Available online at www.sciencedirect.com

ScienceDirect

Procedia Materials Science 8 (2015) 831 – 838

Procedia Materials Science

www.elsevier.com/locate/procedia

International Congress of Science and Technology of Metallurgy and Materials, SAM - CONAMET 2013

Lightweight Concrete: an Alternative for Recycling Cellulose Pulp

Federico N. Andrés, Loreley B. Beltramini, Anabela G. Guilarducci, Melisa S. Romano, Nestor O. Ulibarrie*

Centro de Investigación y Desarrollo para la Construcción y la Vivienda (CECOVI), Universidad Tecnológica Nacional, Facultad Regional Santa Fe, Lavaisse 610, (S3004EWB), Santa Fe, Santa Fe, Argentina

Abstract

From the analysis of the production process of molded pulp packaging, it can be seen that one of the residues generated in the molding is "pulp". When this waste cannot be reincorporated into the production line, is recovered by centrifugation in the effluent treatment system.
With the intention of recycling this residue it was investigated the feasibility of their use in the manufacture of concrete blocks or panels lightened studying possible ways to use the material, either in the wet state (form is discharged from the process) or dry (dried in a controlled environment), analyzing the advantages and disadvantages of each alternative.
For practical purposes, various dosages were proposed to maintain constant the amount of residue and varying the amounts and proportions of water and cement. Test specimens were made with various amounts of cement per m³ of concrete.

Keywords: concrete, paper, recycling

Nomenclature

RS	dry residue
RH	wet residue
RHA	wet residue with incorporation of sand

* Corresponding author. Tel.: +54-342-469 7728; fax: +54-342-469 0348.
E-mail address: cecovi_materiales@frsf.utn.edu.ar

2211-8128
doi:10.1016/j.mspro.2015.04.142

RHP	pulping wet residue

1. Introduction

Research into the use of waste products from industrial processes is of interest both from the environmental standpoint, since that use reduces the environmental impact of the new material or product, and from a financial standpoint, in connection with the potential cost savings on treatment or disposal of those waste products. The construction industry provides broad scope for potential applications, since it uses large volumes of materials and a wide range features in those materials (mechanical, functional, and others). (Luis Agulló, 2006)

Management options for forest products lifecycle include recycling, deposition in landfills and burned to produce energy. All these actions are related to the emissions of greenhouse gases and carbon sequestration. For their part, the Confederation of European Paper Industries (CEPI) has developed a carbon footprint scheme involving the ten elements that cover the entire life cycle of forest products. This scheme indicates that one of the positive consequences of recycling on greenhouse gases is not methane emission that would occur if the paper is sent to landfill dumps. (Area, et al., 2012)

Thanks to its well-known homogeneity and composition, waste paper production and pulp are increasingly used as secondary raw material in various industries. (CEPI, 2003) This is the case in the packaging industry uses cellulose pulp recycling of paper and cardboard as raw material for the production process.

The evolution of the use of the waste from the manufacture of paper and pulp as a raw material in other production processes, as a statistical estimate made by the CEPI is shown in Fig.1.

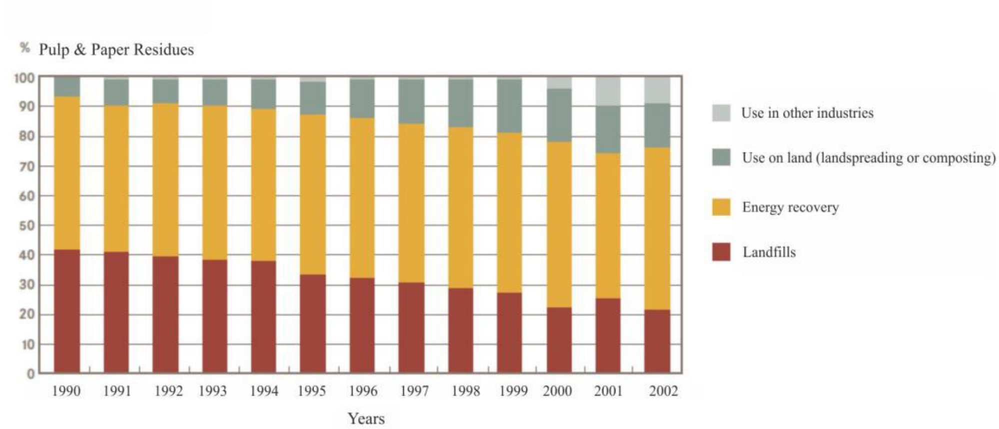


Fig. 1. Fate of residues of pulp and paper (CEPI, 2003)

