EC FOREST PROJECT

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INNOVATION IN THE CHESTNUT TIMBER PROCESSING

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TASK F
Final Technical Report

"Laboratory tests and industrial trials on Chestnut Laminated Veneer Lumber (LVL) and Chestnut Thick Sliced Veneer (TSV)"

With contributions of:

02- CNR/Istituto per la Ricerca sul Legno, Firenze (Italy)

06 - Istituto di Assestamento e Tecnologia Forestale, Firenze (Italy)

07 - Dipartimento di Agronomia, Selvicoltura e Gestione del Territorio, Torino (Italy)

09 - Laboratoire de Mécanique et Génie Civil, Montpellier (France)

10 - ESSTIB, Nancy (France)

13 - Compensati Toro S.p.A., Azeglio (Italy)

Task Leader: 09 - Laboratoire de Mécanique et Génie Civil, Montpellier (France)

TASK F - Laboratory tests and industrial trials on Chestnut Laminated Veneer Lumber and Chestnut Thick Sliced Veneer

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Participant 09 - Laboratoire de Mécanique et Génie Civil, Montpellier (France): Task Leader, Responsible for Sub Task F1 (LVL) and Principal Partner in Sub Task F2 (TSV).

Participant 07 - Dipartimento di Agronomia, Selvicoltura e Gestione del Territorio, Torino (Italy): Responsible for Sub Task F2 (TSV) and Principal Partner in Sub Task F1 (LVL).

Participant 13 - Compensati Toro S.p.A., Azeglio (Italy): Industrial Principal Partner in Sub Task F1 (LVL).

We also would like to give the following Partners appropriate credit for their valuable help in terms of raw material supply, special laboratory testing execution, industrial manufacturing, etc. :

S.I.L.D. S.p.A., Dronero (Italy)
Participant 02 - CNR/Istituto per la Ricerca sul Legno, Firenze (Italy)
Participant 06 - Istituto di Assestamento e Tecnologia Forestale, Firenze (Italy)
Participant 10 - ESSTIB, Nancy (France).

1 INTRODUCTION **[Teams involved: 07,09,13]** (team writing: 07,09)

The task was dedicated to production and use through innovative methods and/or products, of chestnut veneers obtained both by peeling for laminated veneer lumber (LVL) manufacture or by slicing for parquet manufacture (thick sliced veneer, TSV).

1.1 Aims

Chestnut wood is seldom sliced for decorative veneer because of the scarcity of high diameter sound trees, but is not used a t all today for rotary peeling. On the other hand, sawn chestnut friezes are commonly used in France, for example in the manufacture of composite parquets. Chestnut wood is well known in many southern European regions where there was a long tradition of chestnut furniture, carpentry, joinery, posts, poles etc.. Having a very low proportion of sapwood even at small diameter, it is a highly naturally insect resistant wood. So it can be used safely without treatments hazardous for the environment.

The main problem today is to manufacture good quality semi products for industry using the small diameter trees produced by the hundred thousand hectares of chestnut coppices. Rotary peeling and laminated veneer lumber offer a new opportunity to answer to this challenge for a significant part of the potential harvest. New thick slicing technologies (2 to 6 thick veneers) seems also very promising for the production of hardwood friezes for parquetry with a better yield, because the importance of sawdust loses is a major drawback for thin sawn pieces.

The aim of this task was then :

(i) to study the technical feasibility of rotary peeling of small logs of chestnut from coppices;
(ii) to study the technical feasibility of LVL production and to assess the quality of this new product;
(iii) to study the technical feasibility of thick slicing of chestnut and of parquetry manufacturing from these veneers;
(iv) to examine the yield and the economic aspects of these new technologies in order to focus on the weak points needing more investigation in the future in case of real opportunity.

1.2 Background information

1.2.1 Rotary peeling

Rotary veneer cutting of wood has been studied in many countries since some 50 years, showing that a lot of problems dealing with preliminary log treatments (steaming or boiling), machine settings and drying schedule should be solved. Some preliminary laboratory experiments (Movassaghi 1985) or industrial trials on big logs showed that classical good machine settings for medium density hardwoods proved satisfactory in the case of chestnut. But the problem of end checking, strongly amplified by the thermal treatment, appears to be of firsthand importance.

However, it is not yet quite clear if the veneer quality will be good enough at smaller diameters (or cutting radius) although the wood quality is not more affected by cambial age in the case of chestnut.

Major improvement in the study will be focused on thermal treatment and small diameter veneer cutting with also a special care in the machine settings and the drying schedule.

1.2.2 Chestnut LVL

LVL was first developed from softwood to produce structural timber of big dimensions (USA, Finland, Japan...). In the last 10 years, technical research was developed to assess the feasibility of hardwood LVL, sometimes for structural timber, but also more and more often for non structural uses (joinery, furniture...). The results are almost always technically good : the new product has properties quite similar to solid wood, but with an improved homogeneity and dimensional stability. But aesthetical problems, inherent to the process, remains a strong handicap and are a key to the economic profitability of such products on to-day market.

However, it clearly appears that rather small changes in process quality, aesthetical consumer behaviour, and market rules (higher and higher prices for good quality hardwood from natural forest ecosystems) will change the final judgement on the industrial opportunity to promote hardwood for non structural LVL.

Chestnut has not yet been studied for LVL, and the improvements aimed at in the task are mainly :

i - to prove the technical feasibility and assess the mechanical product quality;

ii - to produce a sufficient amount of non-structural LVL in order to promote the product, examine its weaknesses, and suggest the ways to upgrade quality and profitability of such a product;

iii - to give some information about the desirable log quality and the grading rules for harvest operations.

1.2.3 Thick slicing for parquet

The use of chestnut for composite parquet is well known and industry is able to glue and finish these kind of products, provided that it gets good quality chestnut friezes 3 to 6 mm thick.

It is not possible to obtain a sufficient quality with classical slicing, but a new technology called "oblique slicing" developed by the Japanese manufacturer MARUNAKA seems very promising. Research work published by Japanese teams proved that lathe checks strongly diminishes when the acute angle f between log movement (in the fibre direction) and the knife edge has values below 20°.

In Japan this technique is commonly used to produce very thin veneers, by analogy to microtome procedures. Some trials on high quality oak logs proved that it is possible to obtain very good quality veneer as thick as 6 mm, but the main problem is the twisting of the final slice, very important after cutting and free drying, and apparently even too high yet after various trials of flat drying under constraint.

As a result of this drawback, thick slicing of high quality hardwoods is still more or less experimental and the last industrial tests were not conclusive.

The improvement aimed at by the task are as follows :

i - to study the feasibility of thick slicing of small diameter chestnut trees for various veneer thicknesses;

ii - to examine the impact of different defects such as knots, ring shake, end checks, etc., on the final yield for parquet use;

iii - to analyse the twisting effect of the cutting process, and to propose drying schedules able to reduce this problem to acceptable levels;

iv - to examine the global feasibility of TSV for parquet use and to suggest solutions in the log selection for this use.

2 MATERIALS AND METHODS [Teams involved: 07,09,13] (team writing: 07,09)

2.1 Means used to achieve the aims [Teams involved: 07,09,13] (team writing: 07,09)

In order to study the improvements above mentioned, it is necessary to gather the abilities of different specialists in tree and wood quality, veneer cutting and drying, gluing and composite products manufacturing, mechanical and aesthetical assessment. It was also necessary to combine operations at the laboratory level and at the industry level, to produce a significant quantity of new products. And, finally, this task requires a strong, real co-operation between specialists on one hand, between academics and industrial staffs on the other.

2.1.1 Cooperation with industry [Teams involved: 07,09] (team writing: 07)

Rotary cutting tests and tests for the production of Laminated Veneer Lumber (LVL) were carried out at the firm Compensati Toro S.p.A., Azeglio (Province of Turin - Piedmont - Italy), Participant No. 13 in the research programme. At this firm, poplar, beech, and certain tropical species undergo veneer cutting for the manufacture of structural and non-structural plywood.

Tests on lengthwise slicing for producing sheets for prefinished parquet strips were carried out at the firm SILD S.p.A. of Dronero (Province of Cuneo - Piedmont - Italy). At the same factory also tests for vertical-frame multiblade sawing of chestnut wood were conducted with the purpose of producing the same type of sheets.

The composition of prefinished strips for parquet floors was carried out at the works of the firm Alpina S.r.l. of Magliano Alpi (Province of Cuneo), where a relatively recent technology, but one by now consolidated in this sector, was adopted. The innovative elements in this phase are represented by the kind of wood used, insofar as prefinished parquet made with chestnut veneer does not have a particularly wide market in Europe, and by the use of a poplar plywood as subfloor, insofar as subfloor panels made of other kinds of wood and ones having different characteristics are generally used.

2.1.2 Links between teams

Under the authority of the last leader, the links between the different teams involved (Torino Firenze and Montpellier Universities, Compensati Toro and associated industrial partners) were realized through three kind of cooperation :

- general task meetings with teams 06, 07, 09, 13, specially held at Firenze, Torino and Azeglio, or included in the general program meetings at Roma, Milano;
- specific task meeting about industrial operations between teams 07, 09, 13 held at Azeglio and Dronero, generally before or during common work in the manufactury;
- joint work operation in the factories, generally between teams 07, 09, 13 for preliminary rotary peeling or thick slicing tests, for assessing of the roundwood, for industrial rotary peeling and thick slicing and for manufactoring of LVL and parquet with TSV at Azeglio and Dronero.

These commun works involved both team leaders and scientists from the different teams. Between these meetings, material (bolts, veneers, LVL) and informations were exchanged by fax, email, or specific delivery.

2.1.3 Study of raw materials [Teams involved: 07,09,13] (team writing: 07)

For the purposes of the research, samples of roundwood deliberately chosen as representative of the wooden stock normally harvestable from chestnut coppice stands were taken. The timber used was obtained from mature coppices (with an average age of 30-40 years) in Southern France and Northern Italy.

2.1.3.1 Laminated Veneer Lumber (LVL)

For the veneer-cutting tests, three lots of timber of French origin and one of Italian origin were used. The French chestnut, cut into logs of varying length, was taken from two stands located in the Cévennes area, a few kilometres apart, and from one in Val d'Isère. The Italian timber, which was directly in the form of logs of the length of 1.50 m, was taken instead from a coppice stand more than 40 years old on the Serra d'Ivrea (Commune of Torrazzo Piemonte - Province of Turin).

Whatever the origin, the timber was selected without taking into account the presence or otherwise of ring shake or other flaws, but only on the basis of the following criteria of stem size and morphology:

- minimum stem diameter of 18 cm
- sufficiently regular geometrical shape.
-Since no dendrometric measurements or analyses of the stand where felling was carried out were made, no close correlation could be made between the quality of the material worked and the characteristics of the populations of origin. On the basis of the authors' experience, however, the material may be held to represent the ordinary average quality of aged chestnut coppices.

It was, on the other hand, possible to characterize the 4 lots of timber from the standpoints of stem morphology and wood quality, as follows:

Cévennes 1 presented stems of average size and morphology, rather dark wood with tight growth rings and frequent presence of ring shake;

Cévennes 2 provided tapered, heavily branched specimens, wood of a light shade, little presence of ring shake and growth rings that were on average wider than in the previous case (see Fig. F/1);

Val d'Isère provided material that was characterized by the markedly longer stems with usable trunk (up to 18 cm in diameter) of from 10 to 12 metres and absence of ring shake; on the other hand, the logs presented particularly developed diametral checks on the heads due to release of internal growth stresses;

Piedmont 1 furnished timber of larger diameter than that of the other sources, with a shape that was on average regular, of dark-shaded wood, with marked presence of ring shake (see Fig. F/2)

2.1.3.2 Thick Sliced Veneer (TSV) for prefinished composite parquet strips

For the slicing process and in order to obtain the finished product, two lots of chestnut timber from the populations referred to above were used.

The first lot consisted of 48 bolts, each of which 1.50 m long, taken from the uppermost ends of stems from the Cévennes 2 lot. The bolts had a mean diameter of 23.5 cm and were characterized by the presence of rather large and sound knots (in that they were taken from the tops of the stems), well-developed growth stress checks and scant presence of ring shake. The total volume amounted to 2.989 m^3.

The second lot, referred to as Piedmont 2 (see Fig. F/3), which had an overall volume of 6.721 m^3, was instead made up of 55 logs from a 34-year-old chestnut coppice located in the township of Vialfrè (Province of Turin). The average length of the logs was 4.5 m, and in some cases represented the base portion of the stem, whilst in others an intermediate portion. From a morphological standpoint, they presented a regular shape, with a minimum diameter (at the tip) of approximately 15 cm, with small, at times abundant, knots.

