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# EVALUATION ON UTILIZATION OF FIBRES FROM ANNUAL PLANTS FOR THE MANUFACTURE OF RESIN- OR CEMENT BONDED PARTICLE BOARD*

by

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## Introduction

In many countries the supply of wood which so far has been the common raw material source for the manufacture of board has become problematic. In several cases this has been caused by the strong growth of the industry. On the other hand, there are many regions in the world where wood is, and has long been, very scarce.

Since in the countries of the first mentioned category a further increase of the production volume can be expected, the particle board industry is intensifying its efforts to substitute wood by other suitable raw materials. Apart from biomass (hogged-up total bush and thinnings including leaves) and bark, there are in wood restricted areas large quantities of residues from annual plants available. Although presently in Europe the utilization of annual plants for panel manufacture in relation to the consumption of wood is still very low, the production of board from flax, hemp and rape seed shivers was an economical, successful development.

In tropical countries the production of board from bagasse, the residue of sugar cane, has in the meantime become quite important. A specialized manufacturer has successfully installed a number of installations producing both, thin and thick bagasse board respectively using continuous pressing operations and single daylight press lines.

But also cotton stalks are used as raw material on some single-opening particle board press installations, and panels with excellent properties are made showing figures of same or even better level than those of wood.

Rising raw wood prices and increasing scarcity of same plus a growing need for panel material for both, construction- and furniture industry, have pushed research and development to use apart from bagasse and cotton stalks also straw, grasses, reeds, bamboo, corn stalks, palm fibre, jute, sisal, coconut fibre and waste paper as well as rice, sunflower and peanut shells. Sometimes mixtures of the mentioned materials are used but also wood flakes are added.

In the following some typical procedures will be described when dealing with some of the important annual plants as raw material for a number of production facilities in different parts of the world. In a table figures of properties of different panels are compared with those of standard resin-bonded wood flake board according to German standards. In another table the properties of laboratory test boards based on annual plant fibres bonded with cement are compared with those of wood flake cement board produced on existing installations.

## 1. Problems in harvesting and storage

As we have in most cases to do with waste- and by-products of the annual plants that are released in large quantities during a comparatively short time, it caused often problems to get rid of this material because so far only few application possibilities were available. On the other hand, the material is produced on good accessible fields so that transportation costs need not to be of much influence on the raw material costs which nowadays play an important role in the cost development of the particle board production.

In comparison to the utilization of wood waste, annual plant residues have the following essential differences:

- intermittent supply of the waste because of the harvest taking only some months;
- variable quality of the raw material because of different growth-, harvest- and storage conditions;
- low resistance against moisture influence and consequently sensitive to fungal attack.

In spite of these differences there are nearly no technical problems involved with the preparation and utilization of these annual plant residues to produce high quality particle board panels, of which the manufacture differs only in the preparation of the particles itself.

On the grounds of quality variations defilements and odd pieces as well as the unfavourable and disturbing components for the working up into particle board, like pith, wool and bark fibres, it is necessary to pay extra attention to the layout conception and construction of the particle preparation equipment.

## 2. Source of raw material

### 2.1 Bagasse

Bagasse is a cellulose containing residue which is obtained in the cane sugar production after extraction of the sugar out of the cane

Sugar cane belongs to the family of the grasses. It is growing up to 6 m high depending on species and cultivation area, and has a cane diameter up to 5 cm. Sugar cane is only growing in tropical and sub-tropical regions with sufficient humidity.

When the bagasse leaves the sugar mill it has the following composition:

| | | |
|---|---|---|
| | 45 - 50 % | fibrous material |
| | 45 - 50 % | water |
| approx. | 2 - 3 % | sugar |
| approx. | 2 - 3 % | impurities |

Related to the dry weight, bagasse therefore has an average moisture content of 100 per cent and a remaining sugar content of approximately 5 per cent.

