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New Types of Plastering Mortars Based on Marble Powder Slime

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Abstract

The use of marble powder residue slimes that can be found in enormous amounts of about 100 tons/day (in the nearby of marble processing companies) to produce building materials represents an efficient manner of diminishing the resource consumption and of significantly reducing its negative impact upon the environment. Consequent to the drying of this product, a fine powder with various grain sizes can be obtained; the grains can be used as a partial or total of mortar aggregates. The experimental program in the present paper includes the production and proposal of more types of plaster mortars where the marble powder slime replaces the aggregate in a percentage of 25%, 50%, 75% and respectively 100% as well as a 15% replacement of the binder. Results show that 25% substitution of aggregate by marble powder provided the highest value of compression strength at 28 days and also the highest value to adhesion to the support layer. Also, plastering mortars with 15% substitution of cement by marble powder, at the age of 28 days, has a resistance to compression of 13 N/mm^2, approximately twice larger than that of the conventional plaster mortar. The present paper is dedicated to the study of the physical and mechanical properties of the plaster mortars in both fresh state and hardened state in their development in time.

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Keywords: sustainable development; waste management; marble powder residue/waste; plaster mortar; physical and mechanical properties; ecological innovative materials.

Introduction

Marble is a building material which has been used since very ancient times. The marble processing industry is a widely spread industrial activity throughout the world and its extent is also linked to the production of waste and by-

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products. The storage and removal of the waste coming from the marble industry represents one of the major worldwide issues related to environment [1]. Though, at world level, the marble powder storage and the detrimental effects upon the environment are a big problem, there a few studies on the behavior of marble powder and its reconversion in building materials.

In Romania, the marble powder slime waste is generated in about 100 tons/day and has a negative consequence upon environment, due to pollution, and also upon human health.

The problem of marble processing industry waste has an international concern, and it has been treated with great attention by interested researchers, in order to obtain new building materials, cheaper than those traditionally, by using of such waste and thus to eliminate the problems related to environment pollution.

Binici studied several mechanical properties of concrete with marble powder and limestone waste. Concrete with 5%, 10% and 15% marble powder and limestone was produced, where marble and limestone replaced the concrete fine part. The researcher studied the resistance to compression of the mentioned products [2].

Corinaldesi, shows that by substituting 10% sand with slime waste, an improved resistance to compression and workability can be obtained [4]. The test was made on several experimental samples where both cement and part of the aggregates was replaced.

The marble powder waste can be used not only as admixtures, but also to produce other types of building materials, such as ceramic bricks, as shown in the research made by Saboya in the paper "The use of powder marble by-product to enhance the properties of brick ceramic" who reaches the conclusion that a percentage of 15-20% marble powder could improve significantly the properties of ceramic bricks [5].

The present paper involves the use of waste sludge from marble powder (considering the context of environment sustainability and that of life quality sustainability) in order to propose some plastering mortars type CS IV where sand is replaced in various amounts (25%, 50%, 75% and 100%) by marble powder slime and then cement is replaced by 15% by marble powder slime. It also represents a well-supported study concerning the influence of the marble powder slime upon the physical and mechanical properties of plaster mortars.

2. Materials and methods

This research deals with the production of five ecological plaster mortars of type CS IV using the marble powder slime as a total or partial substitute for sand and cement, respectively. The materials used in the mortar formula are: the binder, sand, water and marble waste (to replace the aggregate or the binder). The recipes for the plastering mortars do not contain additives for the purpose of the present research.

2.1. Materials

- Cement: The binder for the mortar formulae is the Portland type cement CEM IV/B 42,5N.
- Aggregates used at preparing mortars: The sand used in the mortar formula is river sand, with granulation between (0 – 4) mm. The mortar formula required sand with a proper granulometric curve.
- Marble powder slime waste: Marble powder slime is obtained after the processing of natural rocks, by cutting, shaping and finishing the edges and surfaces in various shapes and colours. The slime used in the samples was collected from the marble company Marmosim Deva, Romania.

In Romania, there are several quarries that daily produce enormous amounts of marble powder, among which the quarried situated in Ruşchiţa (the largest quarry in the country), Podeni, Cărpiniş, Pietroasa, Geoagiu and Başchioi.