2.1.4 Laboratory and factory tests

2.1.4.1. Laboratory tests

2.1.4.1.1 Effect of steaming on cutting forces and veneer quality

Increasing the log temperature prior to cutting is commonly used to improve the cutting process through softening of the material. However, a too high temperature might also induce problems, either in the cutting process itself or due to the development of log end splitting. Therefore, as a preliminary, the effect of steaming on cutting conditions and on veneer quality on one side, on heart checking on the other, was investigated in the case of Chestnut crosscuts.

Steaming conditions were obtained by spreading water circulating continuously and thermally controlled. Steaming time was about 4 hours. Crosscut dimensions ensured that steaming temperature had been reached after a short time (less than 15 min.).

Rotary veneer cutting of matched sampled disks (20 mm thick) were performed on a special laboratory device at 3 temperatures : 20°C, 45°C, and 65°C, with a measure of the cutting forces (Fig. F/4). The following settings were used in this series of tests :

- constant angular speed 1 rotation / sec.

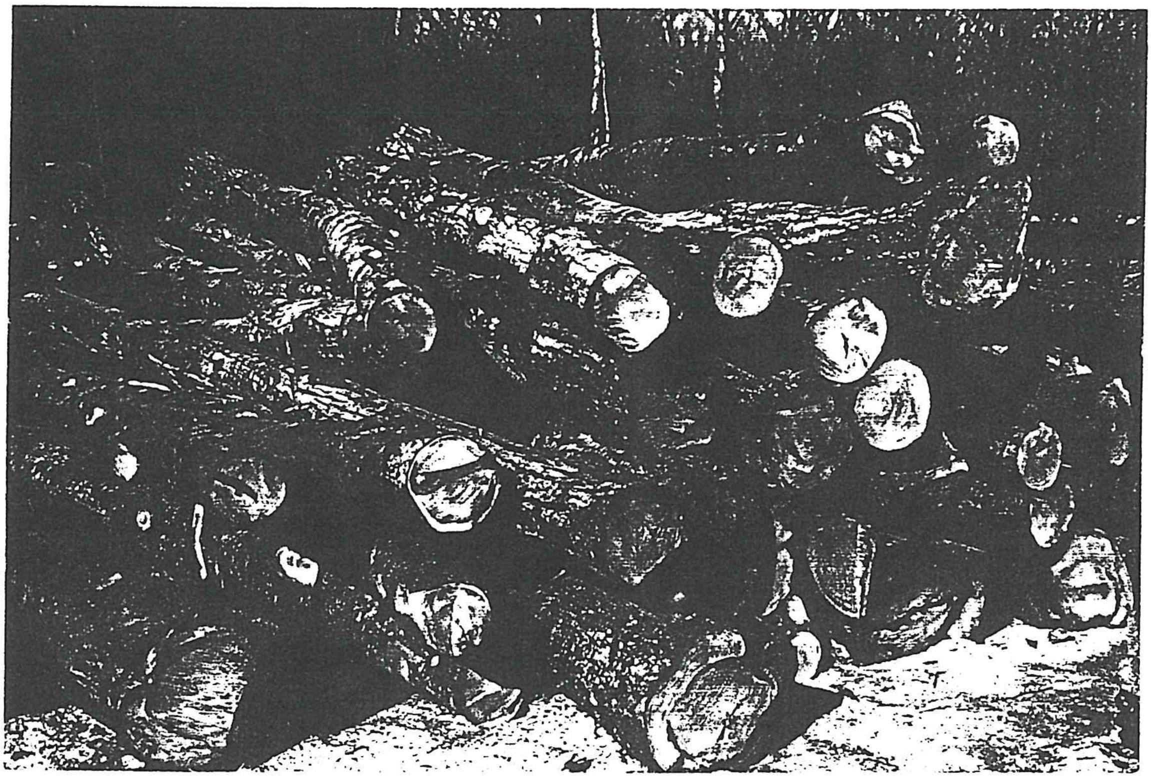


Figure F/1 - Provenance Cévennes 2

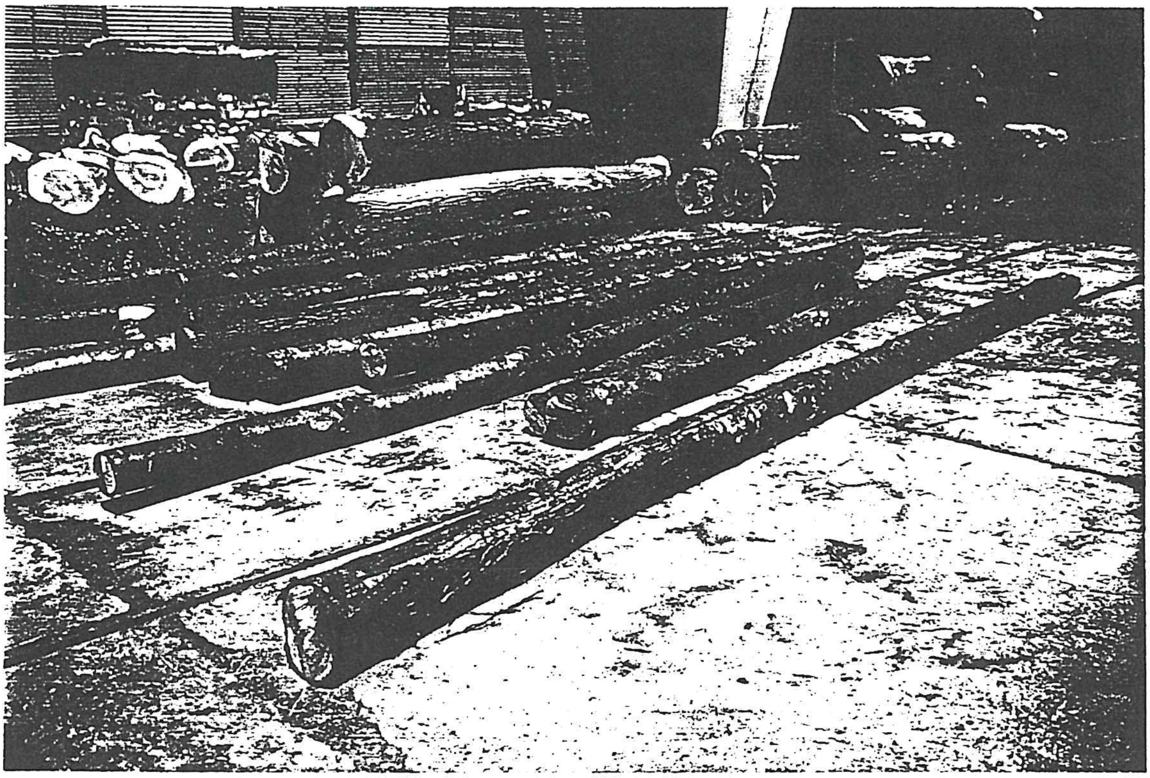
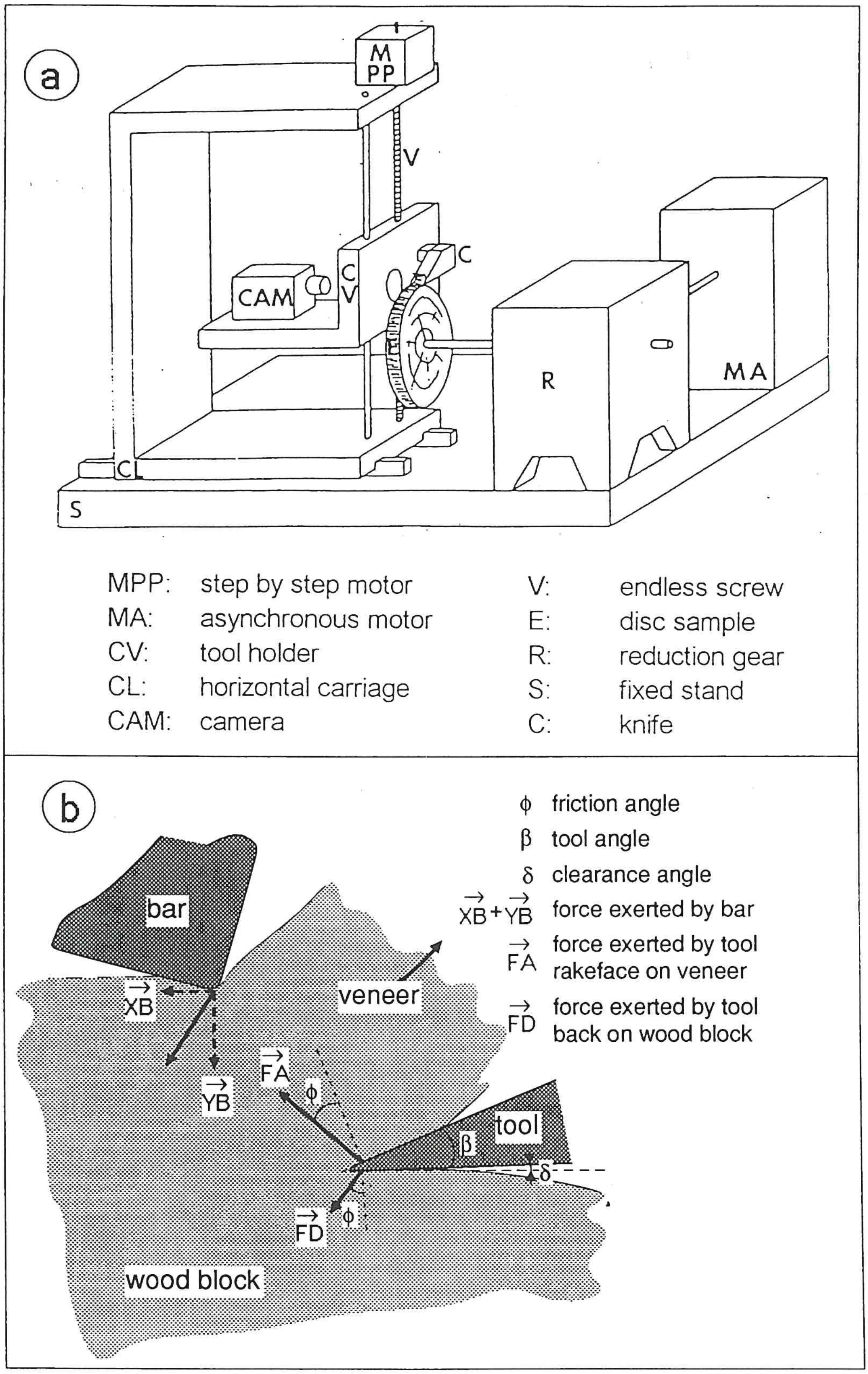


Figure F/2 - Provenance Piedmont 1

Figure F/3 - Provenance Piedmont 2



Working plan of the experimental lathe : (a) general set-up (pressure bar is not shown) ; (b) Description of the forces components.

Fig. F/4

- final diameter 44 mm
- tool angle 21°
- clearance angle 40'
- bar vertical position 0.25 mm
- bar compression ratio 13%
- incident angle of bar 15°
- bar angle 110°
- veneer thickness 14/10 mm

The importance of the cutting checks of the veneers was assessed by a double flexure test. The first test was done with the checks on the tensile side, the second test with the checks on the compressive side. The deflection of the veneer was measured for two fixed weight P1 and P2. The difference of deflection between them is noted FT in the first case (checks on the tensile side) and FC in the second case (checks on the compressive side). We always have FT > FC and :

$$DF = \frac{FT\text{-}FC}{FC}$$

was used as an index of the veneer quality (Fig. F/5). DF is an indirect measurement of the veneer checking resulting from the cutting process.

2.1.4.1.2 Hygrothermal Recovery

End splitting of the logs during steaming or boiling is known to be linked with the hygrothermal recovery of locked-in strains in the log. In order to study the influence of temperature on these phenomena, two tests were done with 2x24 matched wood disks 16 mm thick, one of them being machined on a small angular sector (Fg.F/6). These matched wood disks were them boiled for 30' at temperatures slowly growing by steps of 10°C between 20°C and 90°C. At each step, the closing of the sector's lips was measured on the machined sample, as well as the increase of heart check length on the other sample.

2.1.4.1.3 Specific drying of TSV

TSV manufacture give a final twisted veneer both at the wet and the dry state. The first step was the study and modelling of the global veneer deformation in order to propose drying schedules. After that, different kind of drying under restraint were tested as described below.

