Utilisation of Fiber Sludge Refuse in Gypsum Fiberboards

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Abstract – No waste paper is available in the required amounts in Hungary with acceptable price and light wood species suitable for making gypsum particleboards are not readily available, experiments were accomplished to use fiber sludge from sulphate pulp mill using straw as reinforcing material in gypsum fiberboards. Moreover, the addition of lime sludge, also available as waste in this mill was investigated. A new process was developed characterised by a two-stage fluffing of the fiber sludge and addition of the lime sludge to reduce the setting time of the binder and to avoid formation of lumps and balling in the mixing process of the furnish. The new process and the product-fiberboard- is environmental friendly as material, which until now have not been utilised industrially, but this may change in he future. The fabricated boards utilising natural gypsum (NAT), flue-gas desulfurization gypsum (FGD), phospho gypsum (PHO) and stucco gypsum (STU) show comparable properties with those of published data of commercial gypsum fiberboards. Boards made of various kinds of plaster show different bending strength properties. The best values are show by boards made with FGD and PHO. However, the differences with other boards are noth high, so the conclusion can be made that fiber sludge is a good material as reinforcement for gypsum fiberboards.

Keywords: gypsum / fiber sludge / lime sludge / gypsum fibreboard / environmental friendly and intelligent products

1. INTRODUCTION

Hungary has one pulp plant, using straw as raw material and utilizing the sulfate process, reports a waste of 24 t/d of fiber sludge and 2.5 t/d of lime sludge at the present time. The lime sludge comes from the caustification process according to the folloving:

$$Na_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2\ NaOH \quad (1)$$

$$SiO_2 + 2\ NaOH \rightarrow NaSiO_3 + H_2O \quad (2)$$

$$Na_2SiO_3 + Ca(OH)_2 \rightarrow CaSiO_3 + 2NaOH \quad (3)$$

The SiO_2 comes from the straw. Due to the reaction calcium carbonate beside calcium silicate are found in the lime sludge. It is not possible to recycle $CaSiO_3$, and most of the resulting lime sludge has to be deposited as land filling (TAKATS - SIMATUPANG 1993). It is the purpose of the paper to report on examinations to utilize the forementioned waste products, fiber sludge and lime sludge (*Figure 1*), in the fabrication of gypsum fiberboards.

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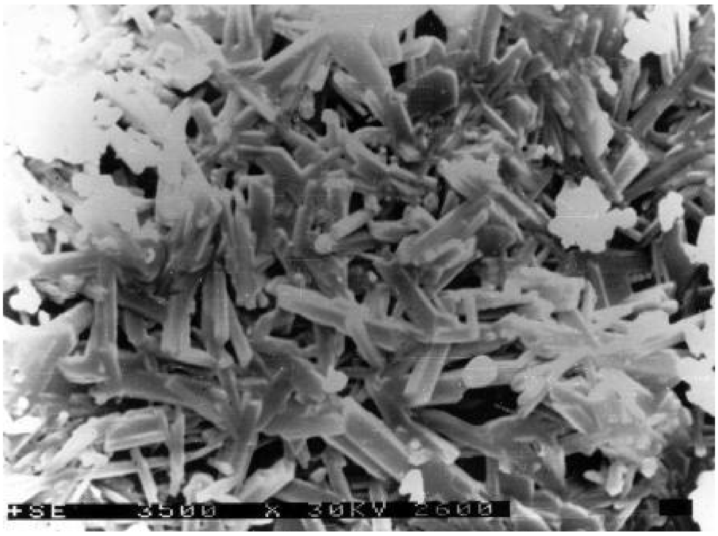

Figure 1. Lime sludge (Amplification: 3500 fold)

1.1. Theory

The aim of the research:

- production of gypsum fiberboard based on secondary raw materials;
- elaboration of optimal water-gypsum (w) and fiber-gypsum (x) ratio using fiber sludge and lime sludge, flue gas desulfurization gypsum (FGD) or phosphor gypsum (PHO) and parallel formation of homogeneous internal board structure ;
- characterization of the secondary raw materials above.

2. MATERIALS AND METHODS

„Fiber sludge" from the pulp plant has a moisture content of up tu 100-125 percent. It is a brownish-blackish and dense mass, and in this form unsuitable to be mixed with gypsum hemihydrate. The pH of the water extract is 6.4 the lignin content is 8.1 percent. However, the reinforcing properties is also influenced by the ratio of fiber length to diameter. The ratio of 26.4 fo the fiber sludge is not unfavorable.

The fiber sludge has a gypsum setting retarding effect. The water extracted fiber are deprived of such compounds. Remarkable is that the various kinds of plaster and show different properties of gypsum materials (*Table 1*).