Before using the slime in the samples, the slime was dried, in a kiln at 105ºC where it was kept until a constant weight was reached; the material was then ground and sorted out.

The main chemical components in the marble are presented in Table 1:

Table 1. Results of chemical analysis of marble powder.

Chemical compounds	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	SO_3	CO_2
Percentage %	55.00	0.62	0.36	0.28	0.04	0.00	0.07	0.06	43.56

In order to highlight the main component of marble powder waste, the optical microscopy method was used. In the following pictures it can be seen the mineral component $CaCO_3$ of the marble powder waste (Fig. 1).

a b

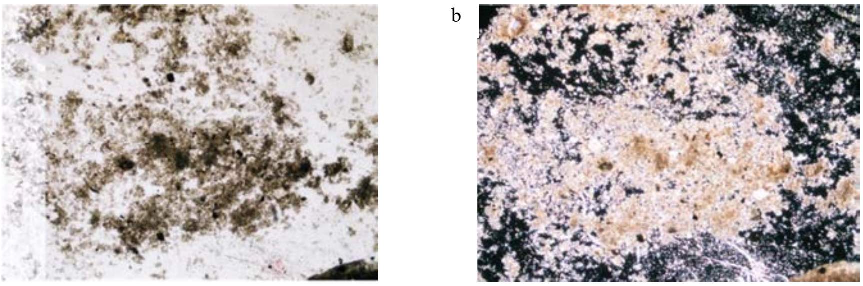

Fig. 1. (a) Marble powder aggregate ($CaCO_3$) (1N); (b) Marble powder aggregate ($CaCO_3$) (N+).

The first step of the experimental program was to study all the slime powder characteristics, considering the fact that the slime powder can replace the binder from mortars, which could lead to a cheaper mortar. Thus, it has been started by studying the physical properties of slime powder: real density, specific area using Blaine permeabilimetre, water for normal consistency slurry, setting time. Specific area of the marble powder is 3994,3 cm^2/g. As it is known that, with common cement the specific area ranges between 2000 and 4000 cm^2/g, it is evident that the specific area of the marble slime is close to that of cement and this makes possible its use as a cement admixture in various percentages in the mortar formula (Table 2.).

Water for normal consistency slurry was also determined in a similar manner to cement cases of common consistency, performed according to EN SR EN 196-3 [7]. Thus, for 100 g marble powder, 26,67 ml water is necessary for slurry of normal consistency (Table 2.).

In the same experimental program, the setting time for the slurry made with marble powder was also determined to be 180 minutes (Table 2.).

Table 2. Features of marble dust obtained from sludge of marble dust waste.

Characteristics	U.M.	Values
Real density	g/cm^3	3,125
The specific surface	cm^2/g	3994,3
The water required for normal consistency paste	ml	26.67
Setting time	min	180

- Water: The water for sample preparation was drinkable water and it is according to SR EN 1008 [8].

2.2. Methods

The experimental program included determining the standard characteristics: apparent density for fresh and hardened mortars, consistency with scattering table, tensile bending strength, compression strength and adhesion of mortars [9][10][11][12][13][14][15][16][17].

All the determinations were performed according to the standards in force.

- Determination of fresh plastering mortar apparent density

The determination of fresh mortar apparent density was performed in conformance with the standards in force: SR EN 1015-6:2001 [9] and SR EN 1015-6/A1:2007 [10]. Apparent density of fresh mortars proposed in the paper, was determined by the ratio between mass and volume occupied when placed and compacted in a measuring container of given capacity, according to an established way of working.

- Determination of hardened plastering mortar apparent density

The determination of hardened mortar apparent density was determinate by the ratio between dry mass obtained when keep samples were dried in a dry kiln and volume occupied when sample were placed in water [10][11].

- Determination of plastering mortar consistency with the scattering table

The determination of the plaster mortar consistency with the scattering table was made according to SR EN 1015-3 and SR EN 1015-3/A2 [13][14]. The scattering value was determinate by measuring an average diameter of the fresh plastering mortar made with marble powder slime wastes.

- Determination of the plastering mortar tensile bending resistance

The tensile bending resistance was tested according to SR EN 1015-11 and SR EN 1015-11/A1 [15][16]. Determination is made with the apparatus for determining the resistance to bending, on prisms with dimensions of 40x40x160mm.