2.1.4.2. Factory tests

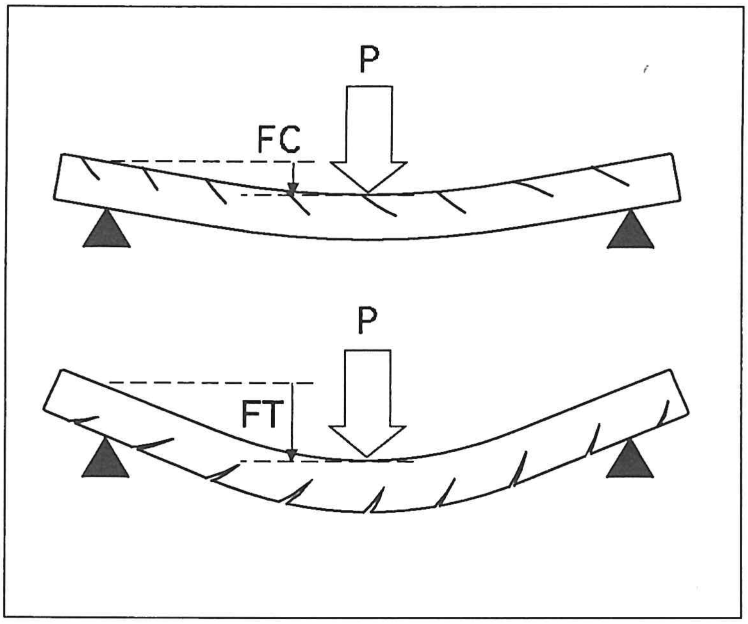
- Based on the laboratory tests, veneer peeling at different thicknesses between 1.6 to 3.2. mm were made on a small lot of logs in the two company (Azeglio). Manufacturing problems in peeling, veneer handling and veneer drying were observed. Selected veneer strips were used to qualify the veneers, first visually for the main defects; some transverse traction tests on veneer samples were done on a universal testing machine in the factory to estimate the tangential resistance of the veneer.
- TSV of different thicknesses (1, 2, 3, 4, 5, 6 mm) were performed on preliminary sampled logs on the Marunaka slicer in the SILD factory (Dronero). Manufacturing problems, veneer global deformation and visual assessment of veneer quality were noted.

2.2 Experimental **[Teams involved: 07,09,13]** (team writing: 07,09)

2.2.1 Subtask F1 - Laminated Veneer Lumber [Teams involved: 07,09,13] (team writing: 07,09)

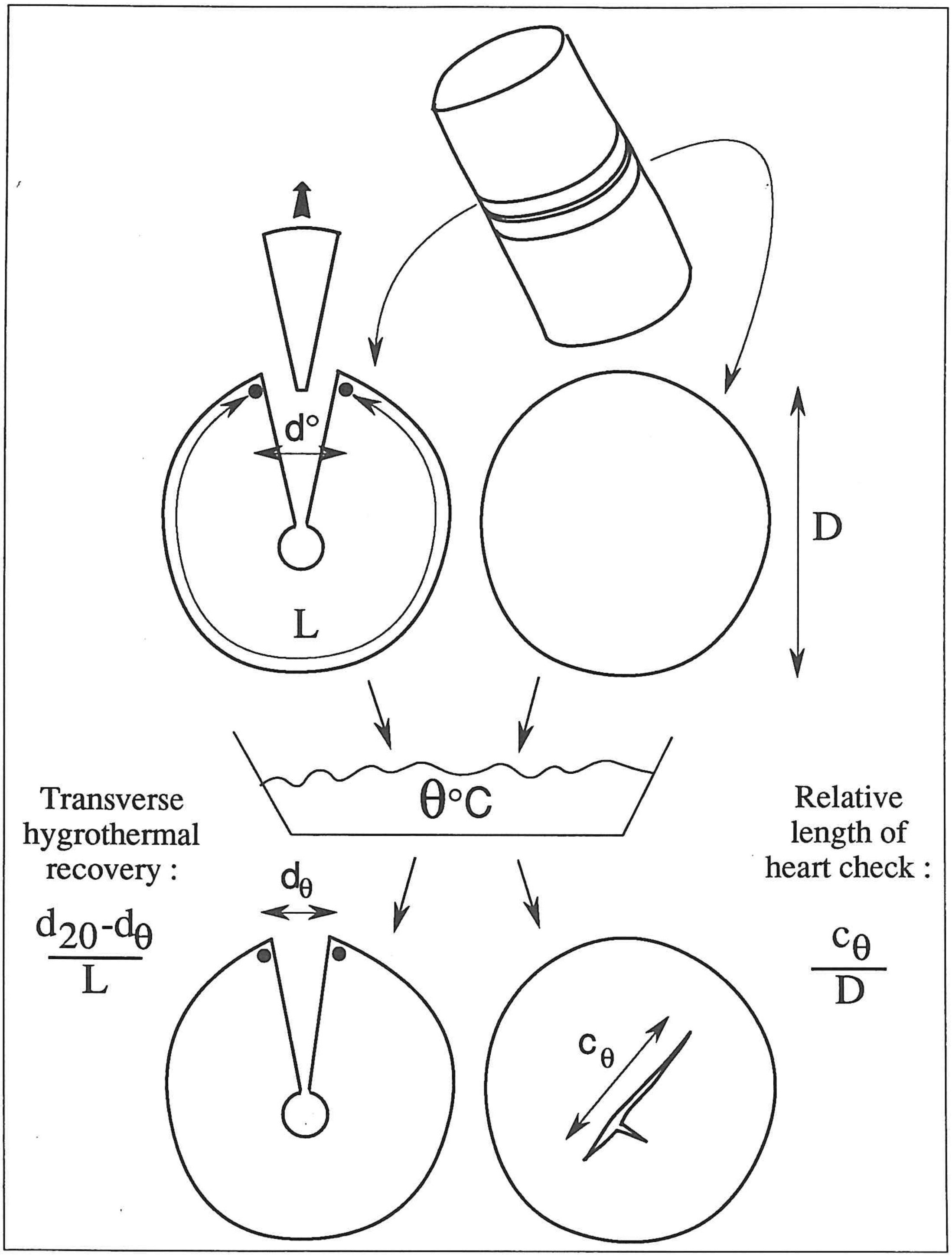
2.2.1.1 Assessing round wood **[Teams involved: 07,09,13]** (team writing: 07)

The timber for the research was obtained from mature coppices (with an average age of 30 - 40 years) in Southern France and Northern Italy. The French chestnut, in trunks of different



Measurement of veneer checking index

Fig. F/5



Simultaneous measurement of the temperature-induced heart checking
and the global hygrothermal recovery in a green crosscut

Fig. F/6

lengths, came from two stands located a few kilometres apart in the Cévennes area and from a population in Val d'Isère; the Italian timber, which was directly in the form of cross-cut bolts 1.50 m long, came instead from a coppice stand more than 40 years old on the Serra of Ivrea (Piedmont).

Whatever the provenance, the timber was selected regardless of ring shake or other flaws, but only on the basis of the following criteria of stem size and morphology:

- minimum stem diameter of 18 cm
- sufficiently regular geometrical shape.

Since the procedure followed for the material selection at the felling site was not known, and since no measurements were made on the plots where felling was carried out, no close correlation could be made between the material worked and the populations of provenance. On the basis of their experience, however, the authors reckon the material may represent the ordinary average quality of aged chestnut coppices.

It was moreover possible to characterise the 4 lots of timber from the standpoints of stem morphology and wood quality, as follows:

Cévennes 1 featured stems of average size and morphology, rather dark wood with tight growth rings and frequent presence of ring shake;
Cévennes 2 provided tapered, heavily branched specimens, wood of a light shade, little presence of ring shake and growth rings that were on average wider than in the previous case;
Isère provided material characterised by the markedly longer stems with usable trunk (up to 18 cm in diameter) from 10 to 12 metres and no ring shake; on the other hand, the trunks presented well-developed diametrical end checks due to release of internal growth stresses;
Piemonte 1 provided timber larger in diameter than that of the other sources, with a shape that was on average regular, dark-shaded wood, with marked presence of ring shake.

2.2.1.2 Preliminary tests (team involved 09,13) **(team writing 09)**

2.2.1.2.1 Influence of cutting radius (team involved 09)

Two Chestnut logs of rather different structure, free of main defects, were selected and made into successive crosscuts of thickness 20 mm. 10 crosscuts (2x5) were steam-heated as follows : 2 crosscuts at 20°C; 4 at 45°C; 4 at 65°C. Steaming and rotary veneer cutting were performed as detailed above. Cutting radius varied from 22 to 95 mm. In both trees the variation of ring width along the radius followed a very different pattern (Fig. F/7). Although the average veneer density, calculated on the 140 mm long bands, did not vary very much, due to the known drastic effect of density, this value was used as weighting factor for the force components.

Evolution of forces and veneer quality differed markedly between both trees, thus confirming that cutting radius, as a purely geometrical parameter, has almost no effect. The results of the cutting depends primarily on the evolution of wood structure from heart to periphery. For instance, in tree 1, forces increased toward heart because ring width increased also, resulting in higher veneer quality.

These results confirmed, again, that no basic problem hinders veneer cutting down to residual diameters of 5 cm.

2.2.1.2.2 Influence of steaming (team involved 09)

2.2.1.2.2.1 Cutting forces

In all cases cutting forces decreased with increasing temperature, as always mentioned in literature. This concerned all three forces FA, FD and YB, between 20° and 45°C, with a relative change of -15 to -50%. Between 45° and 65°, however, FA decreased of 10% and YB of 9% only; FD was almost constant or even tended to increase slightly, by 1%.

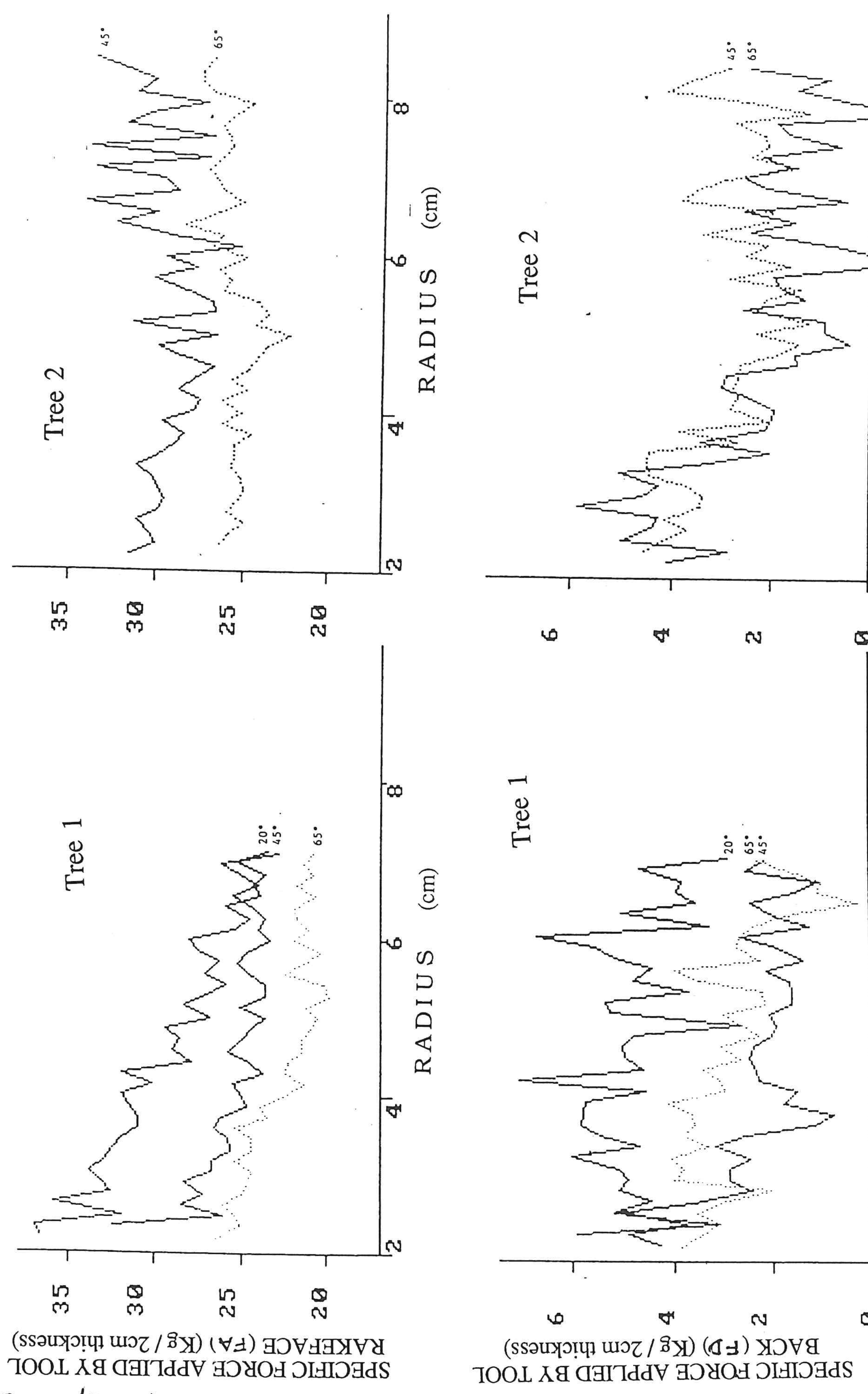


Fig. F/7a-b

Influence of cutting radius for two trees having a different ring width pattern.
(a) Specific force applied by tool rakeface (FA)
(b) Specific force applied by tool back (FD)