This work corresponds to the first instance of one analysis of recycling of waste generated in the production process of pulp molding, which focuses on assessing the feasibility of Portland cement agglomeration for the manufacture of a composite cement residue. This study includes evaluating the physic-mechanical properties of the composite.

Cellulose and paper making industry generates important amount of waste material. The pulp and paper industry is characterized by four major processes: (i) chemical pulping (Kraft or sulphate pulping), (ii) mechanical and chemi-mechanical pulping, (iii) recycled fiber processing and (iv) paper-making related processes. By-products and residues from mechanical and chemi-mechanical pulping include wood, straw and reed residues, fiber rejects, excess sludge from external biological waste water treatment. (Ismail Demira, 2005)

The by-products and residues from pulp and paper industry are managed using several approaches including land filling, incineration, use in cement plant and brickworks, agricultural use and composting, anaerobic treatment, recycling and others. (Ismail Demira, 2005)

The special case of study corresponds to a company dedicated to the production of food packaging for molded pulp, which produces, among other products, fruit dividers, boxes, trays and pizza boxes.

In any process of recycling of recovered paper, the first step is the disintegration or pulping operation that aims to achieve a suitable fibrous suspension to be treated later. During the disintegration is necessary to achieve a good identification of the fibers and at the same time, an efficient separation of contaminants (printing inks, hot melt products, wet strength agents, coatings or metalized plastic, coating components, adhesive and others) using as little energy as possible and achieving maximum efficiency. (Àngels Pèlach, 2012)

After this process and purification, additives are added which will give the final characteristics to the finished product; the fibrous suspension is taken to the molder, where they generate different products.

The pulp diluted at the appropriate concentration, enters the bottom of the molding tray. This concentration is controlled by the driver through piped water entering. Through vacuum, the shaft (immersed in the container filled with pulp) takes the pulp from the container and shape to the product. Excess pulp is returned to the feed tank which has an overflow to the container.

By treatment of the liquid after passing through various chambers and with the addition of flocculants, achieved separation of the residues is washed pulp molding using a centrifugal separator. Here there is the second largest volume of waste generated in the process.

Among the tests carried out to residue, highlights the moisture content determination. It is very important parameter for its influence on the dosage of the composite material because the dosage is the amount of water, cement and residue. The amount of water added to form the cement paste depend mainly of the water containing in the residue-free and therefore, the water available for cement hydration and resistant particle formation.

Because of excess water yielded a pulp residue, adding a setting time accelerator is necessary. There are reports in the literature of accelerators being used in some commercial waste solidification processes in the United States to overcome waste-induced retardation of Portland cement systems, although the effects of this have not been reported in detail. Calcium chloride ($CaCl_2$) is well known to accelerate hydration of C_3S and OPC and these effects have been well documented. (C.R. Cheeseman, 1999)

2. Experimental Procedure / Methodology

To examine the feasibility to use of waste in the production of alternative materials for construction were used waste from the spinning process of effluent treatment. It should be noted that all samples collected were stored in plastic bags properly to prevent disturbances due to high moisture content thereof. The materials used in the study are shown in Fig. 2.

Fig. 2. Materials used to manufacture the composite

The moisture content in the residue was determined by drying the samples in an oven at a temperature of 105 ± 5 °C until obtaining a constant weight of the material. Depending on the result obtained different dosages (by weight) were proposed of the materials involved: residue, cement and water.

