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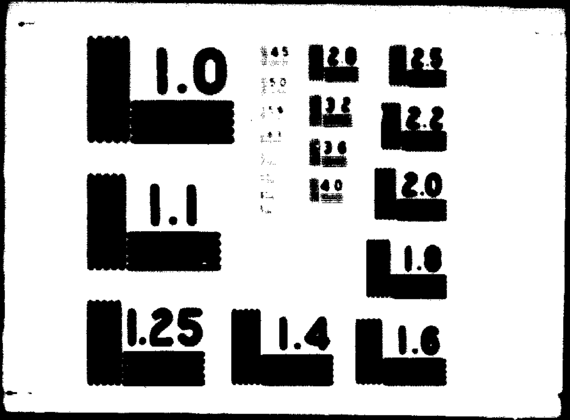

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Expert Working Group Meeting
on the Production of Panels
from Agricultural Wastes

Vienna, Austria, 14 - 18 December 1970

SOME EXPERIENCES IN RESEARCH AND MANUFACTURE OF PANELS FROM AGRICULTURAL WASTES AND NON-WOOD FIBROUS RAW MATERIALS IN CZECHOSLOVAKIA 1/

by

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SUMMARY

SOME EXPERIENCE IN RESEARCH AND MANUFACTURE OF PANELS FROM AGRICULTURAL WASTES AND NON-WOOD FIBROUS RAW MATERIALS IN CZECHOSLOVAKIA 1/

by

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The large, so far unexploited quantities of agricultural waste and of other non-wood plant resources represent a raw material reserve of increasing importance in view of the steadily growing consumption of panels manufactured from particles and fibres.

In Czechoslovakia due attention is being paid to the possibilities of industrial utilization of the raw materials mentioned, not only from the scientific and research point of view; some kinds of agricultural wastes are processed into boards on an industrial scale.

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The whole complex of research problems concerning the processing of wood and non-wood fibrous raw material into boards is being dealt with in the State Forest Products Research Institute at Bratislava, which has at its disposal well-equipped laboratories and pilot plants. The Institute has developed for instance a special patented manufacturing method for processing fibrous raw material into fibreboard by a dry process. The Designing and Engineering Organization LIGNOPROJEKT at Bratislava is experienced in planning and establishing manufacturing plants for the production of different types of panels.

Some 20 years ago the production of sandwich boards with a core made up from corn cobs and covered with veneer sheets was introduced; these boards have proved to be suitable for building purposes.

A favourable development shows the manufacturing of particle boards from flax and hemp shives attaining a yearly production figure of 60,000 m^3. The boards are successfully used for furniture production and a large proportion is being exported.

From other non-wood fibrous raw materials which have been studied, the following have to be mentioned: bagasse, cotton stalks, date palm waste, bamboo, papyrus, reeds and esparto. Chemical analyses of the raw materials and physical properties of boards manufactured are listed in tables. The research work for some of the raw materials was performed in the frame of feasibility studies worked out for agencies of the United Nations.

Both the research work and economic studies performed demonstrate that all raw materials mentioned can be processed into agglomerated boards. Their quality is of course in most cases lower than for similar boards manufactured from wood. The lower quality is to be sought in the morphological structure of non-wooden raw materials as well as in some specific chemical components which are not present in wood.

Nevertheless boards made from non-wwod fibrous raw materials may be of interest for those developing countries suffering from a shortage of wood. In spite of their lower values in physical properties, which in many cases do not reach the level required by world standards, such boards may find their economical use for building purposes, for fruit boxes etc.

Before establishing a plant for producing boards on the basis of the new raw materials, all the complexity of production and marketing problems has to be thoroughly evaluated. Due attention has to be given to the selection of the most suitable type of board and to the optimum capacity of the production line.