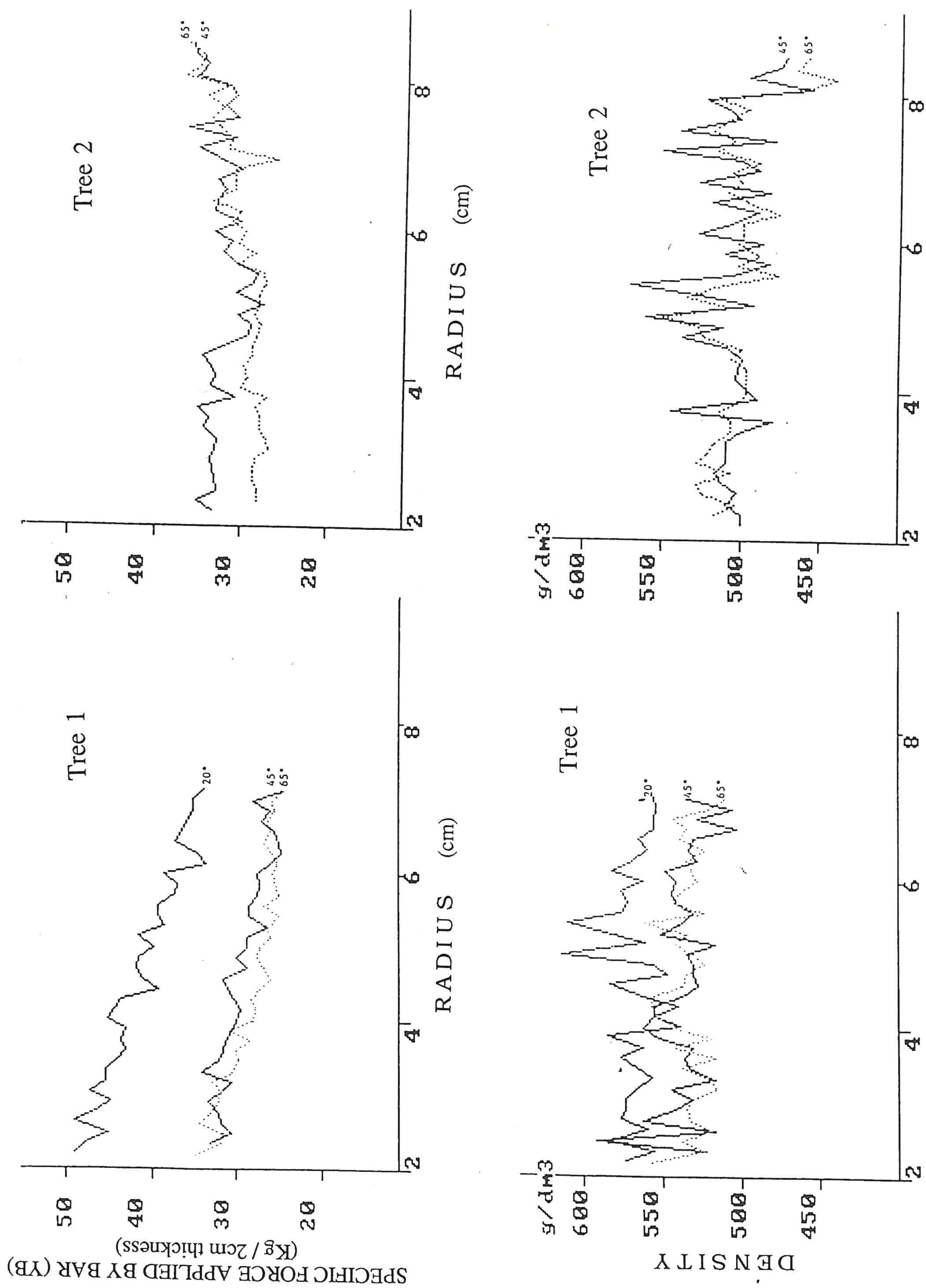


Fig. F/7 c-d

Influence of cutting radius for two trees having a different ring width pattern.

(c) Specific force applied by bar (YB)
(d) density

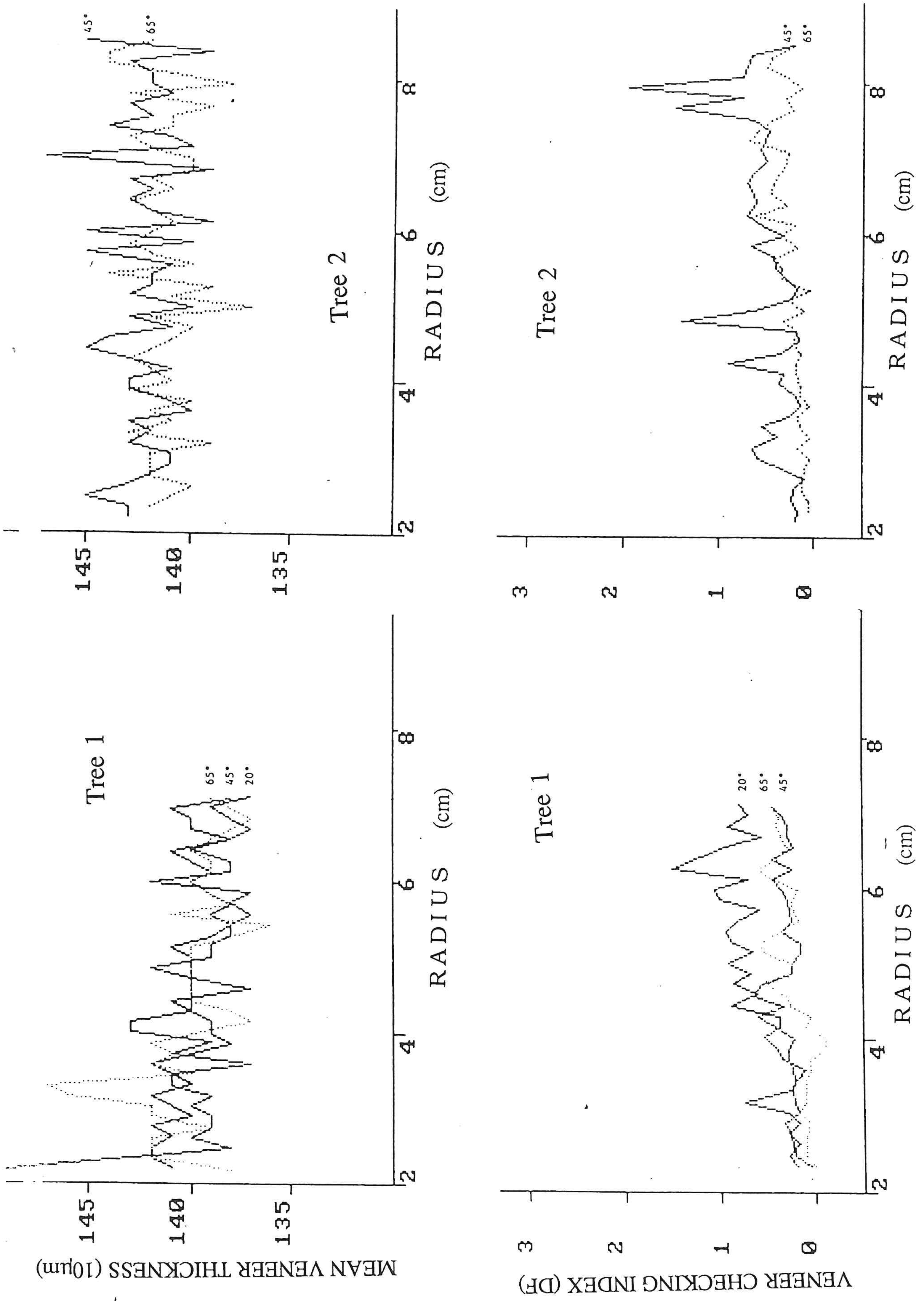


Fig. F/7 e-f

Influence of cutting radius for two trees having a different ring width pattern.

(e) Mean veneer thickness

(f) Veneer checking index (DF)

2.2.1.2.2.2 Veneer quality.

Apart from the increasingly dark colour of lateral faces subjected to the spreading of hot water, no noticeable influence of temperature on veneer colour was observed. Veneer quality, as quantified by the ratio DF, improved markedly between 20° and 45°C. But between 45° and 65°C, the difference was much less pronounced and depended on tests and position within the crosscut.

In average, veneer quality was excellent either at 45 or at 65°C.

2.2.1.2.2.3 Heart checking of crosscuts.

It has been shown that the main cause of steaming-induced log end splitting is a viscoelastic recovery process of the strains locked in the stem during growth. This was evidenced by the experiment described in 2.1.4.1.2. The following results were obtained (Fig. F/8):

- Compared to an initial (elastic) strain recovery of about 0.2% at room temperature, the heating from 20°C to 50°C added a mere 0.1%, but further heating increased drastically the recovery, up to 1% at 100°C.
- The growth of heart checking followed usually a similar pattern: it remained very limited under 50°C (<5% of disk radius), but increased quickly above 50°C (till 40% of disk radius at 100°C);
- For many disks, due to the apparition or development of ring shakes typical of chestnut, heart checks remained very small, and started to develop from 90°C only; in a few exceptional cases, shown separately on the Figure, the ring shaking was so heavy that no heart check developed at all.

The log-end checking depends on a combination of two factors : (a) a potential for strain recovery due to the pre-existing growth stress history, and (b) material properties, especially the strength across the grain, with the unusually low radial strength in some chestnuts resulting in ring shake occurrence. Interestingly, the recovery response, corresponding to (a), was found to be almost independent on the occurrence of ring shakes. Incidentally, the results obtained suggested that crack length measurement might provide with an indirect but convenient evaluation of the extent of ring shakes in a crosscut.

A systematic radial heart checking was observed for crosscuts steamed at 65°C. This kind of checks, often observed right after crosscutting of Chestnut, was very small in all other cases, with a total crack length lower than 1 cm. After steaming at 65°C these cracks always exceeded the diameter of the residual core (4 cm). In practice, it was finally concluded that chestnut can be boiled safely up to 50°C but further heating induces more and more extension of heart checking as temperature increases.

