PAPERMAKING SLUDGE PROPERTIES FOR USE IN CONSTRUCTION AND BUILDING

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When processing the waste paper into the tissue paper products, there arises up to 30 to 40 percent of the paper sludge. Today, this sludge is used as an ingredient to manufacture the bricks, to produce compost, or to reclaim the mining pits. The current methods of disposal and recovery of this sludge are cost-intensive, and they often limit the actual quantities of the processed paper waste. Suitably modified papermaking sludge can be used as construction boards or building blocks. It must endeavour to satisfy the requirements for wholesomeness, compressive strength, density, moisture expansion, fire and frost resistance, and thermal and sound insulation. This work presents the authors' current designing and testing of the manufactured construction elements based on paper sludge.

KEYWORDS

papermaking sludge, sludge modification, experimental building material, tests, construction industry

1 INTRODUCTION

The European Union at present shows annual consumption of materials on a level of 16 tons per person, with up to 6 tons of these becoming waste. According to other data published by Eurostat, in 2014 about 2 550 million tons of waste were produced in the European Union, with only about 36 % of this recycled, with the remainder being disposed of by storage or incineration. Also worth mentioning is the fact that a further almost 600 million tons of disposed waste could be recovered.

The EU policy and legal framework in the area of environmental protection, to which the issue of waste handling also belongs, has been evolving over several decades. A starting point for fulfilling the goals of the Strategy was the approval of a new framework directive by the European Parliament and Council 2008/98/ES on Waste, applying the approach of taking into account the dimensions of the life cycle, including a waste environment hierarchy.

A significant milestone was the approval of a Thematic Strategy for preventing the formation of waste and for its recycling, which represented the global efforts of the EU to trend towards a so-called "Recycling Society" which would try to avoid the creation of waste and also use waste to a maximum degree as a source of raw material or energy.

Recycled cellulose has become an important raw material in the papermaking industry due to its acceptable price in comparison with a corresponding quality of fresh cellulose. The environmental outcomes of processing collected paper include primarily lower amounts of emissions released into water, of solid wastes and of emissions released into the atmosphere.

During the recycling of paper various secondary material flows which contain in addition to undesirable elements, are produced other materials which should be perceived as sources of valuable raw materials, and these can be further used in the production of other products [Likon 2012], [Study report 2013], [Soos 2007]. The goal of "increasing the economic value of recycled paper" offers new possibilities for support of the development of technologies which, without their quality parameters being exploited, enable the capturing of raw materials which today often end up as waste.

At the present time, in harmony with the hierarchy of waste economy the following methods are regularly applied:

1. material valuation,
2. use in the re-cultivation of agricultural and forest soils,
3. energy valuation – co-combustion, pyrolysis, gasification, and similar,
4. usage in the production of cement and bricks,
5. storage in dumps.

Up to the present, the most widespread method of handling various types of waste, including papermaking sludge, was storage. The selection of a method for dealing with sludge from the production of paper and cellulose, which is classified as secondary waste, depends on the physical, chemical and biological properties of sludge. The sludge coming out of a technology line (Fig. 1a) in the processing of paper has a relative humidity of 49 – 55% and an inorganic content of 55-65 % (Fig. 1b).