For promoting the utilization of the raw materials in question it is recommended to work out documentation outlining the most important technical and economical information for potential investors considering the erection of a production unit in developing countries. The proposed documentation should include:

- a brief description of the properties of the different types of boards including the respective samples;
- an outline of the potential uses of individual types of boards;
- a concise description of the technology;
- advice on the preliminary calculation of production costs;
- advice on carrying out a marketing study;
- concise outlines for sales promotion including quality control and technical instructions for further processing of agglomerated boards.

1. INTRODUCTION

The production of agglomerated particle and fibre boards shows in industrially developed countries an ever increasing trend, as may be seen from the FAO statistical figures (1). In developing countries the production of agglomerated boards is still in its preliminary stage, mainly because of the very limited marketing possibilities, the chief reason being the low level of industrial production as well as the low National Income.

Wood resources as the main raw material basis for agglomerated board manufacturing are unequally distributed in developing countries. In the tropical forests of South America and of Western Africa, huge reserves of wood are still available, although their exploitation is very often connected with difficult transport problems, not to mention the excessive diversity of wood species with various properties, which affect the processing technology. In arid and semi-arid zones, on the contrary, the wood resources are insufficient and not adequate to cover the needs of the population. In almost all developing as well as in many industrially developed countries considerable amounts of not yet exploited agricultural wastes (2) and non-wood plants (3) still exist, which as fibrous lignocellulosic raw materials can be processed under special conditions into agglomerated boards (4, 5) and hence substitute wood. Already in the past the problem of utilizing agricultural waste has attracted considerable attention in Czechoslovakia, in spite of the fact that the percentage of forests in this country is relatively high (34 per cent).

2. AGRICULTURAL WASTE

2.1 Corn cobs

Shortly after the end of the second World War the manufacture of sandwich boards was introduced, which were composed in principle of covering sheets of coniferous veneers and a core of maize cobs crosscut into equally long pieces. The outer frame of this core was made of coniferous sawnwood. The products of this type were trade-marked as LIKUS-boards and have been manufactured in several low capacity plants, the respective dimensions being 45.55 mm and 80 mm in thickness and 100 x 300 cm for width and length respectively (6).

NOTE: The figures in brackets refer to the bibliography.

For the manufacture of LIKUS-boards the air-dried maize cobs (up to 12 - 15 per cent moisture content) were crosscut by means of a semi-automatic multiple circular sawing device into exact lengths corresponding to the height of the LIKUS core. The crosscut maize pieces were afterwards laid in an upright position in the space of the wooden frame. The frame, after being filled, was covered by double cross-band veneer. The frame was then turned over 180° and the other side covered in the same way. Ureaformaldehyde resin was applied as glue, which was spread only onto the veneers and not towards the maize pieces. The prepared sets were afterwards pressed according to a method similar to that used for block boards, and finally dimension-sawn and sanded.

The LIKUS-boards were used as load-bearing elements for the building of stores and low-cost housing. They were used also as shuttering plates for concrete works. For these purposes the LIKUS-boards had satisfactory mechanical properties (bending strength without wooden frame approximately 80 kp/cm2 and the buckling strength 1.250 - 2.200 kg - depending on the thicknesses), as well as physical properties (water absorption after 24 hours of immersion was 98 per cent, swelling after 24 hours was 10 per cent, thermal conductivity, λ= 0,075 kcal/m/h/°C and sound insulation showed 30 db on an average). The production of LIKUS-boards, introduced in the period from 1950 to 1960 did not develop to a larger extent due to the lack of success in mechanizing the work of laying maize billets into the frames. It seems that this manufacturing process is still very ineffective as far as manual work is concerned.