Table 1. Properties of gypsum materials (DIN 1168)

Denomination	NAT	FGD	PHO	STU
Water-gypsum (w)	0.64	0.73	0.89	0.62
Initial set (min)	8.5	5.5	12.5	4.0
Final set (min)	52.0	39.5	48.0	28.0
Sieverest %>0.2 mm	6.8	1.8	2.1	3.4
Bending strength (MPa)	4.26	5.4	3.71	5.74
Compression strength (MPa)	11.52	15.28	7.95	9.61
Density (kg/m^3)	1145	1192	934	1159
pH	6.5	5.8	5.1	6.3

A retarding effect of the reinforcing material is desirable, because it may prolong the open time of the inorganic binder. In the fabrication of gypsum bonded composites ample time should be available for mixing an forming the furnish befor it is pressed to ultimate thickness. From this point of view the fiber sludge has favorable properties.
Moist „*Lime sludge*" shows moisture content of abaut 70 percent. The chemical constitution is depicted in Table 2.

Table 2. Quantitative analysis of lime sludge [a)]

Phase	Volume %
1. Iron Oxide FeO	1.09
2. Calcite $CaCO_3$	96.02
3. Calcium Chlorite $Ca(OCl)_2$	2.72
4. Aluminium Chloride Hydro $Al_{11}(OH)_{30}Cl_3$	0.08
5. Calcium Silicate Hydrate Ca_2SiO_4 x 30 H_2O	0.08

a) Philips Röntgen diffractometer.
Accomplished at the Technical University of Hamburg, Germany

Lime sludge is very fine grained and difficult to dewater and to dry. This is the main reason why it can not be used as substitute for lime stone in many technical process. Currently lime sludge has to be deposited and the cost of it is an extra burden for the pulp manufacturer. In our experiments dried lime sludge showed favorable effects.
To make use of the advantageous properties of both fiber sludge and lime sludge in the fabrication of gypsum fiberboards a new working methods has to be developed. In the new process a two stage fluffing of the dense and moist fiber sludge is used. As was already mentioned, after the first fluffing stage some lime sludge is strewed on the surface of the fibers. The fine particles on the surface of the fibers prevent formation of lumps in the subsequent second fluffing. The furnish is manually formed into a mat. The board's dimension is 30 by 30 cm, and the thickness is determined by a distance bar of 12 mm. The target density in all experiments is 1150 kg/m^3.
The accelerator is ammonium sulfat. Gypsum dihydrate is added in some board's recipe (SIMATUPANG - LANGE 1992). Waste material containing gypsum dihydrate, e.g. from trimmings or rejected boards, will always be available in gypsum fiberboard plants. The furnish is slightly prepressed and densified to ultimate thickness in a hydraulic press. The boards are then dried overnight in an ovon with forced circulation at 40 °C and then cut into specimens of 21 by 5 cm. Test are accomplished on conditioned specimens according to DIN standars for wood particleboards.

3. RESULTS AND DISCUSSIONS

The optimum of fiber sludge to gypsum hemihydrate according to the experiments is between 0.2 and 0.25. These values correspond well with published data for gypsum fiberboards. Boards made of various kinds of plaster show different bending strength properties. The best values are shown by boards made with desulfurizing gypsum and phosphor gypsum. Addition of ammonium sulfate, gypsum dihydrate and lime sludge resulted into boards with the highest

bending strength properties. Ammonium sulfate is in the experiments the best accelerator, but resulted into boards with the lowest bending strength.
How does the lime sludge improve the bending strength of boards?
If this material is mixed with neat plaster the strength properties decreased. Addition of lime sludge will decrease the density, and also the strength properties. If, however, lime sludge is added to binderin the fabrication of gypsum fiberboards the bending strength increases. It is supposed that calcium carbonate from the lime sludge reacts with ammonium sulfate to give carbon dioxide according to the fallowing reaction:

$$CaCO_3 + (NH_4)_2SO_4 \rightarrow CaSO_4 + (NH_4)_2CO_3 \quad (4)$$

$$(NH_4)_2CO_3 \rightarrow NH_3 + H_2O + CO_2 \quad (5)$$

Carbon dioxide will react with calcium hydroxide which is mostly available in a small quantities in burned gypsum dihydrate. The formed calcium carbonate may act as supplementary binder as was reported in the carbonation of cement- bonded particleboards (ALPAR et al. 2004). The conditions for carbonation are favorable and corresponds well with those in the carbonation of cement fiberboards. Another advantage is the formation of water during the reaction of ammonium sulfate with lime sludge. This water will increase the amount of gauge water without influencing the mixing properties of the furnish. A critical parameter in mixing lignocellulosic fibers with plaster is the water-gypsum ratio which has to be as low as possible to avoid lumps and balling.