The chemical composition of bagasse does not differ very much from that of wood:

| | Bagasse | Pine |
|---|---|---|
| Cellulose | 49 % | 42 % |
| Lignin | 21 % | 29 % |
| Pentosane/Hexosane | 26 % | 22 % |
| Miscellaneous | 5 % | 7 % |

A section of a sugar cane consists principally of two main parts:

- the bark layer, consisting of stiffening tissues (fibre)
- the storage texture, generally called pith and in which an additional part of the stiffening tissue is embedded.

The greater part of the stiffening texture, however, is located in the bark layer.

Depending on the species of sugar cane and the growth circumstances, the quantity of pith varies from 25 to 35 per cent and the fibre part takes 65 to 75 per cent accordingly.

Depending on the harvesting method and also on the system of sugar extraction, the fresh bagasse contains apart from a varying percentage of so-called trash material (leaves, weed and the cane tops) also a strongly varying quantity of dirt in form of sand, stones, clay and other odd particles, which can cause serious wear of the fibre preparation equipment. In order to prevent this, we make use of a number of so-called heavy particle dropouts in the transport system by which all larger parts, like stones and metal pieces, are separated.

The most important part of the process of bagasse preparation is the pith removal by special depithing machines of different designs. It has to be mentioned that there is a German pith separator on the market which has proven to be very suitable and is performing the depithing operation very efficiently, without influence on the fibre strength. Such depithing separators are very sturdy machines consisting mainly of a vertical cylindrical screen with open top and bottom sides in which a vertical shaft with rotor is placed. The rotor carries very heavy cranks on which the rotor blades with wearing surface are placed. The blades can be easily replaced and recovered. The blend is charged by dosage in the top part of the cylinder and blown open by the beating action of the rotor blades; the pith and the fines pass through the screen so that they are separated from the fibre. An additional screening of the bagasse fibre is not necessary. Height and diameter of the screen cylinder define the capacity of the machine which is, at favourable power consumption, quite high.

After depithing, predrying of the green bagasse down to a moisture content of 20 - 30 per cent follows in order to obtain favourable conditions for the conservation and storage of the bagasse. In predrying the greater part of the fungus sprouts sticking on the bagasse are destroyed and on top of that due to the lower moisture content a too strong fermentation is prevented, whereas green bagasse with a moisture content of approximately 100 per cent and a remaining sugar content of 3 - 5 per cent happens to be an ideal culture medium for all kinds of fungi.

A portion of the depithed and predried bagasse is going straight to the actual board production line which is usually located close to the sugar mill due to lower transport costs.

The bagasse that has not been used during the harvesting period is compressed into bales by a baling press and is stored by stacking the bales, leaving about 2" (5 cm) space between each stack for ventilation and for prevention (spontaneous combustion).

During the rest of the year the bales are opened up again by a bale breaker, and the bagasse is transported to the particle board mill by a belt conveyor.

Further processing of the material is executed by special hammer mills in wear-resistant execution, and afterwards the shortened bagasse is conveyed to the main dryer.

There are no essential differences between a bagasse- and a wood particle board process as far as glue blending, forming and pressing are concerned. There are only some press-related adaptations needed due to the low bulk weight of bagasse. Already at lower specific weight - and of course under condition of same resin consumption per m3 board - properties can be achieved that are equal to those of wood particle board.

In case that the bagasse board factory has to be located at a considerable distance from the sugar mill, it is advisable to do the depithing, predrying as well as the baling at the sugar mill's site because fermentation might take place when its transportation is delayed and also during intermediate storage. At the same time there are considerable savings in transport costs because pith and trash and water are not transported.

Since the depithing and predrying installation as well as the baling presses are only in operation during the sugar campaign, their capacities are planned accordingly.

Green bagasse that is not depithed starts to ferment by fungal attack already after having been stored for a few hours. There is heat developed so that a sort of drying process is started. When comparing the sugar content figures during the fermentation process, a decrease of the remaining sugar can be observed already after 10-14 days. At that moment the temperature in the stockpile is at its highest, and there is the strongest attack by sprouts of fungi. Afterwards, the fermentation starts to destroy the pentosans, the lignin, and finally the cellulose fibres are attacked and ruined. At the same time dark coloration of the material is taking place and this is getting worse during the rotting process.