2.2 Flax and hemp shives (7-11)

In Czechoslovakia the development of shive boards manufacturing was very favourable. Since 1959 three plants have been erected, two for flax and one for hemp shive processing. All three plants use the LINEX-VERKOR manufacturing method and are equipped with SIEMPELKAMP machines (7). At present the production of shive boards attains 60,000 m3, the thicknesses being from 9 to 45 mm and the width and length dimensions 1220 x 2440 mm. A certain proportion of the boards produced are surface-finished. In one of the plants, melamine impregnated papers are used for finishing especially densified boards. The shive boards produced are mostly exported (44 per cent) and the rest are used within the country (maily in furniture making). The plants for manufacturing flax shive boards are managed on an average with 17 per cent profit, the production of hempshive boards assures approximately a 25 per cent profit.

3. OTHER NON-WOOD FIBROUS RAW MATERIALS

Besides the above mentioned industrial production of boards on the basis of agricultural waste, the State Forest Products Research Institute in Bratislava, together with the Organization for Designing and Engineering (LIGNOPROJEKT) in Bratislava have already devoted themselves for many years to research work, respectively to the designing of particle and fibreboard manufacturing technologies on the basis of the above-mentioned waste and various other non-wood fibrous raw materials. The work orientated in this direction has been done partly at the request of our foreign trade enterprises, and partly at the direct order of interested foreign parties, and this to a considerable extent in the form of experts' activities for organisations of the United Nations such as UNIDO and FAO. The research institute mentioned has at its disposal all equipment necessary for laboratory research as well as for pilot plant verification of research results obtained in the field of particle board and fibreboard. The State Forest Products Research Institute (SDVU) has moreover a patented technological method for fibreboard manufacturing by dry processing, noted for its really progressive advantage that it does not necessitate glue, which is especially important for developing countries lacking a chemical industry and a synthetic resins manufacturing industry.

Among non-wood raw materials tested in the State Forest Products Research Institute, and evaluated in co-operation with LIGNOPROJEKT's experts the following may be mentioned.

3.1 Bagasse

This material is now under consideration for use in many developing countries. It is the most promising ligno-cellulosic raw material, the harvest of which surpasses in some developing countries the quantity of industrial wood produced. This waste is a result of sugar cane (Saccharum officinarum L.) processing, and consists partly of lignified cells and partly of parenchymatic pith. Its average fibre length ranges from 1.7 to 2 mm with a diameter of 20 μm, and so bagasse, in principle, fulfils the requirements for use in the manufacture of agglomerated boards as well as in manufacturing pulp and paper.

The content of parenchymatic pith has an unfavourable effect on the quality of the boards, because it decreases the value of the mechanical properties and therefore must be eliminated to the highest possible degree. From this point of view it is more advantageous to use the bagasse produced by the so-called diffusion process by which the bagasse is more thoroughly disintegrated and a relatively large part of pith is separated from the fibre. Bagasse resulting from the older method of extraction processing is coarser and therefore contains a bigger proportion of undesired pith (12 - 17 per cent). At the State Forest Products Research Institute in Bratislava, bagasse of Cuban origin was tested with the aim of determining its feasibility for use in particle and fibreboard manufacturing. The results obtained are given in Table 1 (Boards made from bagasse).

The particle boards produced were one-layer boards containing 8 per cent ureaformaldehyde glue and 0.8 per cent paraffin. The pressing cycle included 8 minutes at a temperature of 160°C, and the pressure applied at the laboratory press attained 16 kp/cm^2.

The fibreboards were produced by dry processing, following the SDVU patented process.

In connection with the problem of utilizing bagasse one of the authors of this report was entrusted by UNIDO with the evaluation of the possibilities of utilizing bagasse in Fiji for the production of particle boards.

3.2 <u>Cotton-stalks</u>

The cotton-tree (Gossypium) is a plant with a one-year vegetation cycle, the stalks of which are 1-2 cm thick and 1-1.3 m high. The weight of a dry plant is on an 80 g average. The stalk contains a considerably lignified part which is covered on the outside with a fibrous bark and includes in its centre the parenchymatic pith. After harvesting, the stalks are extracted from the earth and burned, partly to enable other products to be raised in the soil during the interim period, and partly also for the extermination of eventual insects, and diseases of the cotton plant. The world reserves of this raw material are very considerable, and are estimated at approximately 28 million tons (2,20,23).

