MULTICENTRIC COMPARATIVE STUDY REGARDING THE CHARACTERISTICS OF THE MATERIALS USED IN THE MANUFACTURE OF MORTARS

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Abstract: *Starting from the most common cause of building degradation, the humidity of the mansonry which is actually the support of water migration in the form of salt solutions, in this paper, we set to approach two important topics that will be reflected in a multicentric comparative study on characteristics of mortars. We will pay attention to the possibility of obtaining mortars with high-performance characteristics in terms of combating moisture in buildings and, on the other hand, we will pursue the recovery of waste, by introducing them in the manufacturing technology of mortars. The management of the generated waste represents a major problem of mankind, taking into account the large quantities of generated waste, the lack of storage spaces, respectively the insufficiency of recovery operations. The aim of this paper is to carry out a multicentric comparative study on the possibility of identifying several categories of mortars that are obtained through a technology that involves waste recovery. In the experimental part we analyzed four types of ecological mortars that contain various wastes: sawdust mortars, rubber granule mortars, PVC mortars, respectively glass mortars. Using the comparative method, the most efficient types of ecological mortarts were identified taking into account their characteristics. The results of the study highlight the characteristics of mortars obtained from the related technological processes, in which waste was included.*

Keywords: *multicentric study, ecological mortars, waste, construction materials*

JEL Classification: L61, L74

Introduction

The plaster solutions currently used for the rehabilitation of heritage buildings frequently present a problem related to their adhesion to the substrate (Mohammed et al., 2015; Zarzuela et al., 2019, Faria et al., 2017; Popa et al., 2018). To avoid this, mechanical, physical, chemical and aesthetic compatibility with old masonry must be ensured by obtaining a mortar based on the characteristics of the original mortar and with adequate performance (Mohammed et al., 2015; Meng et al., 2013). Recent literature related to the rehabilitation of heritage buildings mentions some requirements on the characteristics they should meet (Hou et al., 2016; Popa, 2007).

Starting from these premises and taking into account the possibility of waste recovery, we

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proposed in this first stage, to carry out a study through which we will identify several categories of mortars that are obtained through a technology that involves waste recovery. Mortar is defined as a construction material, consisting of sand, water and binder. The binder can be cement, lime or plaster. The purpose of the article is to identify the most efficient ecological mortar taking into account the general characteristics such as density, strength, elasticity, etc.

Due to the general problems related to the protection of the environment, much emphasis is placed on the identification of several types of ecological mortars, respectively on their promotion and use, therefore research in this field is ongoing. So far, various types of ecological mortars have been discovered, such as: sawdust mortars, glass containing mortars, ash mortars, PVC waste mortars, rubber granule mortars.

Glass waste can be found in various forms, such as: bottles, jars, windows and windshields, light bulbs, tubes, etc. (Idir, 2010). The main obstacle to glass recycling is the potential high cost of glass transporting, from the collection points to smelting facilities, and this has made the economy of glass recycling unattractive (Shafaatian, 2012).

Rubber granules are used in the manufacture of mortars by partially replacing aggregates with this type of waste. Rubber has been used in the technological process of manufacturing mortars due to its essential characteristics such as low density, high elasticity, energy absorption. The size of the rubber granules, respectively the quantity used, significantly influences the properties of the mortars (Matias et al., 2018).

Research methods

To carry out this study we used the method of processing the information obtained from the documentation, respectively the comparative method and the interpretive method. Case studies focusing on ecological mortars aiming at the introduction of waste in the technological processes of mortar manufacturing were analyzed.

Results and discussions

PVC waste mortars

The materials used in the manufacture of this type of mortar are: cement, sand, plastic granules (PVC), respectively water. The plastic waste was chopped to a maximum size of 8 mm, resulting in a material with an apparent density of 500 kg / m^3. The sand from the standard mortar manufacturing recipe has been partially replaced by PVC waste. The advantages of using plastic waste (PVC) in the manufacture of mortars are: durability, low weight and low biodegradability (Aciu et al., 2018). Table no. 1 shows the results of an experiment performed by Claudiu Aciu and his collaborators (Aciu et al., 2018).