There are older bagasse board installations where a bagasse preparation with fermentation but without depithing and predrying was preferred due to saving of investment and energy consumption. The disadvantages, however, of such a system are the following:

- the original material for board production is of great variation in colour and quality;
- the produced panels have low physical and mechanical properties due to the more or less severely damaged fibres;
- it is uneconomical since not all of the waste material purchased by the board mill can be used (pith and fines);
- there is a health risk connected with this way of fibre preparation.

The last mentioned disadvantage item is the most important one. This kind of bagasse preparation causes the dangerous "bagassosis", a long disease that might lead to death if the contact of the workers with bagasse is of long duration.

The spraying of green bagasse with 2 per cent propionic acid (based on the absolute dry weight) would possibly prevent fermentation but is rather costly and predrying therefore is necessary anyway so that the quantity can be reduced to 3/4 per cent. Latest experiences gathered by a number of operations executed with good depithing, predrying and classification systems have shown, however, that the risk of labourers to catch bagassosis does no longer exist.

## 2.2 Cotton stalks

Cotton is one of the oldest plants cultivated in tropical and subtropical areas. It belongs to the category of mallow plants and can be found in many varieties of these species.

The plants grow up to 2 m in height but their shape is herbaceous to shrublike. Most are annual plants but there are also some varieties growing through the winter season. The seed capsule of the cotton plant is utilized as one of the most important natural fibres, whereas the actual plant (the cotton stalk) has hardly been used, and its removal is costly and troublesome to the harvester.

Cotton stalks of various sources as raw material for board production have been tested and in 1975 a large-size single-opening plant was established in the USSR based on their own technological developments.

The production of boards from cotton stalks is different from the wood particle board technology only as far as the preparation of the raw material is concerned. The cross section of a cotton stalk consists of:

- bark
- the cylindrical stem with bast and woody fibres
- the pith

The quality of cotton stalks for particle board production is largely effected by varying the storage conditions. As the harvesting season only lasts a few months each year, the essential factor for the preparation of the material is its moisture content.

At an initial moisture content of over 100 per cent and with a harvesting method cutting only the plant tops, a very high bast fibre percentage of 60 - 80 per cent may be gained under extreme cases. This material tends to form wodly fibre balls which have to be removed prior to further processing. Depending upon species and low moisture contents, the percentage may be in the range of only 10 per cent, at favourable conditions, but 40 - 50 per cent is an average. With regard to the particle yield and quality, it is of great importance to harvest the bottom parts of the plants, including the roots, as well as the tops. The drier the raw material, the easier the refining, however, the separation into bast fibre and woody particles becomes more difficult.

Even if optimum conditions for the storage are considered, both extreme conditions have to be taken into account for the selection of suitable refining machines.

Generally, the preparation of cotton stalks consists of the following steps:

- pre-cutting of the stalks with detaching of the bast fibres;
- disentangling of the wood/bast mixture into separate wood and bast components;
- flaking of the woody particles;
- drying and screening (as normal with any particle board process).

For these variable raw material compositions, a specialized firm has developed a machinery layout facilitating an excellent preparation of the raw material, thus granting a constant uniform board quality. It was found that with regard to its characteristics, e.g. specific weight, pH value, and buffer capacity, the blend is even more uniform than mixtures of various wood species. Consequently, the optimum determination of glue formulae and pressing conditions does not create any unusual problems.

Owing to the comparatively low specific weight of cotton stalks, the rather low density (approx. 620 kg/cbm for 16 mm boards) can be adjusted to obtain good technological data and an optimum compression ratio of particle mat to board. The pH value and the buffer capacity are in proper correlation (i.e. there are no counteracting ingredients). However, the pH value is in the basic range (above 7) contrary to most wood species (4.0 - 5.5). In order to obtain short pressing cycles a higher percentage of catalyst must be applied as additives.

The amount of wood in the cotton stalks is an excellent basic material for the production of particle boards. The average strength properties are comparable to or even exceeding those of usual wood particle boards at nearly the same solid resin contents and equal density. The rather high swelling values, however, require a higher percentage of wax. In order to make use of the proportion of bast fibre from cotton stalks in an economical way, it was taken into consideration to further process this material and to recycle it into the particle board production. This approach did not turn out to be satisfactory, but trials to produce cement-bonded panels from bast fibres were successful.

