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Recycling of paper waste in the composition of plastering mortars

Claudiu Aciu[a,]*, Dana Adriana Iluţiu – Varvara[a], Nicoleta Cobirzan[a], Anca Balog[a]

[a]*Technical University of Cluj-Napoca, 28 Memorandumului Street, 400114, Cluj-Napoca, Romania*

Abstract

The paper presents a study on the recycling of paper waste, which is frequently found in almost all activity areas, in order to obtain an ecological plastering mortar. The materials used, in four mortar recipes, as well as the methods for their preparation are presented. The research leads to the conclusion that the methods for the preparation of plastering mortars with paper waste allows for the use of non-polluting technology with low energy consumption. Following the tests to which the test tubes were submitted, the optimal proportion of paper in the recipe for the manufacture of the material was determined.

Keywords: Waste management; recycling; paper waste; building materials; plastering mortars.

1. Introduction

Waste management refers to education regarding the collection, transport, treatment, recycling and storage of waste. The term usually refers to materials resulting from human activities and to the reduction of their effect on the people's health, the environment, or the aspect of a habitat. Waste management may also contribute to saving natural resources through the reuse of recoverable parts [1].

Of all European countries, Romania recycles only 1% of all produced waste, the rest being dumped to the landfill [2]. Every year until 2013, Romania's objectives of selective collection and recycling of packaging waste will

* Corresponding author. Tel.: +40 748 103613.
E-mail address: claudiu.aciu@ccm.utcluj.ro

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increase gradually, until they reach European standards. Romania's objective of use by recycling was 38% in 2009, 42% in 2010 and 46% in 2011 [3].

Household waste is collected non-selectively and eliminated by storage; only 5% of the amount of household waste is estimated to be collected in order to be reused [4].

In 2010, the recycling objectives for paper were 60%, for plastic 14%, for glass 44%, and for metal 50% [3].

The volume/weight ratio for paper waste is relatively low. This type of waste is a very common component of city waste, which is why paper and cardboard recycling is expected to represent an opportunity to reduce the impact on forests and the environment [5].

Paper is the most frequent type of waste found in almost all activity areas and represents an important source of cellulose fibers. In various forms (quality paper, mixed paper, newspapers and journals, undulated cardboard), paper represents about 41% of all household waste produced today [6].

Paper is a recyclable material that after reaching the garbage dump has a biodegradation period of 3-12 months. This is why the benefits for nature through paper waste recycling are extremely important [6].

Recycled paper allows for the saving of about 25% of the amount of electricity and 90% of the amount of water (300 l) necessary for the production of 1 kg white paper. Also, by recycling paper waste, toxic chlorine required for the production of white paper is eliminated [4].

The current stage of the recycling technique of paper waste mainly includes:

- recycling in the technological flow that generated it;
- manufacture of products for construction;
- manufacture of fuels obtained from paper waste (mixed with plastic and wood waste) [7].

Paper can be recycled in the technological flow that has generated it for the manufacture of paper (optimal use) or the manufacture of cardboard and pasteboard (inferior use). Paper can only be recycled 6-10 times, because with each recycling, the length of the cellulose fiber is reduced, resulting in a decrease of the mechanical strength and quality (appearance, color) of the manufactured paper and an increase of technological losses [6].

At the end of this number of recycling cycles, the lower quality paper can be successfully used in a different industrial branch, for example construction [6].

The recycling technologies of paper waste in construction consist of the manufacture of products such as: plasterboard, cellulose fiber insulation and bricks made of paper fibers agglomerated with cement.

The technology for the manufacture of plasterboard allows to obtain from calcined gypsum, water and addition materials a fluid plaster paste that is dosed in a uniform layer, between 2 cardboard sheets [8].

Cellulose fiber insulation uses recycled newspaper as a raw material, from which raw fibers are extracted and subsequently treated with special additives for fire proofing, as well as for protection against pests. The manufacture technology involves the application by injection of cellulose fibers. It can be used for the thermal insulation of walls, floors, as well as ceilings and roofs, ensuring at the same time good sound insulation [9].

Bricks made of paper fibers agglomerated with cement are an inexpensive material, with good thermal insulating properties, with remarkable resistance, produced through the recovery of paper waste. The technology for the manufacture of the material is non-polluting and does not involve high energy consumption. One of the recipes for obtaining this material consists of a mixture of: 60% paper (journals and newspapers), 30% sifted sand, 10% cement [10].