Table no. 1 Characteristics of PVC mortars

No.	Type of mortar	Cement (kg)	Water (l)	Sand (kg)	PVC waste (kg)	Density (kg/m^3)	Resistance (N/mm^2)	Percentage of introduced waste
1.	Mortar with plastic waste (PVC)	1	0,83	3,37	1,13	1997,4	23,45	25 % PVC waste
		1	0,77	2,25	2,25	1857,6	24,53	50 % PVC waste
		1	0,75	0	4,5	1253,9	14,77	100 % PVC waste

Source: Aciu et al., 2018

The density of plastic containing mortars decreases as the percentage of sand replacement increases (Aciu et al., 2018; Vidya et al., 2020).

The bending strength, respectively the compressive strength of the mortar decreases with the partial replacement of the sand with plastic waste. At only 15% by volume of sand replaced with plastic waste, compressive strength showed a decrease of 35%. The decrease of compressive strength has been confirmed in several studies (Khazaal et al., 2020).

Due to the low adhesion between cement and plastic waste, the mechanical properties of mortars diminish (Merlo et al., 2021), but the addition of plastic waste also contributes to the higher shrinkage, water absorption and lower thermal conductivity of concrete (Babafemi et al., 2018).

Glass mortars

Glass dust and glass sand can be used in the technological process of manufacturing mortars as an auxiliary cementitious material, respectively an aggregate, but the content of glass sand should not be higher than 20% (Huang et al., 2021). Table no. 2 illustrates the characteristics of the glass mortars.

Table no. 2 Characteristics of glass mortars

No.	Particle size (mm)	Density (kg/m^3)	Glass powder content (wt.%)	Cement (kg)	Glass powder (kg)	Sand (kg)	Water (l)	Glass sand (kg)
1.	0-13	2510	20	0,320	0,080	0,900	0,188	0
2.	13-38	2490	20	0,320	0,080	0,900	0,188	0
3.	38-75	2480	20	0,320	0,080	0,900	0,188	0
4.	0-13	2510	20	0,320	0,080	0,720	0,188	0,180
5.	13-38	2490	20	0,320	0,080	0,720	0,188	0,180
6.	38-75	2480	20	0,320	0,080	0,720	0,188	0,180

Source: Huang et al., 2021

Experiments have shown that when glass sand replaces classical sand by 20%, respectively 100%, the expansion rate is 0,179%, respectively 0,212% (Huang et al., 2021), much higher than the allowable limit which is of 0,1% (Zhao et al., 2021). It is resulting that there are high risks to the safety of mortars if glass waste in the form of glass sand is applied directly to the mortar manufacturing process. If an additional suppression treatment is applied and replaced with 20% glass sand, with particles size between 13-38 μm, the expansion rate decreases significantly to 0,02% and the quality of the mortars increases (Huang et al., 2021). It is possible to replace the sand with glass in a proportion of

100% without any special addition or mixture, and the properties such as durability, permeability to water vapor are not affected (Tittarelli et al., 2018). Another study shows that the total replacement of natural sand with glass increases the resistance of mortars both to compression and bending by about 5 times higher to frost / thaw (Skoczylas and Rucińska, 2020).

With the addition of 5%, 10%, 15% and 20% glass mortar, the density of the mortar decreased by 0,6%, 1,2%, 1,5% and 3,2% compared to the classic mortar (Małek et al., 2020). The same effect of adding glass on density has been observed by other researchers (Lee et al., 2013).

Sawdust mortars

To obtain a mortar with sawdust, the following materials are necessary: cement, water, respectively mixtures of sand and sawdust. The method used for the production of sawdust mortar consists in the following steps: preparation of the sawdust waste by neutralization with physico-chemical treatments, weighing of the materials, homogenization, respectively pouring of the material obtained in the mold. Sawdust waste replaces 50% of the sand required in the technological process of mortar manufacturing (1). The characteristics of sawdust mortars are presented in table no. 3.