The production of cement-bonded boards requires considerably less effort for reprocessing the fibres and with this material the building industry finds a panel product which is resistant to fire, water and fungus.

Among the raw materials available from seasonal plants, cotton stalks represent an increasing share. Since the disposal of cotton stalks becomes more and more a problem (environmental pollution) a German manufacturer offers the facilities for most economical utilization of cotton stalks:

- production of particle boards from the wood/fibre proportion of cotton stalks;
- production of cement-bonded panels from the bast fibre proportion.

Depending upon the quantity of raw material available, the plant size requested and the application requirements for the boards, it is then possible to produce cement-bonded panels of the wood and bast proportion, or of the wood proportion only from cotton stalks.

Converting bagasse, cotton stalks and other annual plants into boards for the manufacture of prefab houses, partitions, furniture, etc. is of great importance for the national economy of most of the developing countries. In many cases these countries have a shortage of construction timber, or their precious hardwood species could better be exported to hard currency countries where they can attain high prices on the markets for wood oriented. products.

Coming back to the statement at the beginning of this paper why there are comparatively few board factories in the world utilizing annual plant wastes:

- In some cases the market showed just as much prejudice against boards from annual plants as there was in the beginning period of wood particle board versus solid core plywood (blockboard).
  A similar situation also occurred in Western Europe when flax-board was introduced, but this changed completely due to good quality.

- Extensive information and also educational instruction for the utilization, application, workability and machining, etc. undertaken by the producer and assisted by institutions, can do a lot against above-mentioned prejudice.

- In developing countries main reason is lack of initial funds for the comparatively high investments needed for the establishment of such an industry. Foreign Government Assistance Institutes and World Bank affiliates could eventually give a helping hand to local financing institutions.

- Feasibility studies made for those cases where excess of raw material was available indicated good economical results and short pay off time; also in cases of integration with sugar mills, cotton mills, etc. the outcomes are generally looking very promising.

  The unfamiliarity with the new products unfortunately has been responsible for plans often not being executed. The excess material with excellent properties still is shoveled into rivers or burnt up.

3. Conclusion

In time where environment problems are being discussed, savings on natural resources, waste utilization, low-cost housing for the millions that still have no decent shelter nor privacy, etc. Governments and Financial Institutions should be more encouraged to initiate the establishment of industries of the kind mentioned. Both, from technical as well as from economical points of view, specialized manufacturers can prove that there are great possibilities.

ANNEX 1

**Physical properties for boards based on fibrous materials of resin bonded boards in comparison to wood based boards (Test results of Bison Research + Development Laboratory)**

| Raw Material | Bagasse | Bagasse | Bagasse | | Groundnut shells 66% cotton stalks 34 % | Bagasse | | Cotton-Stalks | | Jute Rosalia | Coconut Fiber | | Alfagrass | Jute | Sunflower | Limba | Teak | Wood | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country of Origin | Indonesia | India | Cuba | | Nigeria | Cuba | | Mexico | | Indonesia | | | Marocco | | Turkey | Congo | India | DIN 68761* | |
| Density kg/m3 | 68o | 625 | 74o | 772 | 766 | 7o3 | 657 | 568 | 7oo | 625 | 746 | 82o | 6oo | 8oo | 674 | 68o | 568 | 45o 6 | 75o 13 |
| Thickness mm | 12 | 16 | 3,3 | 3,1 | 15.9 | 15,6 | 16,8 | 13,8 | 16,6 | 16 | 19,3 | 14,o | 5 | 4 | 16 | 16 | - | 13 | 2o |
| Modulus of Rupture, kp/cm2 | 275 | 227 | 244 | 26o | 178 | 281 | 255 | 198 | 32o | 259 | 214 | 226 | 15o | 3oo | 193 | 335 | 27o | 18o | 2oo |
| Internal Bond kp/cm2 | 4,2 | 5,2 | 7,3 | 7,1 | 4.5 | 5,8 | 5,2 | 3,8 | 7,3 | 6,4 | 6,o | 6,2 | 2,o | 4,o | 6,1 | 8,9 | 5,5 | 4,o | 3,5 |
| Swelling % (2 hrs) | 2,8 | 6,1 | 3,1 | 3,2 | 7.3 | 2,6 | 3,o | 1o,4 | 11,2 | 7,6 | 3,o | 5,6 | 5,5 | 4,5 | - | 5,9 | 2,5 | 6,o | |
| Swelling % (24 hrs) | 13,3 | - | - | - | 16.3 | - | 13.0 | 21,8 | 2o,o | 15,1 | 1o,9 | 14,9 | - | - | 23,8 | - | - | - | |
| Resin % | 8,5 | 8,5 | 12 | 12 +) | 9.3 | 8,5 +) | 8,5 +) | 9,5 | 1o | 8,5 | 12 | 12 | 12 | 12 | 3,5 | 9 | 8,5-9 | - | |