In connection with verifying the machinery and equipment as well as with the LIGNOPROJEKT's experts' activities in Burundi under an agreement with UNIDO, the State Forest Products Research Institute in Bratislava has carried out testing of this raw material, partly on samples from USSR and partly from Burundi (See Table 2 Boards made from cotton stalks).

The chemical composition of cotton-tree stalks from Burundi is:

Humidity	5 %
Benzene alcohol extract	3.4 %
Cellulose	42.7 %
Lignin	25.1 %
Pentosans	12.8 %
Ash	2.33 %

The samples of fibreboard have been produced by the patented SDVU method, but in order to reach a sufficient bending strength, 1 per cent paraffin and 2 per cent phenol-formaldehyde resol have been added without any additional thermal treatment.

The tests have proved that the cotton-tree stalks are a suitable raw material for a one-layer particle board as well as for hard fibreboards manufactured by dry processing. The properties of the boards produced in the laboratory are qualitatively inferior if compared with boards manufactured from wood. In order to achieve mechanical properties corresponding to Czechoslovakian as well as to most international standards, it was necessary to increase the content of glue in the particle boards and to apply 2 per cent phenolic resin in the fibre boards, whereas using wood it is possible to reach similar values for fibreboard without resins.

As cotton-tree stalks have a considerable number of branches, and are therefore bulky goods, this raw material requires at harvesting, storing and desintegrating special arrangements which can be avoided when using wood as the technological raw material.

3.3 Palm-tree waste

In many developing countries with a shortage of wood, palm leaves and stems can be used for manufacturing agglomerated boards, but of course with certain reservations. There are different palm species which may be taken into account, mostly the coconut palm (Cocus nucifera), the wildly growing palm (Hyphaena borassus), and others. The best conditions for harvesting and concentrating palm waste seems to be found in the date-palm (Phoenix dactilifera L.), which is cultivated for its dates in big plantations in many Arab countries, especially in Iraq. The palm stems are not a very convenient raw material for manufacturing because they contain a high proportion of thin-walled vessels and parenchymatic cells, which on desintegrating are crushed into fines so that the yield of usable chips is very often less than 50 per cent of the original volume.

According to manufacturing results, palm leaves would seem to be a more appropriate variety of palm waste, yet fruit stems collected when harvesting dates are the most suitable raw material for processing.

In Iraq for instance, where there is practically no exploitation of wood for industrial purposes, and all saw wood as well as agglomerated boards are imported, attention is being given to utilizing the palm waste for manufacturing boards. In plantations of date palms, which are concentrated in particular regions around Baghdad and Basra where quantities of about 32 million stems are harvested annualy, the availability of palm waste is being estimated each year as up to 700,000 tons of dry material, as has been shown in a Feasibility Study prepared by LIGNOPROJEKT Bratislava for UNIDO in 1969 (21).

The State Forest Products Research Institute in Bratislava was already engaged in 1960 in a study on utilizing this waste for particle board manufacturing at the request of the Iraqui Date Association. A detailed project was elaborated, based on laboratory and pilot plant research, aimed at introducing the production of one-layer particle boards.

The properties of these boards are specified in Table No. 3 The Iraqui Government, nevertheless, later decided to manufacture hard fibreboards, because the demand for boards for the packaging of dates and for the building industry (doors, ceilings, partitions walls, etc.) was much more important than the need for particle boards for furniture making.

The State Forest Products Research Institute has also carried out laboratory tests on fibreboard manufacturing by the dry process; it was necessary to apply water-repellent additives (_ per cent paraffine) and 2.5 per cent phenolic resol in order to give sufficient strength to the boards.