The determination was made on all types of plastering mortars proposed on the present paper, at different intervals of times: 3, 7, 14, 28 and respectively 60 days.

- Determination of the plastering mortar compression resistance

The resistance to compression was tested according to SR EN 1015-11 and SR EN 1015-11/A1 [15][16]. Using the hydraulic press, the test was conducted on the remnants of prism after testing prisms at bending strength.

The average values were recorded at 3, 7, 14, 28 and 60 days.

- Determination of slime based plastering mortar adhesion

Adhesion was determined according to: SR EN 1015-12 [17]. This type of testing is done at 28 days, immediately after the samples are taken of the place that were kept until testing.

2.3. Sample preparation and composition of plastering mortars

The mortars produced in this experimental program are ecological plaster mortars, in the composition of which marble industry waste was introduced to replace both the aggregate and the binder. The samples have the shape of a prism of sizes 40x40x160 mm. The prisms were prepared in the Laboratory of Building Materials with the mixer; they were poured in metal molds and kept in wet air boxes up to 7 days and moved in a room of humidity (65±5)% at a temperature of (20±4)ºC, up to the test age time. Prisms were cast in two layers, each layer being compacted with a mechanical vibrating machine.

The recipes (Table 3) can be divided in two categories:

a) plastering mortars where sand is replaced by marble slime in various amounts 25% - MMW 25%, 50% - MMW 50%, 75% - MMW 75% and respectively 100% - MMW 100% (every sort is replaced in the percentage mentioned) and

b) plastering mortars where the marble slime replaces cement in an amount of 15% - MMWC 15%.

The mortars were investigated in both fresh and hardened state. The physical and mechanical characteristics were tested after 3, 7, 14, 28 and 60 days, respectively.

Table 3. Plastering mortars recipe with marble powder waste.

Type of mortar	Quantity of component materials in percentage											W/C ratio
		Sand					Marble powder waste					
	Cement	0/0.2 mm	0.2/0.5 mm	0.5/1 mm	1/2 mm	2/4 mm	0/0.2 mm	0.2/0.5 mm	0.5/1 mm	1/2 mm	2/4 mm	
MMW 25%	1	0.75	0.75	0.75	0.75	0.75	0.25	0.25	0.25	0.25	0.25	1.5
MMW 50%	1	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1.27
MMW 75%	1	0.25	0.25	0.25	0.25	0.25	0.75	0.75	0.75	0.75	0.75	1.52
MMW 100%	1	0	0	0	0	0	1	1	1	1	1	1.84
MMWC 15%	0.85	1	1	1	1	1	0	0.15	0	0	0	0.80

3. Results and discussion

3.1. Apparent density of fresh plastering mortars

The smallest value of the apparent density of the fresh mortar is 1.84 g/cm^3, found in mortar MMW 100% when sand is fully replaced by the slime. In all the tested samples, apparent density ranges in the limits required by the standard in force.

3.2. Apparent density of hardened plastering mortars

The apparent density of plastering hardened mortars decreases over time, which shows that there is a reduction in the mass by evaporation of the water and also by the processes of hydration of minerals compound of cement. The mortar MMW 25% has the highest value of apparent density, and which also indicates highest resistance.

3.3. The plastering mortar with marble powder slime consistency

In order to determine the consistency of these materials, in the experimental program for every type of mortars, were made three samples. For each sample were read minimum six diameters for every type of mortar, respectively MMW 25%, MMW 50%, MMW 75%, MMW 100% and MMWC 15%. The analysis of the values obtained show the influence of the increase of the percentage of slime included in the mortar; the value of consistency decreases, thus, MMW 100% mortar has the lower value and makes it less workable. This result can be interpreted as the consequence of replacing sand with marble slurry, which is capable of binding and changes consistency.

a

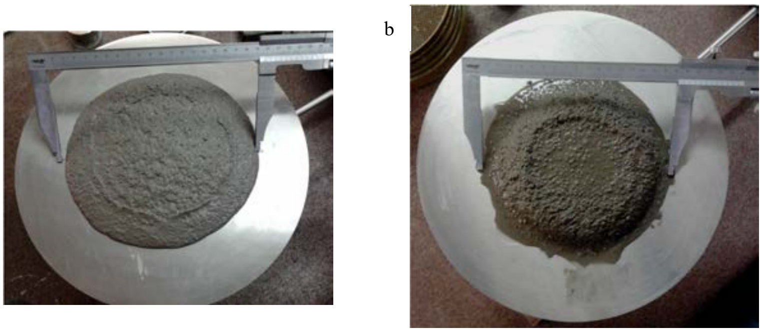

Fig. 2. Plastering mortars consistency (a). Mortar type MMW50%; (b) Mortar type MMWC 15%.