At the time of molding of the specimens there were two alternatives: use dry residue in a controlled environment (RS) and use wet residue as it leaves the process (RH). It also considered molding cubes of the same size with the addition of sand to cement ratio 1:1. The addition of sand, seek a drying shrinkage decrease of the blocks and increase compressive strength by fill the empty spaces with a finer aggregate.

Dosages for the dry residue (RS), the wet residue (RH) and the wet residue with incorporation of sand (RHA), are shown in Table 1.

Table 1. Evaluated dosages.

Sample	Water / Cement Radio	Residue/Water/Cement/Sand relations
RS1	2	4:2:1:0
RS2	1	2:1:1:0
RH1	1	2:1:1:0
RH2	0,5	4:1:2:0
RH3	2	4:2:1:0
RH4	1	4:1:1:0
RHA1	1,5	2:3:2:2
RHA2	1	4:5:5:5
RHA3	1	4:1:1:1
RHA4	0,5	4:1:2:2
RHA5	2	4:2:1:1

Because residue particle distribution is not homogeneous, it raised the alternative of pulping process of wet residue (RHP) prior to mixing with cement. It is noted that it was necessary to incorporate calcium chloride accelerator sets. Thus, test pieces were molded with a constant pulp / water ratio of 0.24 and varying amounts of cement and calcium chloride. The proportions used and the names of the samples are shown in Fig. 3.

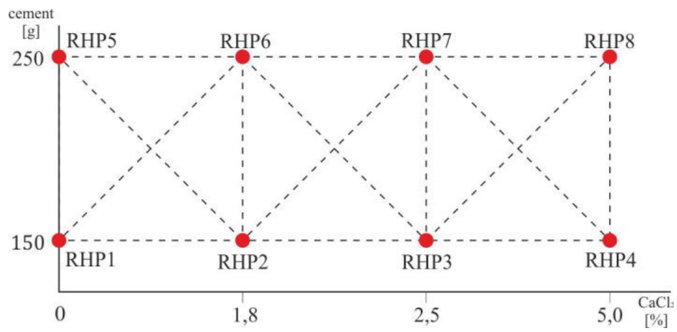


Fig. 3. Evaluated RHP samples.

Thus determining the compressive strength and density of the materials obtained were performed in 7cm cubic samples and were tested at 28 days of age. To obtain the value of resistance, it was used a cell load of 10 tons, with appreciation of 0.5 kg.

3. Results and Discussion

The moisture content obtained in the samples taken from the plant was 301.3%. This high value could be explained by the high capacity of fibers possessing material for absorbing water during the process of recycling paper and cardboard at the plant. While after 68 days extracted from the plant, the moisture content of the sample was 198%. This decrease in water content in the sample, warns the difficulty of storing the residue for subsequent use.

Molded specimens with the dry residue (RS) did not show adequate agglomeration with cement paste, resulting in the disintegration of the material. This correlates with the particular features which acquires the residue after drying (water resistance and hardness greater than the material in the wet state due to the additives incorporated into the generation of the pulp). Therefore it was not possible to assess their density properties and compressive strength.

In the case of using the RHP and RH, fresh mixture had a good workability and was possible to generate samples for subsequent testing. The samples generated are shown in Fig. 4.