Tabel no. 3 Characteristics of sawdust mortars

No.	Type of mortar	Cement (kg)	Water (l)	Sand (kg)	Sawdust waste (kg)	Consistency (cm)	Density (kg/m^3)	Resistance (N/mm^2)
1.	Sawdust mortar	1,7	7,5	1,6	1,6	8	1185	0,31

Source: http://biblioteca.regielive.ro

The sawdust mortar can be used both as a masonry mortar and as a plaster mortar. Also, due to the densities obtained the sawdust mortar falls into the category of light mortars. Following the analysis of the determinations obtained, it was found that the ordinary mortar, with a density of 2140kg / m^3, belongs to the category of heavy mortars and the sawdust mortar, with a density of 1120kg / m^3, belongs to the category of light mortars (http://biblioteca.regielive.ro). Depending on the consistency obtained, both mortars can be used both as masonry mortars and for plasters. Following this study, due to the high amount of sawdust in the mortar composition, resulted a compressive strengths with very low values, respectively 0.31 N / mm^2 and a tensile strength value close to zero (http://biblioteca.regielive.ro). The reduction of the resistance has been observed by other researchers (Osei and Jackson, 2016). Although very low strengths have been obtained, the sawdust behaves very well as an aggregate in the composition of the mortar; if we reduce the amount of sawdust to less than 30% of the classic aggregate, then we will obtain appropriate strengths, which will lead to the successful application of the sawdust mortar. Due to its water absorbing property, sawdust does not allow the mortar to dry quickly, which prevents cracks (http://biblioteca.regielive.ro).

Another study concludes that the density of mortar decreases as the percentage of sand replacement with sawdust increases, because the density of sand is higher than the density of sawdust (Osei and Jackson, 2016). It was founded that there was a significant increase in water absorption capacity and porosity as the amount of sawdust increased (Abed and Khaleel, 2019).

The resulting mortar can be used successfully to improve the thermal and acoustic insulation capacity, both as a plaster mortar and as a masonry mortar (http://biblioteca.regielive.ro). Also, these advantages have been supported in other research (Patel et al., 2016).

Rubber granular mortars

Previous research shows that rubber concrete is useful in harsh environments because it is durable and very resistant to acids (Valente and Sibai, 2019). As the amount of rubber granules increases, the impact resistance is gradually improved. The rubber granules in the mortar deform elastically under external loads, preventing the appearance of cracks (Xue and Cao, 2017). The higher rubber content reduces the workability and the density of the mortar (Samar Raffoula, 2016).

The adhesion between rubber particles and cementitious materials is weak, which reduces the strength of the mortar (Xue and Cao, 2017).

Comparision of the characteristics of the studied mortars

In the following figures the main characteristics of the studied mortars are compared. Figure no. 1 shows the mortar with the highest density, while fig. no. 2 presents a comparation of the resistance of the sawdust mortar and plastic waste mortar (PVC).

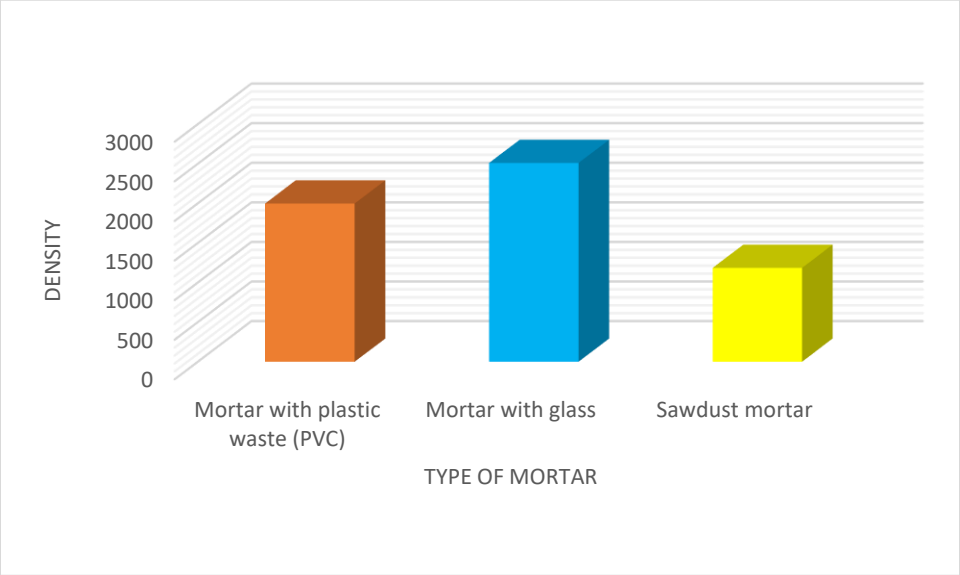

Fig. no. 1 Density comparision
Source: own source

Regarding the density, as a result of the comparisions made it is found that the glass mortar has the highest density, while the sawdust mortar has the lowest density.