+) depithed bagasse

N.B.: All thin boards 3 up to 6 mm were made on continuous operating presses
All thicker boards on single-opening flat presses

*Compared to minimum requirements of German standard

**ANNEX 2**

**Test results of cement-bonded particle board based on annual plants residues in comparison to wood flake boards**

| Raw material | Bagasse | | | | | | | | | | Cotton stalks debarked | | Cotton stalk bast fibre | | 100 % rice husks | | 50% rice husks 50% spruce | | wood flakes (spruce) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Moisture content % | 113 | | | | 17 | | | | 110 | | 42 | | 42 | | 42 | | - | | 41 | 41 | 41 |
| Setting time days | 7 | | 28 | | 7 | | 28 | | 7 | 28 | 7 | 28 | 7 | 28 | 7 | 28 | 7 | 28 | 28 | 28 | 28 |
| Density kg/m$^3$ | 1570 | 1535 | 1407 | 1421 | 1470 | 1500 | 1467 | 1443 | 1470 | 1347 | 1452 | 1380 | - | 1255 | 1496 | 1420 | 1440 | 1390 | 1213 | 1110 | 953 |
| Board thickness mm | 10 | 16 | 10 | 16 | 10 | 16 | 10 | 16 | 10 | 10 | 9.3 | 9.3 | - | 10.3 | 10.2 | 10.0 | 10.3 | 10.2 | 15.2 | 15.2 | 15.1 |
| Modulus of rupture kp/cm$^2$ | 90 | 91 | 127 | 128 | 110 | 112 | 170 | 170 | 83 | 107 | 64 | 104 | - | 62 | 42 | 50 | 75 | 86 | 173 | 11.9 | 87 |
| Internal bond kp/cm$^2$ | 5.5 | 4.7 | 7.2 | 7.0 | 5.7 | 4.7 | 7.4 | 7.4 | 4.1 | 4.6 | 5.6 | 5.9 | - | 4.1 | 2.3 | 2.8 | 2.9 | 3.5 | 5.7 | 3.7 | 2.8 |
| Swelling % (2 hours) | 0.2 | 0.3 | 0.7 | 0.5 | 1.1 | 0.9 | 1.0 | 0.4 | 0.8 | 0.6 | 0.8 | 0.8 | - | 0.8 | 0.8 | 1.3 | 0.7 | 1.0 | 1.3 | 1.6 | 1.6 |
| Swelling % (24 hours) | 0.8 | 0.7 | 1.1 | 0.8 | 2.3 | 1.7 | 1.3 | 0.7 | 1.2 | 1.2 | 1.5 | 1.5 | - | 3.- | 1.5 | 1.9 | 1.3 | 1.6 | 1.6 | 2.0 | 2.6 |
| Rest moisture content % | - | - | - | - | - | - | - | - | - | - | 21.3 | 14.2 | - | 10.3 | 24 | 16 | 25 | 17 | 19.3 | 20.5 | 19.7 |

N.B.: All tests are based on a fibre:cement ratio 1:2.75
with the exception of the last 2 spruce flake tests which were done with a ratio
1:2 and 1:1.75

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