The average value of consistency of MMWC 15% mortar, in which the waste of marble powder replaces 15% of cement, is appropriate to average value of consistency of MMW 75% mortar type.

3.4. The plastering mortar tensile bending strength

In Fig. 3, one can see the graphical representations of the results reached for the tensile bending resistance of plaster mortars made with slime, at various time intervals, that is after 3, 7, 14, 28 and respectively 60 days (Fig. 3.).

The mortar MMW 25%, with a percentage of 25% of marble powder slime wastes as a replacement of sand, has the higher value of tensile bending resistance during the evolution of age of all types of plastering mortars. However, the values of tensile bending strength of plastering mortars with marble powder wastes varies between 1.72 N/mm^2 for MMW 100% mortar up to 4.90 N/mm^2 for MMW 25% mortar.

By comparing the MMWC 15% mortar, in which the cement is replaced by wastes of marble powder in 15%, with mortars in which the sand has been replaced with wastes of marble powder in different percentage: MMW 50%, MMW 75% and respectively MMW 100%, it can be observed that MMWC 15% mortar has the highest value of tensile bending resistance. It can be observed that, MMWC 15% mortar has a lower value of tensile bending resistance than a CS IV mortar, with approximately 32%.

By comparing the results obtained at tensile bending resistance of classical plaster mortars type CS IV made with Portland cement CEM IV/B 42,5N - having an average value of 5.73 N/mm^2, with plaster mortars made with marble powder wastes, it can be concluded that MMW 25% mortar has the most appropriate value – of 4.90 N/mm^2, being followed by MMWC 15% mortar with a value of 3.10 N/mm^2.

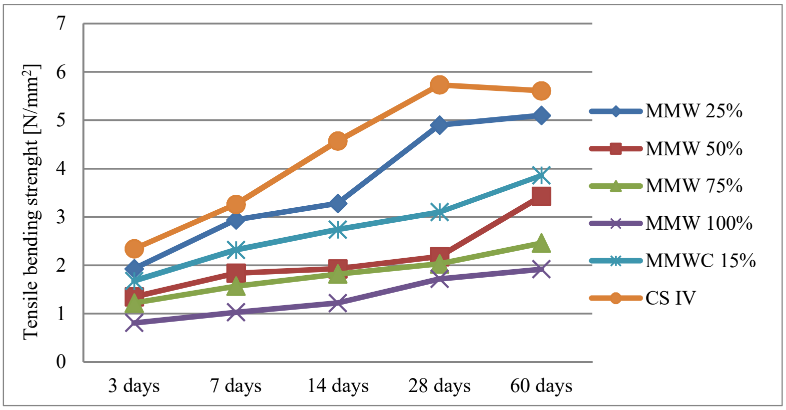

Fig. 3. The tensile bending strength of plastering mortars.

3.5. The plastering mortar strength to compression

Fig. 4 shows the graphical representations of the results for the resistance to compression of slime based plaster mortars, at various time intervals, respectively at 3, 7, 14, 28 and 60 days (Fig. 4).

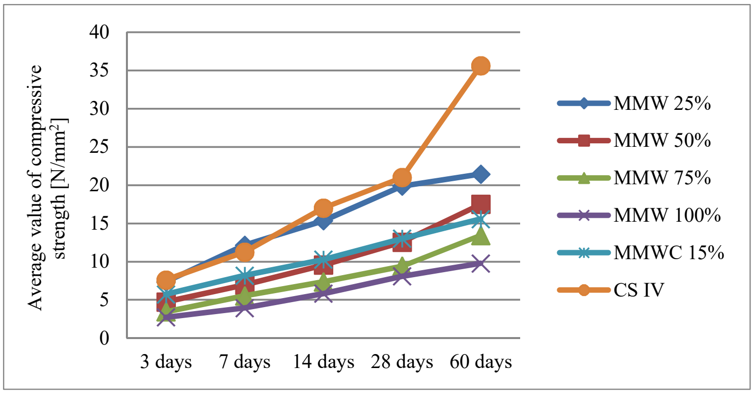

Fig. 4. Compressive strength of the plastering mortars in time.