2. Material and Method

The recycling of paper waste in the building materials industry is an efficient solution with beneficial consequences for the construction industry as well as for environmental protection and improvement, contributing at the same time to the conservation of natural resources. One ton of recycled paper is equivalent to saving 17 trees, 4102 KW and 26000 liters of water, as well as to the non-release of 27 kg toxic agents in the atmosphere [5].

In this context, the study on the use of paper waste in order to obtain ecological plastering mortar is presented. The materials used for the experimental part were: Portland cement 32.5, sand with 0-4 mm granularity, water, newsprint paper or copy paper.

The study was performed in four mortar recipes whose composition is shown in Table 1.

Table 1. Mortar recipes.

Recipe	Cement [kg]	Sand (0-4) [kg]	Water [l]	Copy Paper [kg]	Newsprint Paper [kg]	Used Paper [%]
I	200	300	320	810	-	50
II	400	400	440	810	-	40
III	400	400	440	-	810	40
IV	500	400	440	-	810	38

The applied method for the preparation of mortars with paper waste consisted of: preparation of paper waste (the paper waste was cut into shreds, soaked in water and after two days the material was drained); weighing of materials; homogenization of the component materials with the mixer; casting of the test tubes (4 x 4 x 16 cm prisms and cubes with a 7 cm side length).

Physical-mechanical and fire behavior determinations were performed after 28 days in test tubes cast and stored according to standards during this period.

3. Results and Discussions

The following physical-mechanical characteristics were determined in the test tubes: the apparent density of the set mortar, adhesion to the support layer, bending and compressive strength, water absorption by capillarity and fire behavior.

The results obtained following the performance of physical-mechanical determinations are shown in the diagram of Figure 1.

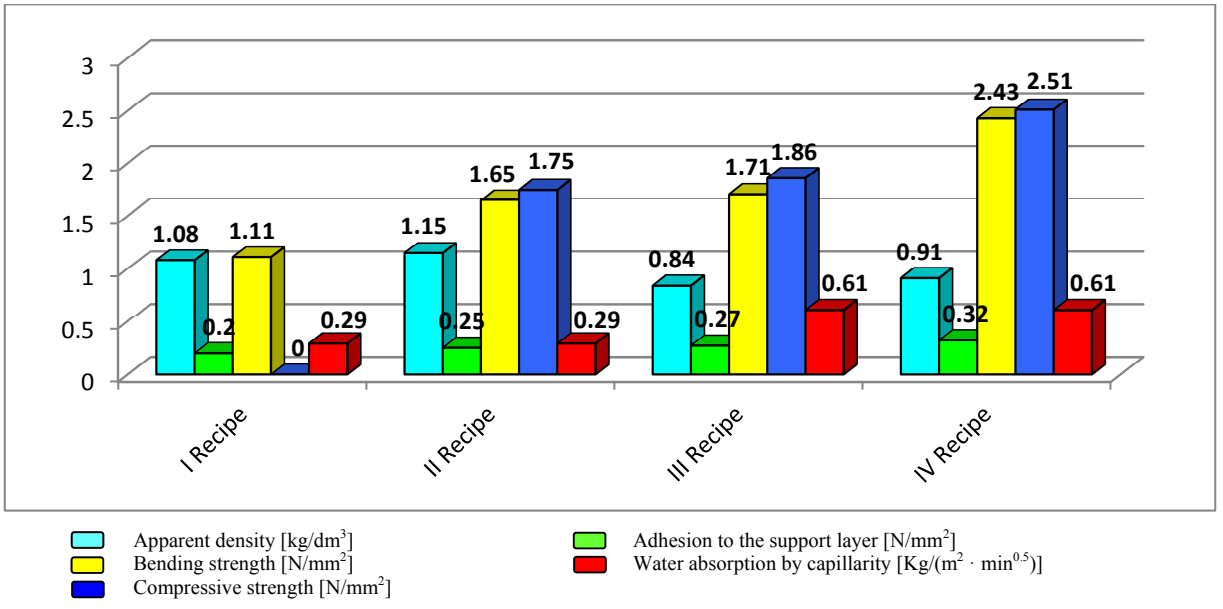

Fig. 1. Physical-mechanical characteristics

Figure 1 shows that the *apparent density* of mortar test tubes containing copy paper is higher than that of those containing newsprint paper, which can be explained by the fact that copy paper has a higher density than newsprint paper.

The densities of copy paper mortar test tubes are at the lower limit of light mortars and the densities of newsprint paper mortars fit into the category of very light mortars.

The values of the *adhesion to the support layer* of paper mortars are relatively low; however, newsprint paper mortar prepared according to recipe IV is comparable to classic mortars.

Of the cubes submitted to the *compression test*, the test tube based on recipe I (with the lowest cement content) had an elastic behavior. After being taken out of the press, the sample almost completely regained its initial shape. This is why compressive strength could not be recorded.