a

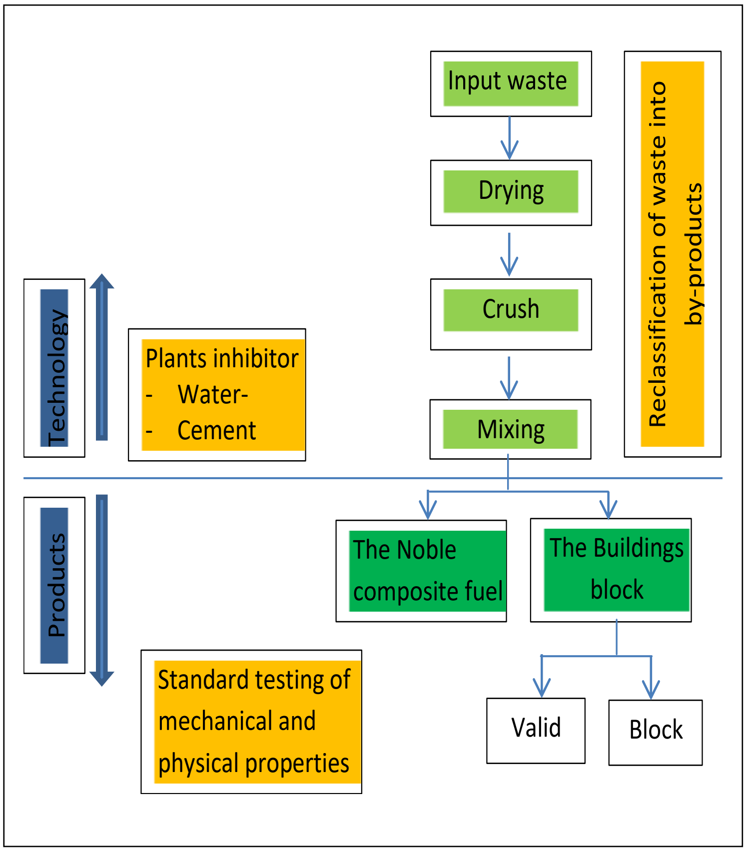
b

Figure 1. Papermaking sludge: *a* - at a filter press outlet, *b* - structure and form of sludge [Soos 2015]

2 MATERIAL RECOVERY OF PAPERMAKING SLUDGE

The properties of papermaking sludge from paper based on collection paper depend significantly on the properties and composition of the collection paper and also on the properties of the paper produced. These types of sludge are mixtures of additives and pigments, fibres, short fibres, print dyes and glue components. The material recovery of these sludge types may derive from their high content of inorganic components or from their fibre contents. If sludge is to be used in the production of fibre glue or compressed wood-fibre boards, it is then appropriate for sludge to have a higher content of fibre. A high content of ash in papermaking on the other hand is appropriate for use in the brick and cement industries.

Papermaking sludge can be effectively recovered in terms of both material and energy. In the resolution of the research task [Soos 2015] undertaking in our institute, we analyzed both possibilities of recovering papermaking sludge. The basis of the material recovery of waste was a proposal for the final products and, depending on this proposal, the resultant technological approach, Fig. 2a. Prior to the actual application of any kind of approach it was necessary to modify the papermaking sludge mechanically. The necessary conditions include disintegration, homogenization and reduction of the sludge's humidity, Fig. 2b - 2d.



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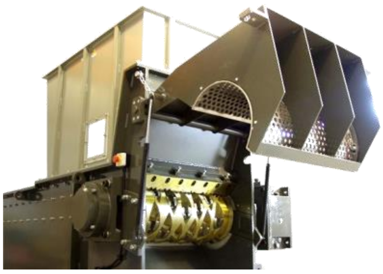


c

d

Figure 2. Process of modification of papermaking sludge: *a*- block diagram; *b* – drying; *c* – disintegration; *d* - homogenization [Soos 2015]

3 LABORATORY TESTS OF MATERIAL RECOVERY OF PAPERMAKING SLUDGE

Production of blocks and boards – Research and development work has shown, [Soos 2015] that papermaking sludge can also be successfully used in the production of construction blocks and boards. The input raw material for the production process illustrated in Fig. 3 is an 80 % mixture of papermaking sludge and 20 % of cement. The tests showed that the manufactured blocks and boards exhibited very good mechanical properties. The level of effectiveness of the production of such construction elements will depend on the percent of sludge, the binder, and other ingredients.

3.1 Laboratory testing of the mechanical properties of construction boards

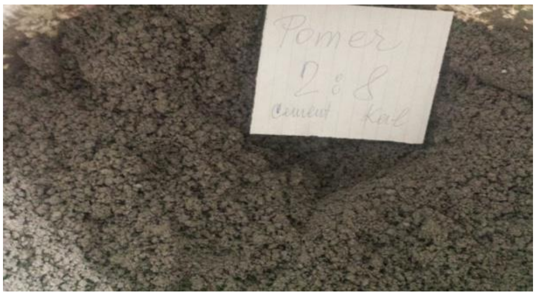
Construction boards with a thickness of 12 mm were manufactured from a mixture of cement and papermaking sludge in three mass ratios of cement to sludge (in %): 50 : 50, 60 : 40, and 70 : 30.

Shear strength of construction blocks

To determine the shear strength, a universal shredder with an output of 5kN and a motion speed of 10 mm.min^{-1} (Fig. 4) was used. The tested board samples produced from the above-stated mixtures had the dimensions of 200 x 150 mm and were fixed to the shredding tool by 4 screws. The tensile load increased and was recorded until the corruption of sample at the fracture load (Fig. 5) occurred. The fracture load per one fixing with the *b* screws of each sample was calculated as

$$b = F_{max}/4 \quad \text{(N)} \qquad (1)$$

The resultant average values of fracture load for each ratio of cement and sludge mixture are stated in Tab. 1.