It can be observed that the values of compressible resistance are decreasing as the percentage of waste increases, thus, MMW 25% mortar has the higher value of compression strength throughout the evolution of mortar age, at 3, 7, 14, 28 and 60 days. Analyzing the graphic (Fig. 4), it can be concluded that at 28 days, mortar type MMW 100% - 8.08 N/mm^2, has the lower value at compression strength, and mortar type MMW 25% - 19.88 N/mm^2 has the higher value at compression strength. By comparing the MMWC 15% mortar, in which the cement is replaced by wastes of marble powder in 15%, with mortars in which the sand has been replaced with wastes of marble powder in different percentage: MMW 50%, MMW 75% and respectively MMW 100%,it can be observed that MMWC 15%

mortar has the highest value of compression resistance. Also, by comparing the MMWC 15% mortar with a classic mortar it can be observed that, MMWC 15% mortar has a lower value of compressive resistance than a CS IV mortar, with approximately 56%. Analyzing the results it can be mentioned that the mortars made with marble powder wastes are approaching the value of an classical mortar type CS IV, and also that the values are higher than those mentioned in norm SR EN 998-1, in which the minimum value is 6 N/mm^2. From the graphic (Fig. 4) it can be observed that the highest values of the resistances of mortars are obtained at 60 days, issue which is supported by the fact that the binder has an important role in obtaining the mechanical resistance of the mortars, through the hydration process of mineralogical components which do not stop after 28 days, but continues, in time.

3.6. The adhesion of slime based plastering mortar

The adhesion to the support layer with the highest value over 3.88 N/mm^2, was found for MMW 25% mortar where 25% of the sand was replaced by marble powder slime. Table 4 shows a reduction of the adhesion speed coming with the increase of marble powder slime content in the mortar. In the following table are presented the results obtained at different testing days at tensile bending resistance, compressive strength and adhesion of slime based plastering mortar.

Table 4. Table summarizing results obtained under experimental program.

Age of mortar at the moment of testing	The plaster mortar tensile bending resistance in time $f^{med} = \frac{\sum_1^n f}{n}$; [N/mm2]					
	MMW 25%	MMW 50%	MMW 75%	MMW 100%	MMWC 15%	CS IV
3 days	1.93	1.35	1.22	0.81	1.68	2.34
7 days	2.94	1.84	1.57	1.03	2.32	3.26
14 days	3.28	1.93	1.82	1.22	2.74	4.57
28 days	4.90	2.18	2.03	1.72	3.10	5.73
60 days	5.10	3.43	2.46	1.92	3.86	5.61
The plaster mortar resistance to compression in time $f_{ck}^{med} = \frac{\sum_1^n f_{ck}}{n}$; [N/mm2]						
3 days	7.36	4.73	3.45	2.72	5.72	7.50
7 days	12.16	6.95	5.52	3.93	8.18	11.25
14 days	15.34	9.55	7.35	5.83	10.27	17.00
28 days	19.88	12.55	9.40	8.08	13.00	20.98
60 days	21.44	17.49	13.42	9.77	15.57	35.62
Adhesion at support layer [N/mm2]						
28 days	3.88	2.86	1.29	1.04	3.59	1.5

The tests performed highlight that all the values for the strengths for all the plaster mortars with waste, according to the curves found, exhibit larger values than those in standards irrespective of the percentage of waste used as a sand substitute. From the table (Table. 3) it can be observed that the highest values of the resistances of mortars are obtained at 60 days, issue which is supported by the fact that the binder has an important role in obtaining the mechanical resistance of the mortars, through the hydration process of mineralogical components which do not stop after 28 days, but continues, in time.

4. Conclusion

The research required the development of several experimental programs in which marble powder residues are used as partial or total replacement for sand, in a range from 25%, 50%, 75% and 100% respectively, or as a 15% cement substitute.