The diagram of Figure 1 shows that the *compressive strength* of the test tubes varies between 1.75 – 2.51 N/mm^2; the composition of recipes II-III can be categorized as class CS I, and that of recipe IV as class CS II.

Bending strength varies between 1.11 – 2.43 N/mm^2.

By comparing bending strength and compressive strength, it can be seen that their values are almost equal, unlike common mortar, whose bending strength represents about 10-20% of compressive strength.

Newsprint or copy paper mortar is much more elastic and has a much higher bending strength. The explanation for this can be the fact that the paper was cut into shreds that act as a dispersed reinforcement in the mortar, improving its bending strength (Fig. 2).

a) Residual newsprint paper prism b) Residual copy paper prism

Fig. 2. Residual prism following the determination of bending strength

From Figure 2 it can be seen that copy paper mortar breaks suddenly, while in the case of newsprint paper mortar, there is an initial stretching of the material, followed by breaking.

Regarding the paper used, it can be observed that newsprint paper confers higher strengths. This is evidenced by a comparison of recipes 2 and 3, based on the same amounts of materials, but with different types of paper.

Following the determination of *water absorption by capillarity*, the following mean coefficients of water absorption due to capillary action were obtained: 0.61 $Kg/(m^2 \cdot min^{0.5})$ for newsprint paper mortar and 0.29 $Kg/(m^2 \cdot min^{0.5})$ for copy paper mortar.

Thus, mortars using recipes I and II can be assigned to class W1 and those using recipes III and IV can be assigned to class W0.

The *fire behavior of mortar*, when burned with a gas lamp, is presented in Figure 3.

After 300s, the mortar subjected to the direct action of the flame of the burner (~1000°C) allowed to place the hand on the opposite side (Fig. 3a). This was due to the fact that the temperature of this side increased by only 1.5°C (from 14.7°C to 16.2°C), measured as shown in Figure 3b. This demonstrates that the material is a good thermal insulator.

a) Copy paper test tube burned with the gas lamp

b) Temperature recorded in the side opposite to fire exposure

Fig. 3 Fire behavior of the test tube

From the point of view of the fire behavior of mortar coming into direct contact with a flame, the following were found:

- during not only the 60s allocated for the standard test, but even throughout the duration of 300s of the testing of the samples, there were no smoke emissions, no important material detachments and no significant deformations of the surface subjected to the action of the flame;
- there were no small flames on the front or lateral sides;
- after 60s, a protective carbonized layer was formed on the surface in direct contact with the flame, which did not allow for the further carbonization of the material in the 60s – 300s time interval (Fig. 4b);
- the sample was subjected to the burning of the edge and there were no smoke emissions or self-supporting flames; in contrast, material detachments were seen, which can be explained by the fact that copy paper in the composition of the material remained in the form of round shapes, as a resulting residue from shredding (left side of Figure 4b);
- the thickness of the carbonized layer in the center of action of the flame was approximately 6 mm (Fig. 4c).

a) Copy paper mortar test tube

b) Test tube burned with the gas lamp for 5 minutes

c) Cross-section of the burned test tube

Fig. 4 Test tube subjected to the determination of fire reaction

4. Conclusions

As shown above, paper, which is waste that is frequently found in almost all human activity areas, is a material that can be recycled through the manufacture of various building materials.

Following the study performed on the production of ecological plastering mortars based on paper waste, it can be seen that the optimal proportion of paper in the mortar recipe is around the value of 40%.

The developed technology ensures the manufacture of a new ecological plastering mortar, with minimal embodied energy and with good thermal insulation properties. At the same time it ensures the recycling of paper waste, which can't be recycled in the technological flow that has generated them.

Compared to classic mortars, the plastering mortar obtained is a light material with an apparent density ranging between 842 – 1147 kg/m^3, and can be assigned depending on compressive strength to class CS I or CS II, and from the point of view of water absorption by capillarity, it is categorized as class W0 or W1.

Fire resistance is good, because paper fibers are saturated with cement and consequently, oxygen cannot penetrate the mass of the material to support burning. In a fire, mortar will slowly turn black, but will not burn faster than most traditional materials.

Given its very good thermal insulation characteristic due to the fact that each grain of sand in the cement matrix is surrounded by paper fibers and pores that increase the heat transfer duration, plastering mortar containing paper waste is a material that can improve the energy performance of buildings.

The results obtained in this study open the way to new recipes for the manufacture of mortars and other building materials for which paper can be recycled without affecting their technical characteristics that can even be improved.

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