Than the points of the complex criterion were calculated. The points (as an optimized property) were input to the computer and the computer code designed new composition. The new composition was prepared; its point values was determined and again input to the computer code, which suggested another composition. In this sequential way another thirteen mixtures (GD5 to GD17) were gradually prepared. After that the optimization was stopped, because it started to be obvious, that the set target properties are unrealistic without the help of other additives. On the materials with the lowest bulk density the thermal conductivity was measured. The compositions of all prepared mixtures and the results of the bulk density ρ_V, flexural strength R_y, compressive strength R_c, and thermal conductivity λ are presented in Table 2.

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