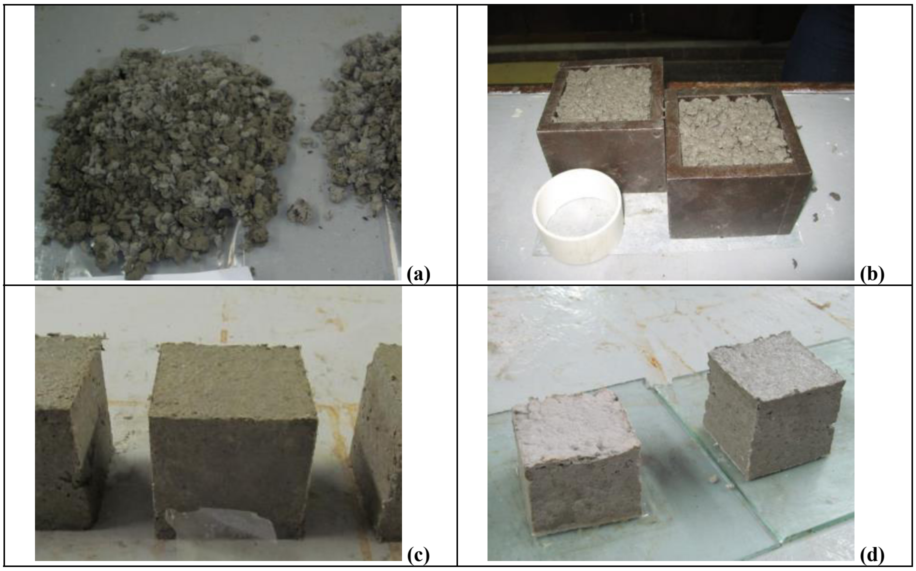


Fig. 4. Specimens generated with: (a) dry residue: RS, (b) wet residue: RH, (c) wet residue with sand: RHA and (d) wet residue pulping: RHP.

Test results of density and compressive strength of the specimens performed on RH, RHA and RHP are shown in Tables 2, 3, 4 and Fig. 6, respectively.

Table 2. Density test results of RH samples.

Sample	Density [kg/m3]	kg cement / m^3 concrete
RH1	889	286,9
RH2	686	286,9
RH3	481,41	143,45
RH4	638,74	143,45

Table 3. Density and compressive strength test results of RHA samples

Sample	Density [kg/m^3]	kg cement / m^3 concrete	compressive strength [kg/cm²]
RHA1	1024	581,1	13,85
RHA2	1155	708,47	18,13
RHA3	679	145,77	0,93
RHA4	949	340	2,85
RHA5	1082	163,99	1,44

The significant difference in the results of compressive strength for samples RHA2 and RHA1 in respect of the rest could be due to the variation of the initial moisture content of the samples as they were extracted at different seasonal periods. The variation in the relative amounts of water/cement mixture influence the resistance to compression thereof.

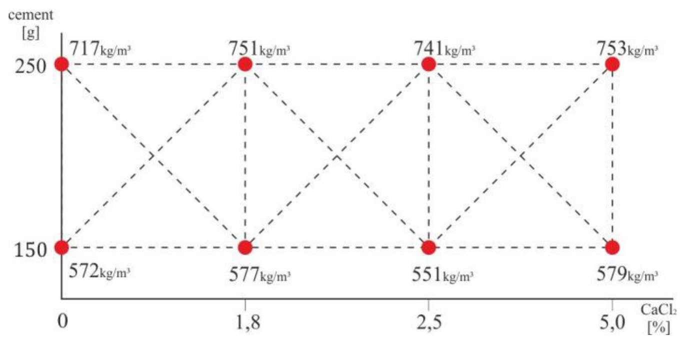
Another aspect to mention is the apparent independence between density and the amount of paper incorporated into the mixture. As shown for the specimens RHA5 and RHA1, their densities are similar in composition even when the specimen RHA5 has four times more paper than the first.

In relation to the values of compressive strength, for the particular case of the specimens RHA1 and RHA5, add the effect of the absolute amounts used in the manufacture of the specimens.

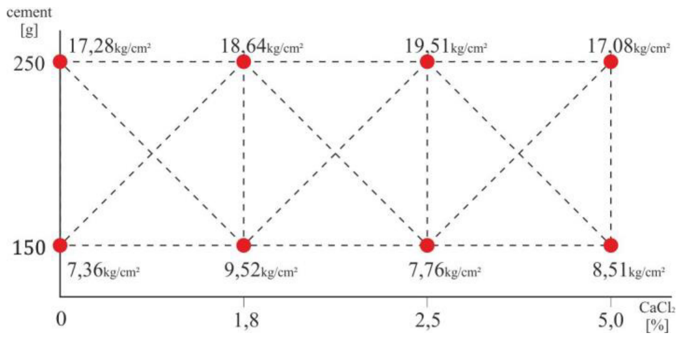
Table 4. Density and compressive strength test results of RHP samples