1. The chemical composition of palm leaves is:

Humidity	9.6 %
Cellulose	29.4 %
Lignin	24.5 %
Pentosans	11.7 %
Ash	13.7 %

2. The chemical composition of palm fruit stems is:

Humidity	9.2 %
Cellulose	32.5 %
Lignin	18.8 %
Pentosans	15.0 %
Ash	5.7 %

The average length of fibres is: 1.14 - 1.35 mm.

Hence it appears that both particle board (with 10 per cent glue) and fibreboard produced from palm waste - assuming the same production conditions apply - show in some properties lower figures if compared with similar boards manufactured from wood; nevertheless their quality may be considered as sufficient for packaging purposes and for various uses in the building industry.

3.4 Bamboo

This raw material includes different types of cultivated, but also of wild-growing plants, which grow in quantities of 2 - 5 t/ha/year, and are harvested usually at intervals of 2 - 4 years. Besides its utilisation for a large variety of uses by the native population, bamboo can be very well converted industrially due to the remarkable length of its elementary fibres (2.5 - 3.4 mm), which equals the fibre length of temperate zone conifers. Already in 1960/61 large laboratory and operation tests were performed in the State Forest Products Research Institute in Bratislava, which proved the technical viability of bamboo conversion into particle boards. If compared with wood, the relatively high content of silicates in bamboo leads to quicker wear in knives during desintegrating operations (19). Table No. 4 (These boards had been made under laboratory conditions from bamboo of the varieties Phyllostachus species).

3.5 Papyrus and reeds

Papyrus (Cyperus antiquorum, Cyperus papyrus) and reeds (Phragmites communis, Arundo donax, and others) grow on the wide marshy banks of big rivers and lakes in many developing countries. Papyrus attains the height up to 3 m and has stalks of a typically triangular cross-section of 2-3 cm thickness. The length of the elementary fibres is about 1.2 mm. From 1 hectare it is possible to get 40 to 100 tons of organic fibrous material. In comparison with papyrus, the reeds as raw material for agglomerated boards have the advantage of a hollow stalk with a lower content of pith, furthermore the leaves have no other vegetation adhering to them as is the case with papyrus.

Following the preliminary experiments and tests as can be seen from the bibliography (20, 24, 25), the conversion of these raw materials into agglomerated boards can be considered as possible. With respect to the considerable length and shape of these grasses, they are very suitable for manufacturing building mats, with dimensions of 150 x 200 cm and 2 - 5 cm thick. They can be processed in whole lengths by simple machinery they are compressed and stitched with wires which have been either galvanised or protected in some other way against corrosion. The mats of this type are successfully used for house construction work, especially for walls, partitions, flooring pads and even as roofing material. When used in tropical countries, these mats are resistant against termites without any preservation having been carried out.

3.6 Esparto grass (Stipa tenacissima)

This grass species grows on an area of almost 8 million ha in the countries of the Maghreb. Provided adequate markets are ensured, it is possible to exploit esparto grass in quantities of about 600,000 t/year. The fibre of esparto is shorter (its length being 1.1 mm on an average), but very thin (9 µm) on account of some advantageous technical properties, esparto was especially used for the production of high-quality printing papers.

In the past esparto grass was exported to England, France and Spain in considerable amounts for processing into paper. After some improvements in technological procedures for processing cheaper broad-leaved species were introduced, esparto became a less attractive item for European paper mills, mainly for economic reasons. The countries of the Maghreb are therefore interested partly in their own production of pulp from esparto and partly in the possibilities of its utilization in the manufacturing of agglomerated boards. Harvesting esparto is namely in the high areas of the Atlas mountains a very important source of income for a large number of inhabitants of this infertile region, and presents a big social problem.

On the basis of a contract with UNIDO, LIGNOPROJEKT has studied the manufacturing possibilities of agglomerated boards from esparto in Algeria, Morocco, Tunisia and, consequently, samples of particle board and fibreboard have been produced and evaluated on a laboratory and pilot-plant scale. The properties of laboratory-made boards are given in Table 5.