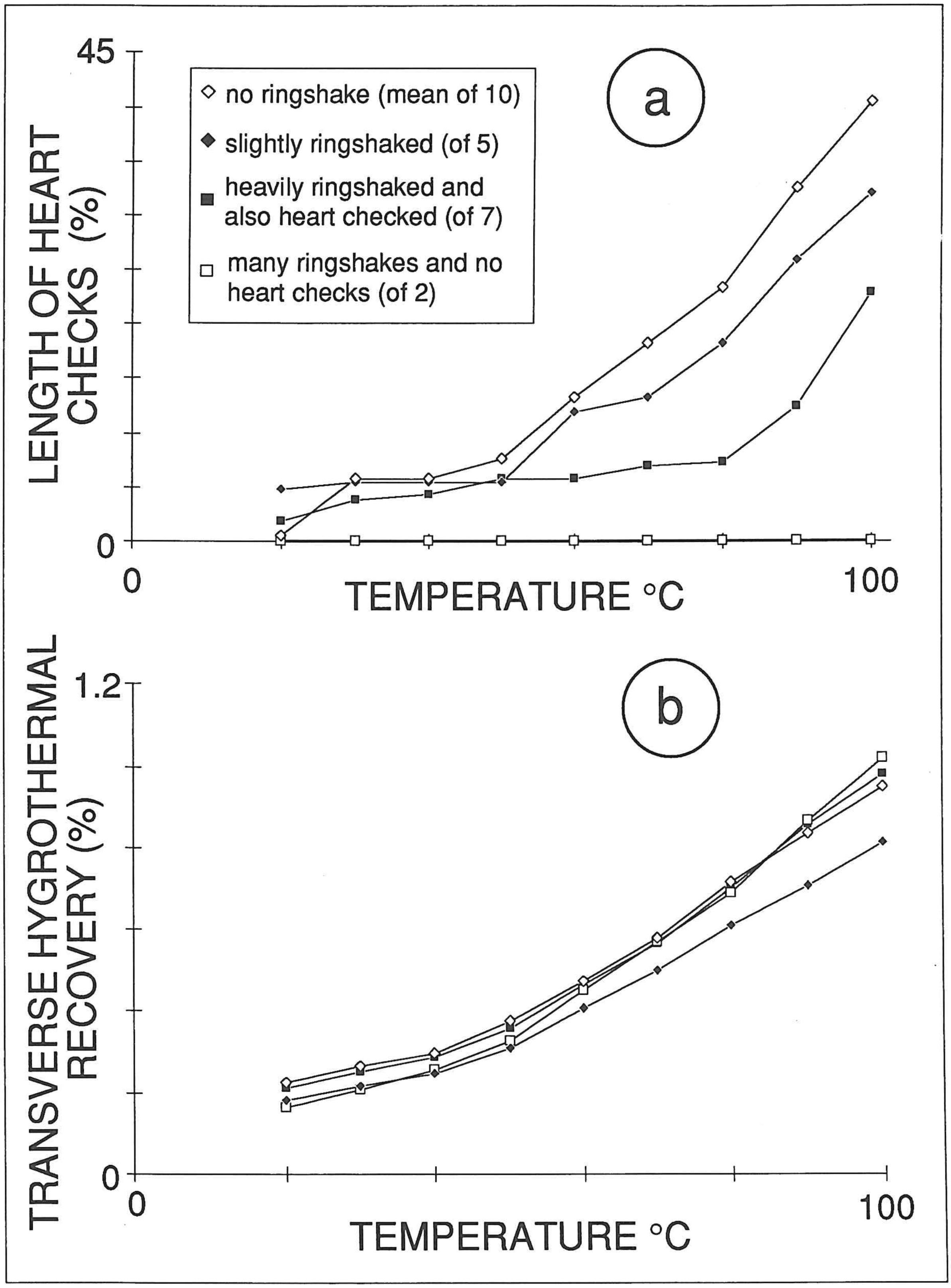
As a conclusion, it clearly appears that :

(i) boiling chestnut at temperature higher than 45°C is quite efficient to enhance veneer quality;
(ii) hygrothermal recovery in the case of chestnut leads to serious problems of end splitting, and this phenomenon is highly activated at temperatures above 55-60°C;
(iii) since enhancement of veneer quality, on the contrary, is much slower above 45°C, a good compromise for boiling temperature appears to be in the range of 50 to 55°C, and it is very important that the temperature never exceeds 60°C, since hygrothermal recovery at log ends, causing the splitting, can occur as rapidly as within 10 minutes.

2.2.1.2.3 Optimisation of veneer thickness (team involved 09,13)

Preliminary industrial tests were made in industry (table #1) in order :

(i) to assess the fitness of the proposed boiling and drying procedure;
(ii) to choose as a first approach, what seems to be the best veneer thickness for chestnut LVL manufacture.



Temperature dependance of (a) the extent of heart checking and (b) the global hygrothermal recovery in a green crosscut

Fig. F/8

Table #1 Preliminary veneer cutting tests (Compensati Toro, Italy)

Date	Thickness (mm)	Number of logs	temperature (°C)
January 1993	1.8	6	20
	1.8	8	45
	2.2	8	45
July 1993	2.6	30	55
	2.6	30	55
	2.6	30	55

It should be emphasised that, if necessary in the future, a more comprehensive optimisation technical research can be promoted on a much bigger set of bolts (thousands of bolts) to know the cost/benefit changes associated with small changes around the values used in this research (boiling temperature and duration, veneer thickness).

The boiling and machine settings were as follows:

- boiling temperature : 50 to 55°C (always < 60°C);
- boiling time : 8 hours;
- kind of treatment : complete immersion in hot water;
- vertical and horizontal opening : resp. 20% and 85% of veneer thickness.

the following precautions were taken :

- end checks were marked on one face of the bolt;
- rotary veneer operation was witnessed by one scientist making notes of occurring cutting problems;
- strips 20 cm wide were selected regularly from each bolt for visual observation and thickness measurement;
- tangential tensile tests were made on a selection of samples extracted from these strips.

An example of test sheet is shown on Fig.F/9

Main results were as follows:

- boiling procedure proved to be very successful with few growing of existing checks, and easy veneer cutting for all thicknesses;
- contrary to the laboratory peeling device, the industrial rotary peeling machine was not well matched to smaller diameter logs, and the machine vibrations, significant of low veneer quality, began to be rather high at small peeling radius;
- ring shakes, often very apparent at log end, caused sometimes serious cutting problems leading to higher core diameters; but many caused only minor veneer checking or peeling problems solved by stopping and restarting the machine;
- the chosen drying schedule proved to be satisfactory both for the final moisture content and for the low level of end splitting of chestnut veneer of sufficient thickness;
- although thin veneers (1.6, 1.8 mm) have a higher surface quality, they were rather fragile in the different process steps between peeling and use of LVL, particularly in the dry state;
- it was possible to get rather good veneer qualities at thicknesses as high as 3 mm (Table #2 and Fig. F/10), but surface qualities around knots began to get worse and worse for the higher thicknesses ;
- although a more complete technical and economical optimisation study would be needed in future, it was decided during a co-ordination meeting with the industrial manager, to choose a 2.6 mm veneer thickness for all industrial peeling operations.

Table #3 summarises the treatments and settings that were finally agreed upon.

Compensati TORO S.p.A. AZEGLIO (TO) - ITALY

SERVIZIO ASSICURAZIONE QUALITA'

LABORATORIO PROVE FISICO-MECCANICHE

Prova a vel. o inc. di carico costante

PMA 5 GALDABINI

Certificato Statistico

Trazione trasversale sfogliati - larghezza provini 50 mm
Forest 2: provenienza Cevenne

Risultati
(1/ 1)

Fm N	C.Tot mm	Rm N/mm²	F.Ult N	C.Ult mm	Data	Ora	Codice
5.38E+01	7.40E-01	3.20E-01	1.60E+01	8.80E-01	29-06-1993	10:35:37	LO-40
4.23E+01	5.00E-01	2.50E-01	2.75E+00	7.90E-01	29-06-1993	10:36:36	LO-40
2.85E+01	4.60E-01	1.70E-01	1.75E+00	8.20E-01	29-06-1993	10:49:52	LO-85
6.50E+01	8.60E-01	3.90E-01	5.00E+00	1.02E+00	29-06-1993	10:51:11	LO-85
9.10E+01	1.20E+00	5.50E-01	1.50E+00	1.36E+00	29-06-1993	10:53:02	LO-85
5.65E+01	9.50E-01	3.40E-01	2.50E+00	1.15E+00	29-06-1993	10:56:13	LO-46
4.80E+01	7.90E-01	2,90E-01	8.25E+00	1.04E+00	29-06-1993	10:58:55	LO-46
6.00E+00	4.40E-01	3.00E-02	4.00E+00	9.80E-01	29-06-1993	11:01:00	LO-35
2.30E+01	5.00E-01	1.30E-01	1.13E+01	7.50E-01	29-06-1993	11:02:38	LO-35
1.28E+01	2.40E-01	7.00E-02	5.00E-01	7.80E-01	29-06-1993	11:03:52	LO-35
3.75E+01	7.60E-01	2.70E-01	5.00E-01	9.40E-01	29-06-1993	11:25:25	LO-80
4.55E+01	8.40E-01	3.30E-01	2.50E-01	9.40E-01	29-06-1993	11:26:56	LO-80
4.45E+01	9.30E-01	3.20E-01	1.75E+00	1.22E+00	29-06-1993	11:28:15	LO-80
2.73E+01	3.00E-01	2.00E-01	5.00E-01	5.60E-01	29-06-1993	11:31:35	LO-52
2.00E+01	1.80E-01	1.40E-01	1.50E+00	4.40E-01	29-06-1993	11:32:33	LO-52
3.63E+01	7.40E-01	2.60E-01	1.25E+00	9.70E-01	29-06-1993	11:34:35	LO-52
7.00E+01	9.60E-01	5.10E-01	7.50E-01	1.12E+00	29-06-1993	11:36:03	LO-52
7.43E+01	9.40E-01	5.50E-01	1.40E+01	1.40E+00	29-06-1993	11:37:40	LO-52
4.20E+01	1.41E+00	3.10E-01	7.50E-01	2.07E+00	29-06-1993	16:05:48	LO-72
5.05E+01	6.70E-01	3.70E-01	1.25E+00	9.70E-01	29-06-1993	16:08:14	LO-72
8.50E+01	1.19E+00	6.20E-01	3.00E+00	1.80E+00	29-06-1993	16:10:31	LO-72
8.25E+00	5.60E-01	6.00E-02	2.50E-01	1.68E+00	29-06-1993	16:14:19	LO-72
2.15E+01	3.03E+00	1.50E-01	5.00E-01	4.04E+00	29-06-1993	16:22:26	LO-33
1.83E+01	6.00E-01	1.30E-01	2.50E+00	8.70E-01	29-06-1993	16:25:19	LO-33
6.60E+01	1.30E+00	4.80E-01	1.75E+00	1.59E+00	29-06-1993	16:27:58	LO-33
4.95E+01	9.40E-01	3.60E-01	1.75E+00	1.09E+00	29-06-1993	16:29:07	LO-33

3.2 mm

2.6 mm

Data :29-06-1993 Ore :16:33:51 Operatore: Palladino

Table #2

F/19

e F

Compensati TORO S.p.A. AZEGLIO (TO) - ITALY

SERVIZIO ASSICURAZIONE QUALITA'

LABORATORIO PROVE FISICO-MECCANICHE

Prova a vel. o inc. di carico costante

PMA 5 GALDABINI

Certificato Statistico

Trazione trasversale sfogliati - larghezza provini 50 mm
Forest 2: provenienza Cevenne

Parametri di selezione risultati

Codice prova : LO-*
Data iniziale : 06-07-1992
Data finale : 29-06-1993
Tipo risultati: Con Superficie / Trazione

Record selezionati: 26

Statistiche

		Min.	Max.	Med.	σ	σ^2
Fm	N	6.00E+00	9.10E+01	4.32E+01	2.30E+01	5.30E+02
C.Tot	mm	1.80E-01	3.03E+00	8.47E-01	5.46E-01	2.98E-01
Rm	N/mm²	3.00E-02	6.20E-01	2.92E-01	1.60E-01	2.57E-02
F.Ult	N	2.50E-01	1.60E+01	3.30E+00	4.27E+00	1.82E+01
C.Ult	mm	4.40E-01	4.04E+00	1.20E+00	6.90E-01	4.76E-01

Parametri di confronto risultati

Min.			Max.
	Fm	N	
	C.Tot	mm	
	Rm	N/mm²	
	F.Ult	N	
	C.Ult	mm	

Fig. F/9

Compensati TORO S.p.A. AZEGLIO (TO) - ITALY

SERVIZIO ASSICURAZIONE QUALITA'

LABORATORIO PROVE FISICO-MECCANICHE

Prova a vel. o inc. di carico costante

PMA 5 GALDABINI

Statistica grafica

Trazione trasversale sfogliato - Forest 2: Cevennes

Parametri di selezione risultati

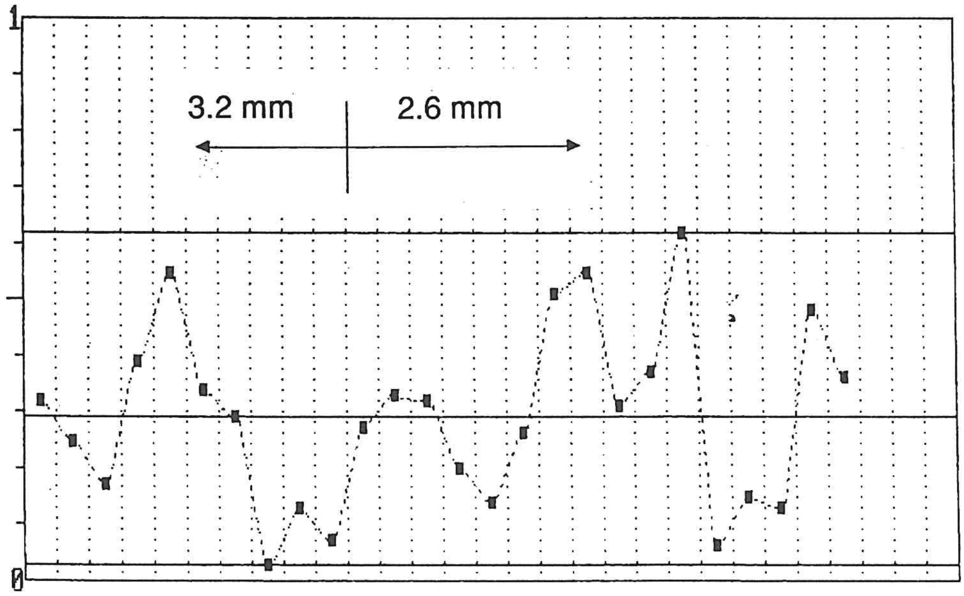
Codice prova : LO-*
Data iniziale : 06-07-1992
Data finale : 29-06-1993
Tipo risultati : Con Superficie / Trazione
Grandezza in esame : Sollecitazione di rottura (N/mm²)

Record selezionati : 26

Limiti impostati

Valore nominale : .29
Limite superiore : .62
Limite inferiore : .03

x : Campioni
y : Sollecitazione di rottura



Pag. 1 / 1.