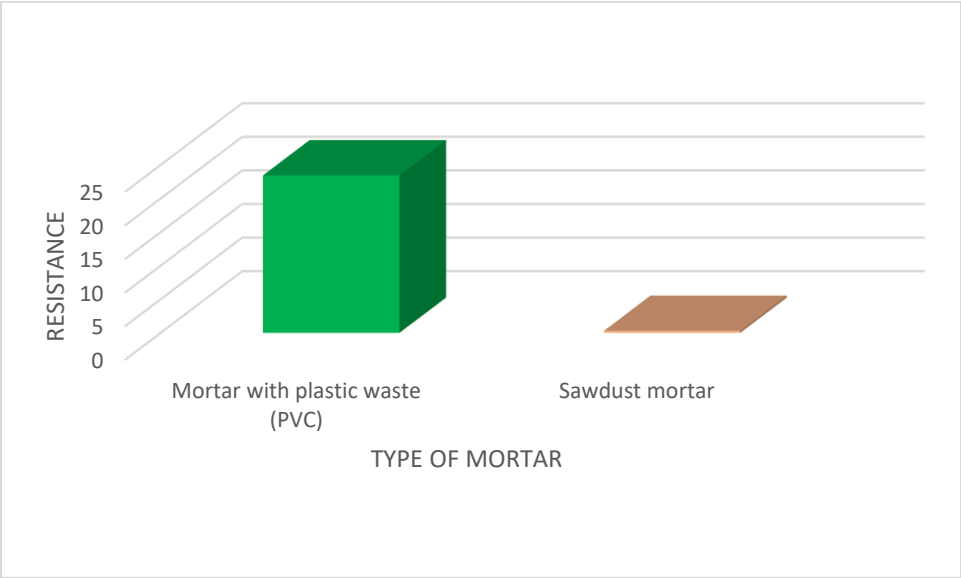

Fig. no. 2 Mortar resistance
Source: own source

According to figure no. 2, mortars containing plastic waste (PVC) have a better resistance than mortars containing sawdust. The difference between the two types of mortars analyzed can be more than 20 units, this is due to the type of waste included in the technological process.

The present study emphasize the following:

- ✓ The density of ecological mortars containing PVC, sawdust, rubber and glass decreases in proportion to the increase of the quantities of waste included in the technological flow;
- ✓ Glass mortars, respectively rubber mortars have a higher compressive and bending strength than mortars with plastic (PVC) and sawdust content;
- ✓ Between the analyzed types of mortars, sawdust mortar contributes the most to improving the thermal and sound insulation process;
- ✓ Sawdust mortar has a higher water absorption power compared to the other types of mortars studied.

Conclusions

In the process of rehabilitating of the heritage buildings, it is recommended to use special mortars that dry the wall without stopping the rise of moisture through the wall, but encourage the evaporation of moisture through the wall. The disadvantage of classic repair plasters is represented by the fact that the salts from the wet masonry migrate in the plaster and crystallize in the pores of the plaster. After a certain time a saturation of the plaster takes place, the salts block the diffusion, which meant the end of the masonry drying process. Special mortars, due to substances introduced into their mixture, create macropores or intercommunicating micropores that increase the total evaporation area.

The present study aimed to highlight the possibility of using in construction materials waste that can provide to the finished product characteristics corresponding to the requirements of the works required for civil and heritage buildings.

Subsequent laboratory studies will highlight the possibility or impossibility of using them in practice.

The current trends highlight and support the opportunity to reduce the volume of waste by capitalizing on them including in the field of construction.

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