The particle boards were prepared from chipped esparto, after eliminating the dust portion, in 3 different thicknesses using 11 per cent urea-formaldehyde and alternatively phenol-formaldehyde glue. The fibreboards were prepared by the wet and by the dry processes into compressed hardboards as well as thicker medium density hardboard.

As can be deduced from table 5 the particle boards manufactured from esparto do not satisfy the requirements of current standards as far as the physical and mechanical properties are concerned, when compared with the properties of particle boards made from wood.

The fibreboards made by the wet process show lower strength values, but the figures for water absorption and swelling were acceptable, because after disintegrating, the dust portion containing different waxes had not been separated.

The fibreboards made by the dry process reached a bending strength above 400 kp/cm^2 only when containing more than 2.5 per cent phenolic resin at a simultaneously higher density. The semihard fibreboards do not reach the strength values of particle boards of the same thickness, neither by the wet nor by the dry process.

The chemical analysis of esparto from the various Maghreb countries did not show any substantial differences. The composition is as follows:

Humidity	5.5 %
Benzene alcohol extract	5.90 %
Cellulose	45.7 %
Pentosans	21.5 %
Lignin	21.2 %
Ash	2.37 %

4. CONCLUSIONS

The concise survey given herewith demonstrates that it is in principle possible to manufacture agglomerated boards from almost all agricultural wastes and non-wooden fibrous raw materials. Though it is necessary to state that these raw materials are in most cases morphologically not as favourable for manufacturing agglomerated boards as wood. They contain, in general, a substantially higher portion of thin-walled parenchymatic cells, which during mechanical converting are to a large extent crushed into dust, which means a substantial decrease in yield. As long as these cells remain with the particles or fibers determined for agglomeration they clearly decrease the strength of the final product.

Many raw materials contain a relatively high quantity of silicate and waxes, which influence the technological process. For reaching values of physical properties usual for boards based on wood, it is very often necessary to increase the content of glue used, respectively to increase the density of the boards. Measures of this type cancel-out to some extent the advantages due to the lower purchase price for agriculture waste. Besides this, agricultural waste is a raw material which is available seasonally and therefore requires a storing of reserves at least for some months. The storage area has to be roofed over to avoid microbiological degradation which takes place in humid piles of waste.

In view of fire hazards the waste should be stored in small quantities at suitable intervals. Most of this waste has bulky character and must be pressed into bales to achieve a more effective utilization of the area when transporting and storing.

Many of the waste raw materials mentioned can only be manufactured into lower quality boards, which are to be used merely in the building industry. Though for building purposes boards with a certain resistance against humidity are preferred, this requires using a more expensive phenol-formaldehyde glue.

Due to limited sale possibilities on the home market and usually also on the export market, many developing countries are confined to erecting and managing only low-capacity plants, which operate less economically compared to the highly mechanized plants in industrially developed countries. Boards produced in developing countries can therefore hardly compete on world markets and their export is possible only in frame work of regional economic collaboration. Furthermore, these low-capacity plants do not solve the problem of utilizing the huge quantities of waste, since they can process only limited amounts.

The marketing possibilities are to a certain extent reduced by the fact that new raw materials are being used, while the consumer usually prefers already known and well proven products produced utilizing wood.

Glues and eventual pesticide additives represent a very important item in the production costs of agglomerated boards as in view of the climatic conditions in developing countries these often have to be imported in a powdered form to secure the conservation of their properties for sufficient long periods of storage. The powdered resins are more expensive in comparison to liquid glues, which in view of their limite storage time can be transported only for shorter distances.

Before introducing and putting into operation the manufacture of agglomerated boards on the basis of new raw materials, the complexity of production must be thoroughly analysed. From the point of view of marketing it is often questionable to produce an inferior product with the sole aim of utilizing certain amounts of wastes although the waste would be cheaper than wood.