Fig. F/10

Media : 2.92E-01 σ : 1.60E-01
Minimo : 3.00E-02 σ² : 2.57E-02
Massimo : 6.20E-01

F/21

Data :29-06-1993 Ore :16:40:30 Operatore: Palladino

Table #3 Final treatments and settings used for steaming, cutting and drying.

Lathe settings	veneer thickness :	2.6 mm
	lead (pressure bar) :	0.7 mm
	horizontal opening (pressure bar) :	0.4 mm
Steaming	type :	immersion in hot water
	water temperature :	50-55°C
	duration :	8 hours

2.2.1.3 Step by step process study ***[Teams involved: 07,09,13] (team writing: 07)***

The process of rotary cutting was carried out at the plywood company, Compensati Toro S.p.A, Azeglio (province of Turin, Piedmont) and consisted of the following stages:

1. cutting of the stems into bolts suitable for veneer making and estimate of cubic volume by sections, using the median section method (Heyer's formula);
2. steam treatment under the conditions described in Section 2.2.1.2;
3. barking- using a rotor debarking machine equipped with two knives and four scrapers;
4. rotary cutting of bolts, using a machine whose cutting device was suitably adjusted for chestnut, as described in Section 2.2.1.2. Immediately before rotary cutting of each bolt, the presence of serious ring shake, checks due to internal stress release involving at least 2/3 of the diameter and of rot was recorded. During processing, the diameter at rounding-off and the diameter of the residual core portion were also recorded;
5. subdivision of the continuous ribbon of veneer into sheets of 1.50 x 1.59 m and into strips, i.e., portions 1.50 m long and of varying width, and in any case narrower than 1.59 m. The latter are obtained by the clipping of the veneer ribbon with the purpose of eliminating any serious flaws that may be present in the wood. The minimum quality level accepted for the sheets and strips was that normally required for the internal layers of plywood made from hardwood. The presence of both adherent and loose knots was tolerated up to a diameter of 5 cm, as were also internal splits or fissuring along the edges of the sheet, and small portions of wood affected by rot and other flaws both natural or caused by the processing which were unlikely to seriously jeopardise the cohesion of the panel. A proportion of the sheets or strips proved, however, to be free from flaws and suitable for the manufacture of the outer, higher-quality layers of the plywood panels.
6. Drying of sheets and strips and conditioning at about 10% m.c.
7. Selection of the sheets in 4 quality grades.
8. Trimming of the sheets from the two lower quality grades in order to obtain strips clean from loosing knots, checks and rots; edging of the strips obtained during the rotary cutting.
9. Jointing of the strips to obtain "jointed" sheets with just the allowed defects.
10. Production of LVL panels of two different thickness and with different compositions.

On the basis of the dendrometric data and from the observations so far described, the veneer-cutting yield data were processed, and the influence of the defectiveness of the cross- cut stem bolts assessed. For computation of the yield, the dried sheets of different quality (1^, 2^ and "jointed") were considered as the end product of the veneer-cutting process, whereas the subsequent phases of production of the LVL panel and the corresponding waste of raw material caused by pressing of the panels and their trimming and sizing were not examined. As a general rule a hypothetical yield of panels with a final dimension of 140 x 140, for both production thicknesses, can be computed by allowing for the average material wasted as the result of pressing and sizing in the normal production of similar plywood panels.

2.2.1.4 Assessing products [team involved: 06] (writing: 06) [mn]

The assessment of LVL was performed through different tests, suitable to assess conveniently the product, as follows:

- basic mechanical tests on full-size squared pieces, based on well known standards, such as:
  - ⇒ bending strength and stiffness;
  - ⇒ shear modulus;
- basic mechanical tests on full-size panels, based on well known standards, such as:
  - ⇒ bending strength and stiffness;
- mechanical tests on glue lines through shear tests with an appropriopriate device, following a standard procedure, adapted for this purpose;
- dimensional stability tests, carried out in climatic chambers, following an experimental (no standardized) procedure.
- machine processing under controlled conditions on 27 mm thick panels (wear tests on tools with known properties).

2.2.1.4.1 Mechanical and physical properties [teams involved: 06] (writing: 06)

The mechanical and physical tests were based on the following standards:

- ISO 8375 Solid timber in structural sizes - Determination of some physical and mechanical properties;
- ISO 6238 Adhesives - Wood-to-wood adhesives bonds - Determination of shear strength by compression loading;
- UNI ISO 3130 Wood - Determination of moisture content for physical and mechanical tests;
- UNI ISO 3131 Wood - Determination of density for physical and mechanical tests;
- prEN 789:1992 - Timber structures - Testing of wood based panels for the determination of mechanical properties for structural purposes.

ISO 8375 for 56 mm squared cross-section pieces and prEN 789 for 27 mm thick panels were chosen even if these standards are conceived to be used for structural elements while Chestnut LVL is mainly conceived for joinery and furniture (non structural purposes);

> Note that Melamyne-Urea-Phormole glue should be suitable also for structural purposes.

Therefore these methods are respectively suitable for testing pieces (squared ones and panels) in full-size dimensions; due to the fact that LVL pieces contain inside also joint and defects scattered along the layers, the tests on small specimens have not been significant.

2.2.1.4.1.1 Bending and shear tests on 56 mm squared pieces [team: 06] (writing: 06)

Following ISO 8375 Standard, the tests specimens had a length of 20 times the depth of the nominal section; the square section was 56 by 56 mm and the length resulted thus 112 cm. The four points tests apparatus had a span of 18 times the nominal depth and the two loading points divided the span length into thirds; the deflection was measured at the centre of a central gauge length 5 times the nominal depth of the section (280 mm) with the deflectometer attached at the centre of the depth; small plates were inserted between the supports and the specimen in order to avoid indentations.
In **Table** /2.2.1.4/ **1** are given the formula for bending strength [1] and the bending modulus of elasticity [2]; the shear modulus [4] was computed through the apparent modulus of elasticity [3] for 56 mm squared pieces.

2.2.1.4.1.2 Glue bond tests on 56 mm squared pieces [teams involved: 06] (writing: 06)

The test procedure is described in ISO 6238 standard, which specifies a method for determining the shear strength of wood-to-wood adhesive bonds; being this method not conceived for LVL pieces, some procedures were modified mainly in the manufacturing the specimens; the specimens - loaded in compression - were machined so that a chosen glue line was tested in shear up to the failure; this purpose was reached through a shearing device containing a self-aligning seat to ensure uniform lateral distribution of the force. The results were expressed as stress at rupture in N/mm^2.

2.2.1.4.1.3 Bending tests on 27 mm panels [teams involved: 06] (writing: 06)

The tests specimens dimensions were: 27 mm thick, the full panel length (1450 mm) and, following prEN 789, 300 mm width; the four points tests apparatus had a the maximum span allowed (1100 mm), due to the large thickness of the panels (27 mm); the two loading points had 300 mm length; the deflection was measured at the centre on 250 mm central gauge length with a deflectometer attached at the centre of the depth. As well as for squared pieces, small plates were inserted between the supports and the specimen in order to avoid local indentations.
In **Table** /2.2.1.4/ **2** are given the formula for the bending bending strength [1], the moment capacity [2], the modulus of elasticity [3] and the bending stiffness [4] for 27 mm panels.

Test	Symbol	Formula	ref	Legenda
Bending strength	f_m	$\frac{a\,F_u}{2\,W}$	[1]	a distance between an inner load point and the nearest support (mm); F_u ultimate load (N); W section modulus (mm^3)
Bending Modulus of Elasticity	E_m	$\frac{a\,l^2\,\Delta F}{16\,I\,\Delta w}$	[2]	a distance between an inner load point and the nearest support (mm); l_1 gauge length (mm); ΔF increment of load below the proportional limit (N); I second moment of area section (mm^4); Δw deflection under the increment of load (mm)
Apparent Modulus of Elasticity	$E_{m,app}$	$\frac{l_1^3\,\Delta F}{48\,I\,\Delta w}$	[3]	l_1 span (mm); ΔF increment of load below the proportional limit (N); Δw deflection under the increment of load (mm); I second moment of area section (mm^4).
Shear modulus	G	$\frac{1{,}2\,h^2}{l_1^2\left(\frac{1}{E_{m,app}} - \frac{1}{E_m}\right)}$	[4]	h actual depth of the section (mm); l_1 span of [3] (mm); $E_{m,app}$ apparent modulus of elasticity, determined in [3] (N/mm^2); E_m modulus of elasticity in static bending for the same test specimen determined in [3].

Table /2.2.1.4/ 1 - *The equations for the computation of the main mechanical properties of 56 mm squared pieces following the ISO 8375 standard*

Test	Symbol	Formula	ref	Legenda
Bending strength	f_m	$\frac{l_2 F_u}{2 W}$	[1]	l_2 distance between an inner load point and the nearest support (mm); F_u ultimate load (N); W section modulus (mm^3)
Moment capacity	M_{max}	$\frac{l_2 F_u}{2}$	[2]	l_2 distance between an inner load point and the nearest support (mm); F_u ultimate load (N);
Bending Modulus of Elasticity	E_m	$\frac{(F_2 - F_1) l_1^2 l_2}{16(a_2 - a_1) I}$	[3]	F_1-F_2 increment of load on the straight line portion of the load-deflection curve a_2-a_1 increment of deflection corresponding to F_1-F_2 l_1 gauge length (mm); l_2 distance between an inner load point and the nearest support (mm); I second moment of area section (mm^4).
Bending Stiffness	$E_m I$	$\frac{(F_2 - F_1) l_1^2 l_2}{16(a_2 - a_1)}$	[4]	F_1-F_2 increment of load on the straight line portion of the load-deflection curve a_2-a_1 increment of deflection corresponding to F_1-F_2 l_1 gauge length (mm); l_2 distance between an inner load point and the nearest support (mm).

Table /2.2.1.4/ 2 - *The equations for the computation of the main mechanical properties of 27 mm panels following the prEN 789 standard*

2.2.1.4.2 Dimensional and shape stability [teams involved: 02, 06] (writing: 02, 06)
The dimensional stability of a specimen shall be here defined as the ability to minimise the deformations when the environmental conditions (mainly the relative humidity) are changing; this purpose was reached measuring on each specimen the relative position of a chosen point referred a reference line (for squared pieces) or to a reference plane (for 27 mm panels).

Another property (sometimes confused with that above described) required from any kind of panel is the flatness or planarity of its surfaces. This is because if the panel loses its original flatness, negative consequences arise on further processing (e.g. machining) or even on the final product. Obviously, the gravity of these consequences depends primarily on the magnitude of the deviation from planarity (distortion or deformation).

Normally, a panel may lose its flatness, during storage or in service, because of the influence of the environmental conditions (mainly temperature and relative humidity) to which the panel is exposed.
If these conditions are equal at the two sides of the panel (homogeneous conditions) but change with time, distortions may occur because of the anisotropic behaviour of wooden elements or layers in respect to moisture change as well as the imbalanced construction of the product. But other factors, such as localized defects or non homogeneity, may exert their influence.
On the contrary, if these conditions are different at the two sides (non homogeneous conditions) but constant with time, the panel is induced to change its moisture content and dimensions by a different amount on each side so that it assumes a curved shape (warping) while moisture gradients develop across the thickness of the panel.
From a general point of view, the ability to maintain the original shape (flatness) against the influence of the environment conditions, whatever homogeneous or non homogeneous, is termed *shape stability*.