Sample	Density [kg/m^3]	kg cement / m^3 concrete	compressive strength [kg/cm²]
RHP1	572	505,99	7,36
RHP2	577	470,34	9,82
RHP3	551	493,75	7,76
RHP4	579	506,09	8,51
RHP5	717	797,19	17,28
RHP6	751	713,57	18,64
RHP7	747	762,15	19,51
RHP8	753	806,65	17,08

Comparing these values with that indicated by the Regulation CIRSOC 101 (INTI-CIRSOC, 2005) for normal weight concrete (density 2400 kg/m^3 for an amount of 350 kg cement per m^3 of concrete) it can be seen that, with the use of the residue, is obtained a material of lower density than the concrete.



(a)



(b)

Fig. 5. Results (a) density, (b) compressive strength.

According to the results shown for samples made with the pulping material, an increase in the amount of cement involves an increase in both the density and compressive strength.

As is shows in (Caijun Shia, 2000) the addition of 4% $CaCl_2.2H_2O$ lowers the early strength but increases the later (28 days) strength at 23°C. Moreover, it is evident that increases in the calcium chloride content not significantly affect the values of compressive strength.

4. Conclusions

According to the observations, it can be concluded:

• Depending loss inherent moisture content during storage of the waste, it is recommended to use it under the conditions out of the process (saturated condition) for the manufacture of the composite.

• Due to the correlation between the moisture content of the extracted plant residue and the final properties of the tested specimen, it is essential to control the storage conditions of the residue to be used as raw material for the preparation of the composite.

• It was not possible to find a suitable dosage for the agglomeration of the dry residue (RS) with cement paste. This corresponds to the impossibility of rehydrating the residue submitted to a drying process.

• With the pulping process is possible to obtain an improvement in material properties, reducing the final density without detriment to the value of compressive strength.

Future Actions

It should continue studies to determine the dosage that allows the use of the residue in a composite material whose characteristics are comparable with commercially available products.

For generation of this composite is critical the integral analysis of the behavior thereof from the point of view of technical potential, as well as from its durability. These aspects involving the determination of parameters such as thermal and acoustic insulation, absorption, flexural strength, fire resistance capacity, etc.

References

Àngels Pèlach, P. M. M., 2012. Proceso de desintegración o pulpeado. En: M. Á. Zanuttini, ed. *RECICLADO CELULÓSICO.* Santa Fe: s.n., pp. 33-72.

Area, M. C., Mastrantonio, G. & Velez, H., 2012. GESTIÓN AMBIENTAL EN LA FABRICACIÓN DE PAPEL RECICLADO. En: M. Á. Zanuttini, ed. *RECICLADO CELULÓSICO.* Santa Fe: s.n., pp. 264-303.

C.R. Cheeseman, S. A., 1999. Effect of calcium chloride on the hydration and leaching of lead-retarded cement. *Cement and Concrete Research,* Issue 29, pp. 885-892.

Caijun Shia, R. L. D., 2000. Pozzolanic reaction in the presence of chemical activators Part II. Reaction products and mechanism. *Cement and Concrete Research,* Issue 30, pp. 607-613.

CEPI, I. C. O. E. P., 2003. *Discovering the high potential of Pulp and Paper Production Residues,* Bruselas: CEPI.

F. Pruckner, O. G., 2004. Effect of CaCl2 and NaCl additions on concrete corrosivity. *Cement and Concrete Research,* Issue 34, pp. 1209-1217.

INTI-CIRSOC, 2005. *Reglamento Argentino de Cargas Permanentes y Sobrecargas Mínimas de Diseño para Edificios y Otras Estructuras.* Buenos Aires: s.n.

Ismail Demir, M. S. B. M. O., 2005. Utilization of kraft pulp production residues in clay brick production. *Building and Environmen,* Issue 40, pp. 1533-1537.

Luis Agulló, A. A. T. G., 2006. Study of the use of paper manufacturing waste in plaster composite mixtures. *Building and Environment,* Issue 41, pp. 821-827.