4. CONCLUSIONS

Fiber sludge and lime sludge from pulp plants using straw and applying the sulfate process, are according to the experiments valuable raw materials for the fabrication of gypsum fiberboards. The product and the process are environmental friendly as material up till now not used may be industrially utilized.
Land filling sites may be relieved. Table 3 presents a comparison of properties and material requirements of available gypsum-bonded composites with those of boards which can be made from the above mentioned waste products.

Table 3. Some characterisics and material requirements of medium-high density gypsum-bonded fiber composites

Characteristic	Sasmax (Finland) Arborex (Norway)	Fermacell (Germany)	Würtex (Netherlands)	Fiber Sludge Boards
Structure of reinforcing material	flakes	wood pulps (recycled pulp)	waste paper	fiber sludge
Binders	gypsum hemihydrate	gypsum hemihydrate	gypsum hemihydrate	gypsum hemihydrate
Products	boards	boards	boards	boards (laboratory)
Density (g/cm^3)	1.0 to 1.2	1.0	1.05 to 1.15	1.05 to 1.2
Bending strength (MPa)	6 to 9	4 to 7	5 to 7	4.5 to 7
Modulus of elasticity (MPa)	3000 to 5000	4000 to 5000	3000 to 5000	3200 to 4700

5. SUMMARY

We have proofed that the secondary raw materials: the fiber sludge and the lime sludge from cellulose and paper mills are suitable for gypsum bounded fiber boards production using appropriate technology. The fiber sludge based gypsum composites open new possibilities in the field of mineral bounded composite.

5.1. The properties of the fiber boards

5.1.1. Wet technology

- The benefit of this technology is the high homogeneity of the fiber-gypsum mixture, high bending strength. The viscosity of the fiber-gypsum dispers system is reduced by the use of lime sludge, as a result, reduction of the free water amount was possible: water-gypsum ratio (w = 0.5).
- The porous structure of the board results good heat conductivity and humidity control capability and the lime sludge has improved the dispersity of the fiber-gypsum system.
- The lime sludge and fiber sludge has not affect the fire retardant properties, same as the other gypsum boards.
- The gypsum-dihydrate crystal structure on the fiber surface working as protective layer against heat. At high temperature it is able to isolate the oxygen from the fiber for longer time (t = 45-50 min).
- The fine crystals on the surface of fibers are initiators of cystallyzation and making bridge between fiber and gypsum.

5.1.2. Semi-dry process

- At the semi-dry process it was clear, that the lime sludge supported to loosen the fibers at a relative high moisture content, u = 80-125%.
- The precipitated lime sludge has bounding delay effect as well, so reduced amount chemical for delaying bounding is necessary.
- We have developed a fast mixing technology that resulted even higher homogeneity in the fiber-gypsum mixture (*Figure 2*).

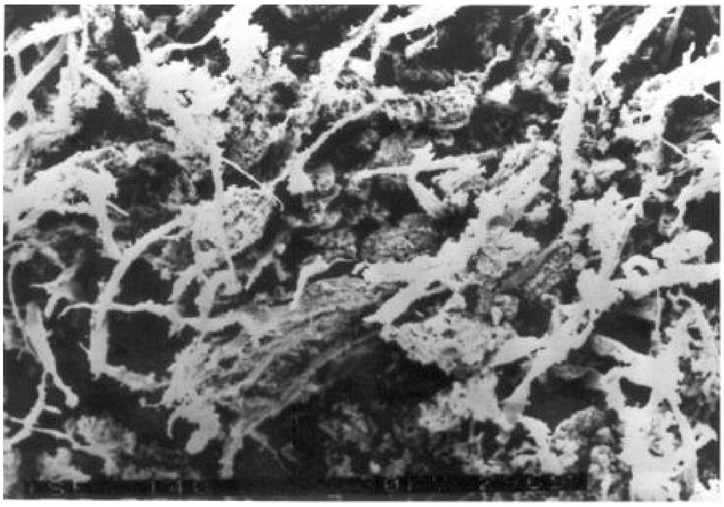

Figure 2. Board produced in semi industrial condition (x = 0.24).
(Amplification 140 fold)

5.1.2. Dry process

- The lime sludge allowed us to develope new technology and we were able to apply higher fiber-gypsum ratio (x =0.24) with good homogeneity.
- The low water-gypsum ratio (w = 0.25-0.30) improved the mechanical and physical properties. The highest strength board was made from FGD gypsum (*Figure 3*).
- The generated CO_2 together with the CaO or $Ca(OH)_2$ - always available in gypsum halbhydrate – resulting the carbonate process.

Figure 3. Wall section of a house, internal board

- We have developed a new technology for loosen fibers and for mixing fibers, that made possible the board production without adding free (or mixing) water.
- Utilization the secondary raw materials and the developed dry technology, where the water-gypsum ratio: w = 0.25-0.30 is lower than the lowest in the industrial practice.
- The applied fiber-gypsum ratio (x = 0.24) is higher than in the highest in the industrial practice.

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