As no european or international standard test method is available at present for determining this property, excepting (pr)EN 318:1990, which deals with change in dimension (but not in shape) of fiberboard, special test methods have been here proposed with the purpose of evaluating this property in each of the two described conditions (homogeneous and non homogeneous).

For panels, two different methodologies, based on homogeneous hygro-thermal conditions (12 specimens tested) and non- homogeneous ones (3 panels tested), were carried out respectively by team 06 and team 02. Below are reported the two different methods adopted.

2.2.1.4.2.1 Homogeneous environmental conditions [teams involved: 06] (writing: 06)
For checking the dimensional stability, so important for a final product continuously stressed by environmental change, such as the joinery, the shape was monitored under realistic consitions. This purpose was reached measuring the shape of the specimens conditioned to a theoretical 12% moisture content, reached by placing the specimens in a climatic chamber setted to 20°C and 65% RH, until the weight resulted stabilised; then it was conditioned to a theoretical 18% moisture content, reached by placing the specimens in a climatic chamber setted to 20°C and 80 % RH.
The shape of conditioned squared cross-section specimens was evaluated as bow, through the measurement of the relative position of a chosen point referred to an instrumented reference bar 1000 mm length. The bow was expressed as a ratio on the basis of 1000 mm length.
The shape of conditioned panels was evaluated as total deformation (mainly cup), through the measurement of the relative position of a chosen point - placed at the center of 600 by 600 mm (27 mm thick) specimens, referred to reference plane. Cup was expressed as a ratio on the basis of 1000 mm length.

2.2.1.4.2.2 Non-homogeneous environmental conditions [teams involved: 02] (writing: 02)

A special test method has been here proposed and experimented. The method is aimed at evaluating the maximum distortion of a panel when subjected to different constant exposure conditions at the two opposite sides of the panel. A detailed description of the method is given below.

Principle

The method is based on the measurement of the maximum distortion (depth of deflection or curvature) of a panel after exposure to different but constant climatic conditions at the two opposite sides of the panel.

Test equipment

The test equipment consisted of:

- a controlled climatic room at standard atmosphere (20°C temperature/65% relative humidity)
- plastic tanks of about 100 dm3 capacity
- demineralized water or oversaturated salt solutions to obtain the desired levels of relative humidity inside the tanks
- supports for sustaining the test specimens above the tanks (a three points support was found to be adequate)
- an adequate means for sealing the specimens to the tanks in order to create a closed volume inside, without affecting their movements (the test specimens must be free to move along all the period of observation)
- a rig provided with a dial gauge placed at mid length and two rounded supports at the ends.

Procedure

The test specimens, squared in shape, had the dimensions of 500 x 500 mm and were cut out of the panels with their edges parallel to those of the panel. One test specimen was cut for each composition.

Firstly, the test specimens were conditioned in standard atmosphere. Then each specimen was placed over a tank by means of a three point support and sealed to it. The tanks contained few liters of water (relative humidity about 100%).

A first set of measures was taken on the upper side of the specimen. Six measures in all (three for each direction) were taken according to Fig. F/11. A single measure (depth of deflection) represents the relative vertical displacement between a point at the centre and the straight line connecting the two end points of the reference span length (450 mm). The measures were then averaged in order to obtain the mean deflections along the longitudinal and transversal direction respectively.

The tanks with the test specimens sealed on them were kept for the entire period of observation inside the climatic chamber. The measurements were then repeated at gradually increasing

MEASURES IN MILLIMETRES

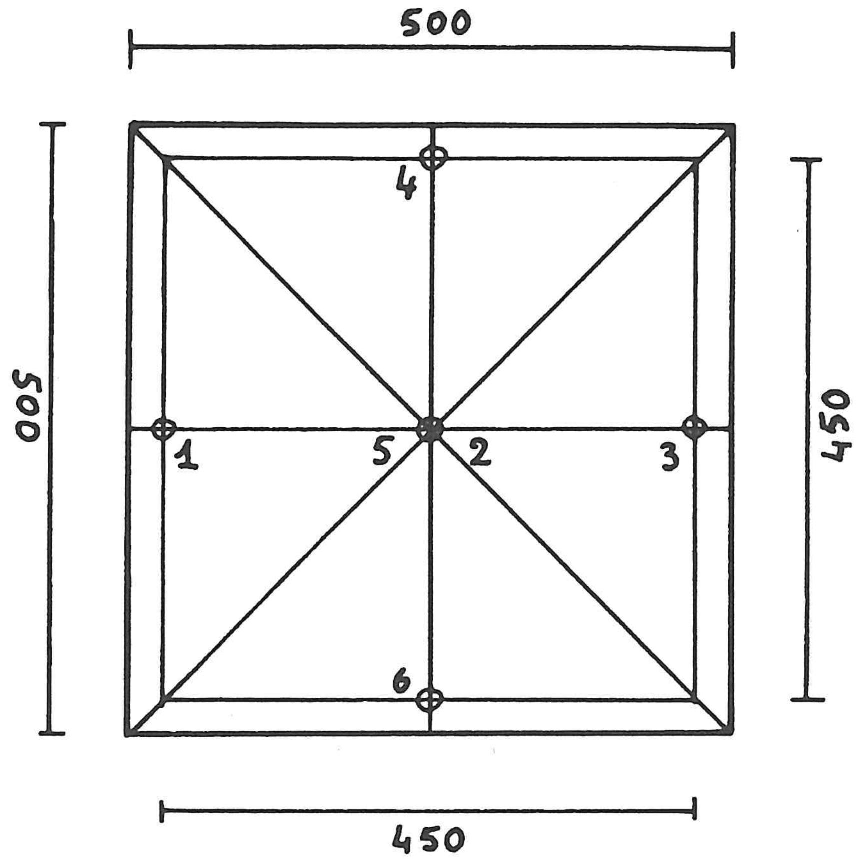


Fig. F/11

intervals, from one per day, at the beginning, to one per month. The period of observation was about 20 weeks.

Because of the higher humidity level inside the tanks, the curvature showed its concavity at the upper side of the test specimens.

In order to obtain information about the development of the moisture gradients across the thickness of the test pieces, three couple of stainless steel screw were inserted at different depths and used as fixed electrodes for the purpose of determining the moisture content by means of an electrical moisture meter.
The depts correspond to the centre points of three immaginary layers whose thickness was 1/3 of that of the panel. Each point was identified by a letter as follows:

A: center point of the lower layer
B: center point of the middle layer
C: centre point of the upper layer.

Furthermore, one 100 x 100 mm test piece per composition was placed inside the tank and fully exposed to the interior conditions. Each test piece was weighed and measured before and after the exposure period and then oven-dried and again weighed and measure.
These data were used to determine the changes in weight and dimensions at the end of the period of observation.

The depth of deflection for 1 m of span length and the radius of curvature were calculated from the experimetal data according to the following equations (VACEK et alii, 1989):

$$r = \frac{\Delta u^2 + (l/2)^2}{2000\ \Delta u} \qquad (1)$$

$$\Delta u_{1m} = \frac{500^2\ \Delta u}{\Delta u^2 + (l/2)^2} \qquad (2)$$

where

Δu: depth of deflection (mm)

r: radius of curvature (m)

l: reference span length (450 mm)

Δu_{1m}: depth of deflection based on 1 m metre span length

The deflection for 1 m length and the radius of curvature are useful parameters for comparing the results with other kind of panels. Moreover, radius of curvature, because of the fact that it does not refer to any refernce length, is very helpful for comparing panels with different dimensions.

2.2.1.4.3 Machinability: wear of tools [teams involved: 06] (writing: 06)

The measurement of the tool wear is the method for evaluating the machinability of the Chestnut 27 mm thick LVL panels. According to previous experiences performed at the Istituto di Assestamento e Tecnologia Forestale (Petrocchi, 1987), the machining tests were performed, milling the panels through a spindle shaping machine with straight cutting edge knives (hardened and non-hardened steel).

The main information about the steel and the tools (knives) are listed below:

- steel composition: 2 % C; 0,2 % Si; 0,3 % Mn; 11,5 % Cr;
  - ⇒ abbreviation following DIN standard: X210Cr12 1.2080;
  - ⇒ abbreviation following BS standard: ~ BD3;
  - ⇒ abbreviation following AFNOR st.: ~ Z200C12;
  - ⇒ abbreviation following UNI standard: ~ Z205Cr12KU;
  - ⇒ produced by Böheler, noted K100;
- hardness Rockwell C of non-hardened steel: HRC 23;
- hardness Rockwell C of hardened steel: HRC 57;
- tool cutting edge: 40 mm length;
- knife angle 40 degrees;
- cutting angle 40 degrees;
- weared cutting edge length: ~ 27 mm (corresponding to the panel thickness).

The spindle diameter was 100 mm. The spindle, normally carrying two knives, for this test was arranged with only one knive; it was equilibrated through a metal plate of an appropriate weigth. The spindle speed rotation was 6000 r.p.m. A feeding device allowed to have a 25 m/min constant feeding speed. The sharping machine was adjusted in order to obtain a 1 mm constant machining depth.

The test procedure was carried out through the following steps:

1. measurement of the sharpened tool profile, through an appropriate device placed on a microscope;
2. milling (planing) of the LVL panel edge;
3. measurement of the weared tool profile at 500, 1000 and 1300 m lengths of machined panels.

2.2.1.4.4 Industrial machining [team involved: 06] (writing: 06)

In order to evaluate, from a qualitative point of view, the suitability of the final product to the foreseen objectives, some LVL squared pieces were machined at *Finestre PB* windows-manufacturing line.

A sample from the experimental production was profiled and machined; as the *Finestre PB* normally uses Chestnut Glulam for joinery production some observations were done.

2.2.1.5 Assessing durability of LVL compared with Chestnut Solid Wood

[Team involved: 02] (Writing Team: 02)

2.2.1.5.1 Research objective

Study on the natural durability of Chestnut LVL against Basidiomycetes fungi compared with Chestnut solid wood to evaluate the influence of industrial treatments (as steaming, drying, gluing) on the natural durability of Chestnut wood.

2.2.1.5.2 Material and method

Panel products have been supplied by Compensati Toro S.P.A, Azeglio (TO).
The raw material came from three areas:
- Cevennes (F)
- Isere (F)
- Torrazzo (I)

For the technical processing parameters see 2.2.1.3 and 2.2.1.4.; here are reported only the data that could affect the natural durability of wood.

- Steaming - warm water (50° C) for 8 hours
- Glue - MUF63T + 10 pp hardener.
- Glueing pressure - 10 and 18 bar.

2.2.1.5.3 Sampling

Three panels were selected for each provenance and each glueing pressure (10 bar and 18 bar), thickness of the panels 26 mm; dimensions of the test specimens were 50x50x26 mm.
Two series of specimens were prepared to expose to fungal attack: the former without accelerated ageing, the latter after accelerate ageing in a wind tunnel (heating 40° C, air flow 1 m/s for a period of 12 weeks).
From different provenances, air seasoned Chestnut solid wood specimens were prepared for control.

2.2.1.5.4 Method

The tests were carried out according to a draft standard "Method of test for determining the resistance against wood destroying Basidiomycetes of panels products made of or conteining wood" elaborated by WG/7 "Particle board and plywood" of European Committee for Standardization / Technical Committee 38 (CEN/TC 38).
The accelerated ageing test was carried out according to UNI EN 73 and the evaluation of natural durability according to UNI EN 350/1.

Natural durability is evaluated on the mass loss of the specimens attacked by fungi.
At first the specimens were conditioned in 20°C / 65%RH atmosphere, until they reached 12% moisture content.
Then they were placed in contact with the mycelium of the selected fungi and stored in a thermostatic chamber at 22°±1°C and 75% RH for 16 weeks.
Specimens of Fagus sylvatica L., as reference species, were exposed at the same conditions.
The test fungi used were:
Coriolus versicolor (L.) Quélet
Coniophora puteana (Schum. ex Fries) Karsten
Pleorotus ostreatus (Jacquin ex Fries) Quélet

After the exposure period, the specimens were cleaned from mycelium and conditioned in 20°C / 65% RH atmosphere until they reached 12% moisture content. Then mass loss was calculated.
The higher mass loss caused by a test fungus was chosen for assessing natural durability.
Natural durability is expressed as ratio of the average mass loss of test specimens to the average mass loss of reference specimens.
Based on the test results, the natural durability of the wood species was classified within a five grade scale for fungal attack (see Table 1).