a

b

c

d

e

f

Figure 3. Preparation of construction blocks: *a* - mixture ratio; *b* – a board from papermaking sludge; *c, d* - mould for producing the construction blocks; *e, f* - construction blocks [Šooš 2015]

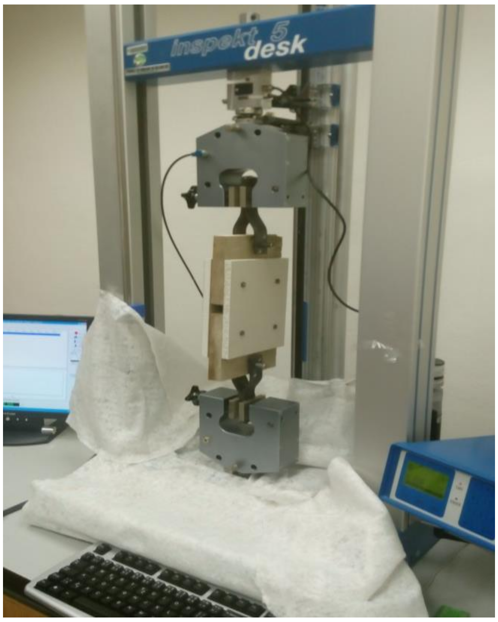


Figure 4. Clamping the test sample on the shredder

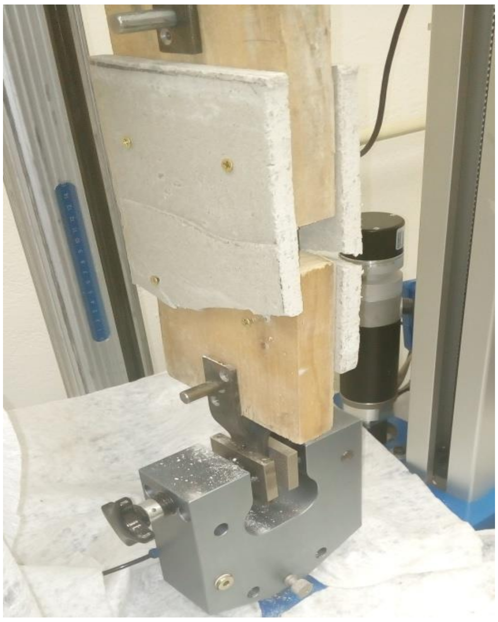


Figure 5. Corruption of the test sample

Measurement No.	Mass ratio of cement and papermaking sludge (%)					
	50/50		60/40		70/30	
	Fmax (N)	b (N)	Fmax (N)	Fmax (N)	b (N)	Fmax (N)
1.	1058,1	264,5	662,5	165,6	2140,6	535,2
2.	693,4	173,4	736,3	184,1	2565,2	641,3
3.	555,9	139,0	882,9	220,725	2891,8	723,0
Average value	769,2	192,3	760,6	190,1	2532,5	633,1

Table 1. Fracture load values

Establishing bending during loading

For the determination of shear strength, the universal shredder with an output of 5kN was again used. The test samples were boards with dimensions of 300 x 200 mm and a thickness of 12 mm. manufactured from the above-specified ratios of cement and slush mixtures (50/50, 60/40, 70/30). The test sample was placed on cylindrical supports (Fig. 6) and was loaded at a speed of 4 $N.s^{-1}$ up to maximal fracture load Fmax (Fig. 7). The resulting values of bending y and maximal fracture load *F*max for each ratio of cement and sludge mixture are stated in Tab. 2.

On the basis of the results from the laboratory tests of the mechanical properties of the construction boards manufactured on a base of papermaking sludge and cement, it is clear that the potential of such elements in construction is high, arising from their great strength in both pulling and bending. With a mass increase of the share of cement from 50 to 70 % the pull strength is more than three times greater, and strength in bending of the boards is more than doubled. According to the method of using these boards it is possible to protect their surface with cardboard, by which their mechanical properties increase even more markedly, and also to protect the surface by acrylic dispersion in order to reduce absorbency.