For certain building purposes boards can be manufactured at a lower price and with less investment costs by using cement as a binding agent, which is at present available almost everywhere in sufficient quantities.

In connection with the aim of utilizing long-stalked plants e.g. reeds and papyrus, in developing countries, the simple technology of manufacturing mats stitched with wire or artificial fibre should be promoted. In combination with plaster, such panels facilitate the quick construction of housing, including walls and ceilings, and in the case of a superficially applied layer of bitumen, they can be used as roof covering materials as well.

5. RECOMMENDATIONS

Officials responsible for economic progress in developing countries and even experts - if not specialised in the matter of panel production - are in many cases provided with only very general and inaccurate information, which may have a rather confusing and misleading instead of clarifying influence on their viewpoints.

For promoting the utilization of agricultural waste and non-wood plants in developing countries, it seems to be very useful to grant the interested parties some documentation material from which they would be able to judge whether the proposed manufacturing of agglomerated boards is advantageous or not, taking mainly into consideration the given raw materials, different products and their potential uses and marketing.

The proposed documentation should include principally the following items:

1. Concise instructions for carrying out a marketing study and outlines for stating the optimum capacity of the envisaged plant.
2. Samples of different kinds of panels with a brief description of their properties and potential end-uses. The data compiled should serve as a basis for estimates of future consumption of specific assortments such as:
   - medium density particle boards for general use up to the world standards;
   - medium density particle boards especially produced for furniture making, having smooth surfaces and high values of tensile strength perpendicularly to the surface;
   - insulating and semi-hard particle boards for building purposes bonded with glue with a high resistance to humidity;
   - thin particle boards for packaging, wall linings, ceilings, eventually for shuttering;
   - particle boards with cement as a binding agent, for building purposes;
   - compressed hard fibreboards for general purposes;
   - semi-hard fibreboards for construction purposes (furniture and building industry);
   - insulating fibreboards, for thermal and sound insulation purposes.
3. Concise description of the technology for the manufacture of particle board and fibreboard (wet and dry process) with a simple production scheme concerning the smallest but still profitably operating capacity, including a specification of main machinery and equipment necessary.
4. Examples of preliminary production cost calculations, e.g. for an annual production of:
   a) 10.000 m^3 of particle boards;
   b) 15.000 t of hard fibreboards;
   c) 100.000 m^2 of cement-bound particle boards.

   All calculations being carried out on the basis of world prices in US-dollars.
5. Concise outlines for sales promotion of produced agglomerated boards (quality control, instructions for further processing of agglomerated boards, etc.).

Table 1

Boards made from bagasse

Type of board	Thickness	Humidity	Density	Water absorption after 24 hours	Swelling after 24 h	Bending strength	Tensile strength perpendicular to the surface	Impact bending strength
	mm	%	g/cm^3	%	%	kp/cm^2	kp/cm^2	$kpcm/cm^2$
1. Particle board	14.5	7.0	0.63	-	7.6	215.0	6.2	—
2. Fibreboard by dry processing without adhesive	3.49	4.8	1.196	34.8	24.8	352.0	2.5	6.3
3. Fibreboard with 1 % paraffin	3.23	4.6	1.165	25.1	20.1	315.0	3.6	3.0
4. Fibreboard with 1 % paraffin and 2 % phenolic resin	3.08	3.7	1.239	18.1	14.1	532.0	11.7	6.3

Table 2

Boards made from cotton stalks

Type of board	Thickness	Humidity	Density	Water absorption after 24 hours	Swelling after 24 h	Bending strength	Tensile perpendicular to the plane	Impact bending strength
	mm	%	g/cm^3	%	%	kp/cm^2	kp/cm^2	$kpcm/cm^2$
1. Particle board (raw material from Burundi)	14.0	-	0.652	79.6 1/	23.2 1/	208	9.2	-
2. Fibreboard (raw material from USSR)	3.0	5.3	1.199	28.6	21.7	478	17.1	10.7