For the mortars made with marble powder slime, one can mention also the fact that the values of the resistance to compression diminish with the increase of the percentage of marble slime; in this context, the highest resistance to compression can be seen in MMW 25% mortar- where 25% sand is substituted by marble powder slime, followed by the mortar in which the sand is replaced in a percentage of 50%. Good results for resistance to compression are also found in the plaster mortar where 15% of the cement is replaced by marble powder slime, noted MMWC 15. It presents values close to MMW 25% mortars and to the witness sample CS IV (CS IV – plaster mortar whose resistance to compression is above $6N/mm^2$).

It can achieve a cleaner environment, by removing waste from marble powder and using it in manufacturing some new plastering mortars, as a total replacement of sand. Obviously, it is an interesting application to use a large quantity of marble powder wastes. All recipes of mortars proposed, correspond from point of resistance view, which justify using the wastes of marble powder in 100% as a replacement of sand.

It can get a cheaper plastering mortar by replacing cement with marble powder wastes. The results of this study showed that all the specific characteristics of plastering mortars have values that are within the limits imposed by standards.

References

[1] Mustafa YÇ, Eyüp S, Geological and technical characterization of Iscehisar (Afyoun-Turkey) marble deposits and the impact of marble waste on environmental pollution, Journal of Environmental Management 2008; 87:106-116.
[2] Benici H, Kaplan H, Yimaz S, Influence of marble dusts as additives on some mechanical properties of concrete, Scientific Research and Essay 2007; 2 (9): 372-379.
[3] Benici H, Shah T, Aksogan O, Kaplan H, Durability of concrete made with granite and marble as recycle aggregates, Journal of Materials and Processing Tehnology 2008; 208: 299-308.
[4] Corinaldesi V, Moriconi G, Naik TR, Characterization of marble powder for its use in mortar and concrete, Construction and Building Materials 2010; 24: 113-117.
[5] Saboya FJ, Xavier G, Alexandre J, The use of powder marble by-product to enhance the properties of brick ceramic, Construction and Building Materials 2007; 21:1950-1960.
[6] Molnar LM, Manea DL, Aciu C, Jumate E. Innovative Plastering Mortars Based on Recycled Waste Glass, Elsevier 2015,Procedia Technology 19, 299-306
[7] SR EN 196-3:1995. Methods of testing cement. Part 3: Determination of setting time and soundness
[8] SR EN 1008:2003. Mixing water for concrete – specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete
[9] SR EN 1015-6:2005. Methods of testing masonry mortars - Part 6: Determination of apparent density of fresh mortars
[10] SR EN 1015-6/A1:2007. Methods of testing masonry mortars - Part 6: Determination of apparent density of fresh mortars
[11] SR EN 1015-10:2002. Methods of testing masonry mortars - Part 10: Determination of apparent density of hardened mortars
[12] SR EN 1015-10:2007. Methods of testing masonry mortars - Part 10: Determination of apparent density of hardened mortars
[13] SR EN 1015-3:2002. Methods of testing masonry mortars - Part 10: Determination of consistency of mortars
[14] SR EN 1015-3/A2:2007. Methods of testing masonry mortars - Part 10: Determination of consistency of mortars
[15] SR EN 1015-11. Methods of testing masonry mortars - Part 11: Determination of compressive and flexuring strength (December 2002).
[16] SR EN 1015-11/A1. Methods of testing masonry mortars - Part 11: Determination of compressive and flexuring strength (September 2007).
[17] SR EN 1015-12:2005. Methods of testing masonry mortars - Part 12: Determination of adhesion of hardened plastering mortars on the support layer
[18] Balog AA, Cobîrzan N, Aciu C, Iluţiu-Varvara DA. Valorification of volcanic tuff in constructions and materials manufacturing industry. Procedia Technology, Elsevier 2014; 12:323-328.
[19] Cobîrzan N, Balog AA, Aciu C, Iluţiu–Varvara DA. Sustainable Uses of Zeolitic Tuff as Building Materials. Procedia Technology, Elsevier 2014; 12:542-547.
[20] Simina M, Molnar L, Manea D, Ardelean I. Monitoring the Air Influence on Cement–Lime Mortar Hydration Using Low-Field Nuclear Magnetic Resonance Relaxometry, Applied Magnetic Resonance 43 (3), 443-450