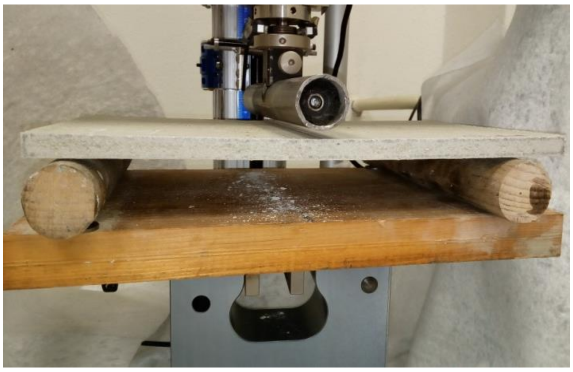


Figure 6. Positioning of test sample

Figure 7. Corruption of sample at *Fmax*

Measurement No.	Mass ratio of cement and papermaking sludge (%)					
	50/50		60/40		70/30	
	Fmax (N)	y (mm)	Fmax (N)	y (mm)	Fmax (N)	y (mm)
1.	170,5	2,0	128,3	1,8	387,4	1,7
2.	149,1	2,8	94.6	1,3	357,0	1,5
3.	140,3	2,3	110,9	1,2	192,2	1,2
4.	90,1	0,8	110,2	1,4	191,1	1,4
5.	106,4	1,0	--	--	261,2	1,3
6.	97,9	0,8	--	--	260,1	1,5
Average value	125,7	1,6	111,0	1,4	273,4	1,4

Table 2. Values of bending at maximal fracture load

4 PRACTICAL APPLICATION OF SLUDGES

The final product was subject to a process of certifying its conformity according to Act no. 90/1998 Coll. on Construction Products. Protocols on testing were issued by TZUS s.p. Prague, Ostrava branch, no. 1018.7 accredited by CIA and TSUS Bratislava: OM 04 , Technical certification TO-09/0155.

In the spirit of the stipulations of Act no. 90/1998 Z.z. on Construction Products, the company IPP Daxner, s.r.o. [IPP 2007] declares that the product is in conformity with the above-stated technical specifications and legal regulations and is designated with a CSK conformity mark. The real products are illustrated in Fig. 8, and the technical parameters of the developed products are listed in Tab. 3.

a *b*

Figure 8. Products of the company IPP Daxner, s.r.o.: *a* – transverse masonry; *b* - perimeter masonry [IPP 2009]

Determination	Transverse "65"	Transverse "100"	Transverse "150"	Transverse "200"	Transverse "250"	Perimeter masonry "300"	Perimeter masonry "350"
Dimensions [mm]	65x140x290	100x200x400	150x200x500	200x200x400	250x200x400	300x200x400	350x200x400
Thickness of wall, unplastered [mm]	65	100	150	200	250	300	350
Volume mass [kg/m^3]	985	868	765	787	700	736	678
Strength in pressing [N.mm^2]	2,99	2,92	2,92	2,92	2,92	2,92	2,92
Volume mass 1 ks/kg	2,60	6,95	11,50	12,60	14,00	17,70	19,00
Fire resistance [min]	60	60	60	60	60	60	60
Volume mass per 1 m^2/kg	64	87	115	157	175	221	237
Heat resistance *R* [m^2.K.W^{-1}]	0,325	0,575	0,650	1,033	1,035	2,33	2,70
Heat transmission coefficient *U* [W.m^{-2}K^{-1}]	------	------	-------	-------	-------	0,40	0,34
Radionuclide content max.120 Bq/m^{-1}	17	17	17	17	17	17	17
Humidity expansion [mm^2.m^{-1}]	2	2	2	2	2	2	2
Soundproofing "*Rw*" [dB.m^{-2}]	37	45	47	54	≥54	≥54	≥54
Fire reaction class	B-s1,d0	B-s1,d0	B-s1,d0	B-s1,d0	B-s1,d0	B-s1,d0	B-s1,d0

Table 3. Technical parameters of produced blocks, [IPP 2009]

5 BLOCK PRODUCTION LINE

The production of blocks is protected by patented technology as an unfired masonry element whose basis is further unprocessable cellulose mixed in a certain ratio with cement, plaster, in case of need with water, and consequently pressed into the desired shape with exclusion of a heat process, Fig. 9. The water used in the production process is recyclable, which means it is preserved and put back into the production process. Products which do not correspond to the required parameters are also returned into the production process as input materials. The projected production capacity is approximately 180 m^3 of products per day, therefore about 44 000 m^3 of products per year, [IPP 2007]. In terms of mass this represents about 104 t of product per day, which translates into 26 000 t of product per year.

a

b

Figure 9. View of the production line: a - production of blocks; b – a pressure compactor [Marston 2009]

6 CONCLUSIONS

The aim of the presented article is to point out possibilities for effective material recovery of papermaking sludge in the manufacture of construction blocks and plates. The experimental tests confirmed the good mechanical and thermal properties of the laboratory-produced blocks. The produced blocks proved technical parameters comparable to the blocks manufactured from the classical construction materials, making them their full-value replacement. On the basis of an analysis of the required technologies, in the final phase of research we designed a technology line for the production of ecological cellulose/cement or cellulose/plaster blocks and boards.

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