1/ Without being treated with water - repellent agents

Table 3

Boards made from date palm waste

Type of board	Thickness	Humidity	Density	Water absorption after 24 hours	Swelling after 24h	Bending strength	Tensile strength perpendicular to the surface	Impact bending strength
	mm	%	g/cm^3	%	%	kp/cm^2	kp/cm^2	$kpcm/cm^2$
Particle board (one layer)	15.0	9.0	0.586	99.5 1/	16.7 1/	146.5	7.3	-
Fibreboard	2.7	3.4	1.095	34.6	36.6	414.0	15.0	5.2

1/ Without being treated with water-repellent agents

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Fibreboard	2.7	3.4	1.095	34.6	36.6	414.0	15.0	5.2

1/ Without being treated with water-repellent agents

Table 4

Boards made from bamboo

Type of board	Thickness	Density	Water absorption after 24 hours	Swelling after 24 h	Bending strength	Tensile strength perpendicular to the surface	Content of urea formaldehyde adhesive
	mm	g/cm^3	%	%	kp/cm^2	kp/cm^2	%
Particle board (one layer)	6	0.63	73.4	18.3	164.7	5.8	10
Particle board (one layer)	6	0.68	65.8	19.8	212.4	7.7	10
Particle board (one layer)	15.1	0.623	37.9	8.7	150.4	6.8	8
Particle board (one layer)	15.2	0.698	39.5	14.0	220.6	8.0	8

Table 5

Properties of boards produced from esparto grass (laboratory results)

Type of board	Parafine content	Adhesive content	Thickness	Moisture content	Density	Water absorption after 24 h	Swelling after 24 h	Bending strength	Tensile strength surface	Modulus of elasticity	Impact strength	Swelling after 2 h in boiling water
	%	%	mm	%	gr/cm³	%	%	kp/cm²	kp/cm²	kp/cm²	kp m/m²	%
Particle board	1	11,UP	4	8.3	0.821	64.9	38.4	152	2.3	-	-	-
	1	11,PF	4	8.2	0.868	-	-	207.4	4.2	21.670	-	6.2
	1	11,UP	15	6.9	0.836	38.7	22.1	153.2	1.7	12.900	0.097	-
	1	11,PF	15	6.1	0.828	-	-	214.7	1.5	18.000	0.169	49.9
	1	11,UP	20	6.8	0.663	83.5	26.3	64.8	0.9	7.640	0.562	-
Fibre-board wet process		0	3.3	-	0.907	21.3	11.2	260	6.5	13.500	0.141	-
		2 PF	3.3	-	1.017	16.6	8.6	336	7.6	21.370	0.159	-
		0	16	-	0.701	14.5	3.5	73	2.8	8.030	0.170	-
		2 PF	16	-	0.735	14.2	2.9	105	3.4	10.420	0.179	-
		0	22	-	0.626	14.7	3.2	65	1.6	5.320	0.152	-
		2,PF	22	-	0.613	12.7	2.6	71	2.6	5.360	0.156	-
Fibre board dry process	1	0	2.6	9.5	1.219	25.3	26.8	338	9.5	-	0.102	-
	1	2,PF	2.98	6.8	1.198	24.7	25.3	351	10.6	-	0.141	-
		2,PF	2.7	3.4	1.228	25.7	23.2	491	18	-	0.092	-
	1	3,PF	3.16	3.2	1.249	18.7	15.1	526	20.5	-	0.056	-
	1	12,PF	2.2	6.4	1.180	15.7	9.7	561	22.8	-	0.082	-
	1	10,PF	15	6.8	0.552	90.6	20.5	15	-	-	0.060	-
	1	10,PF	21.2	6.8	0.525	123.1	19.3	19.2	-	-	0.164	-

UF = urea formaldehyde
PF = phenol formaldehyde

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