Table 2.2.1.5/1 - Classes of natural durability of wood to fungal attack using laboratory tests

Durability class	**Description**	Results expressed as **x***
1	Very durable	$x \leq 0,15$
2	Durable	$0,15 < x \leq 0,30$
3	Moderately durable	$0,30 < x \leq 0,60$
4	Slightly durable	$0,60 < x \leq 0,90$
5	Not durable	$x > 0,90$

$$(*)\quad x = \frac{\text{average corrected mass loss of specimens}}{\text{average mass loss of reference specimens}}$$

2.2.2 Subtask F2 - Thick Sliced Veneer for prefinished composite parquet strips [Teams involved: 07,09] (team writing: 07,09)

2.2.2.1 Assessing roundwood **[Teams involved: 07,09]** (team writing: 07)

2.2.2.1.1 Knots

Search for knots was carried out on the four faces of each square block. The position, dimensions and description of each knot were noted down and recorded, also in graphical form, on a special chart. The knots were classified as follows:

sound, if originating from live branches and forming a single piece with the surrounding wood tissues;
loose, if they tended to detach from the surrounding tissues owing to the presence of bark separating the branch tissues from those of the stem, or because the branch tissues were lacking in consistency on account of the presence of feather rot;
pin-sized "bird's eye", if they had a diameter of less than 0.5 cm, generally, but not necessarily, loose and originating from small epicormic branches which had developed following on a state of suffering of the plant (e.g., an episode of canker of the bark).

The longitudinal position of the knots was recorded as the distance from one of the two tops of the square block, whilst the transverse position (i.e., the distance of the knot from the edges of the square block) was recorded graphically, but without particular precision.

The size of each knot was calculated on the basis of the mean value of two measurements of diameter made at right angles to one another, the first of which corresponded to the major diameter (see Fig. F/12).

During the data processing phase and that of evaluation of the results, it was deemed more useful to consider, for each face of the square block, the surface free from knots rather than the number or the total area of the knots. In fact, considering that in TSVs for prefinished parquet strips, at the most the presence of small-sized sound knots is allowed, it appeared very important to record the distribution of the knots in the piece. A large number of knots that are, however, concentrated in certain areas of the square block are less detrimental than a small number of knots that are scattered throughout the length of the piece, in that they are much easier to eliminate. For these reasons, the maximum length free from defects was measured on each face of the square blocks. For each square block, either the sum of the values of the knot-free maximum lengths of the four faces were then taken into consideration, or else, vertical framely, the maximum value of these, the minimum value, or various combinations of these values. The most significant results were obtained considering only the faces of the square blocks having a knot-free length of at least 65 cm (according to the length of finished strip).

2.2.2.1.2 Ring shake

For slicing, timber for the most part free from ring shake was chosen. Whenever present, this defect was recorded by subdividing each head into eight sectors of equal width and attributing to each split a numerical value according to the number of sectors involved. In this way it was possible to quantify the seriousness of the phenomenon by summing up, for each bolt, simply the values associated to the individual cases of ring shake in each head (see Fig. F/13).

This recording was made systematically on both ends of the bolts before steam treatment, whereas, at the end of this treatment, only the appearance of new ring shake was noted.

2.2.2.1.3 Growth stresses checks

Growth stress checks were recorded before steam treatment on both heads of each bolt and, after treatment, only on one head (the one containing more flaws). For each check, the development on the head of the bolt was measured, and possibly also on the side surfaces if the check extended also onto these. As emerges from previous studies (Cielo, 1992), three types of checks were identified; these are shown in Fig. F/14. The length of the checks of Types 2 and 3 is given by the sum of the length of the individual arms, and hence may be greater than the length of the Type 1 check, even when it does not involve the lateral surfaces of the bolt.

2.2.2.2 Laboratory and preliminary tests **[team involved 07,09] (team writing: 09)**

2.2.2.2.1 Preliminary slicing tests

They were made in two successive trials using the MARUNAKA device at the SILD manufacture (Dronero, Italy). Unfortunately, as mentioned above, the steam treatment ended by more than half an hour of steaming at 90°C, leading to a high level of end checking of each bolt. It was, then, decided to cut the slices more or less parallel to the longest of the end checks.

It was not possible to change the machine settings (bar position, clearance angle) and the oblique angle was 14° (tan f = 0.25). Trials were performed for different thicknesses ranging from 1 to 6 mm as shown in table #4. Observations were made during the cutting process; each veneer slice was numbered and the residual plank was measured.

Table #4 Preliminary oblique slicing tests (SILD, Cuneo, Italy)

Date	Thickness (mm)	Number of logs	pre treatment	comments
July 1993	1-2-3-4-5-6	3	preheating at 65°C, then 30' at 90°	
	2	3		
	2.5	1		
	3	3		
	4	3		
	5	2		
March 1994	3	5	id.	_ 32 veneers/log
	4	4		
	5	4		

A selection of sliced veneers of different thicknesses were taken to the laboratory in order to study the global deformation and test a specific drying procedure. The main results of these preliminary trials are :

(i) oblique slicing of chestnut is easily performed for small coppice trees at thicknesses increasing from 1 to 4 mm;

(ii) for 5 and 6 mm veneer thickness, sometimes slicing difficulties appeared due to insufficient friction between the wood block and the carrying device;

(iii) ring shakes and end checks seemed to be amplified by the cutting process (stress release), resulting in serious down grading of the veneers;

(iv) surface quality of the veneers was fine in regions without knot occurrence, for any thickness, but surface roughness appeared to be high on one side of the wood surrounding big sound knots (diameter above 20 mm). This phenomenon is far more important for the highest thicknesses (5, 6 mm) and almost disappears for small thicknesses (1, 2, 2.5 mm).

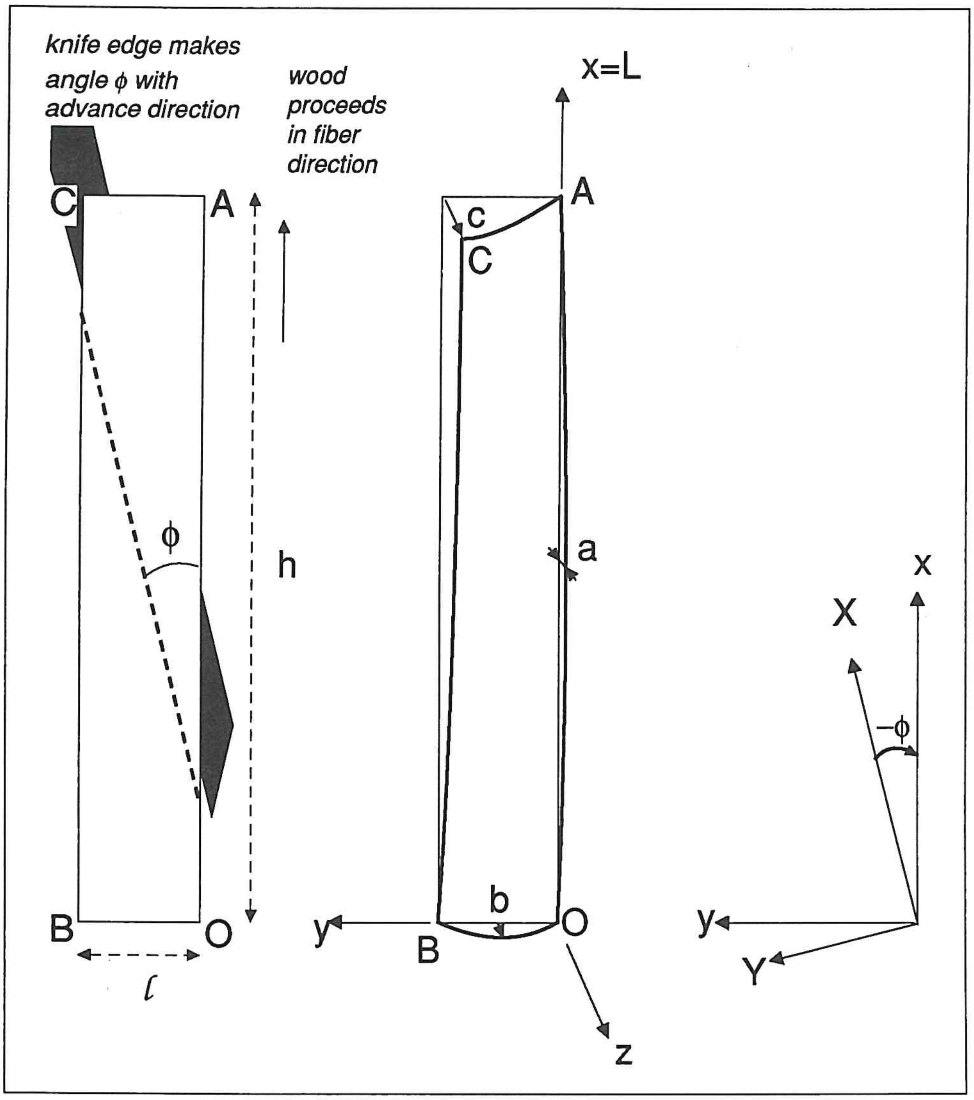
2.2.2.2.2 Global deformation of sliced veneers

After the slicing, a marked distortion of the veneers was observed, clearly caused by the oblique position of the knife edge relative to the advance of the wood block. An attempt to quantify the global deformation of the veneers was made as follows (Fig. F/15) :

Compared to the desired rectangular, plane shape (length h in fibre direction L, width l), the veneer is distorted as indicated in the Figure. Taking the three points (O,A,B) as a planar reference, the warp can be quantified by 3 deflections :

a : "axial bending", measured at the middle of O and A;

b : "transverse bending", measured at the middle of O and B;



Quantification of veneer distortion

Fig. F/15

c : "shear deviation" measured at the level of C

During the slicing process, an initial bending curvature $-k^\circ$ is imposed in direction Y orthogonal to the knife edge. By projection in (x,y) directions :

$$k^\circ_{xx} = -k^\circ \sin^2 f \;\; ; \;\; k^\circ_{yy} = -k^\circ \cos^2 f \;\; ; \;\; k^\circ_{xy} = +k^\circ \, 2\cos f \sin f$$

After immediate and delayed recovery, only a part of these initial curvatures remains. However, the proportion of residual to initial curvature may depend on the material direction involved. Let write (q_L, q_T, q_{LT}) the respective ratios, so that the residual curvature is given by :

$$k_{xx} = -k^\circ q_L \sin^2 f \;\; ; \;\; k_{yy} = -k^\circ q_T \cos^2 f \;\; ; \;\; k_{xy} = +k^\circ \, 2q_{LT} \cos f \sin f$$

Assuming that the residual curvature is homogeneous in the whole veneer, the deflection can be approximated by a second-order polynomial function of coordinates x and y :

$$z(x,y) = \frac{k_{xx}}{2}(x-h/2)^2 + \frac{k_{yy}}{2}(x-l/2)^2 - \frac{k_{xx}h^2 + k_{yy}l^2}{8} + k_{xy}\, xy$$

where it is taken into account that the three points O,A,B remain in the plane z=0.

Hence, the quantities a, b, c are given by :

$$a = z(h/2,0) = -k_{xx}\, h^2/8 = k^\circ \frac{q_L\, h^2 \sin^2 f}{8}$$

$$b = z(0,l/2) = -k_{yy}\, l^2/8 = k^\circ \frac{q_T\, l^2 \cos^2 f}{8}$$

$$c = z(h,l) = -k_{xy}\, h\, l = k^\circ q_{LT}\, hl\, 2\cos f \sin f$$

Table #5 shows the result obtained on 10 groups of 3 to 5 veneers (total 44) of thickness 2 to 6 mm, width 12~23 cm, length 1.4~2.1 m, obtained using the Marunaka slicing machine. For each veneer, the following quantities were measured :

- h : length
- l : width
- b : transverse bending deflection
- c : shear deviation

The thickness e was not actually measured on each veneer; for the present purpose, we use the setting value.

Table #5 - Evaluation of the distortion of TSV.

n°	checks	nb	e (mm)	h (cm)	l (mm)	b (mm)	c (mm)	e_T (%)	q_{LT}/q_T	a (mm)
10-4 (G)		3	4	195,7	204,7	20,33	114,3	1,751	1,195	1,165
10-3 (G)		5	3	208,4	213,8	26,4	116	1,563	0,908	1,567
10-5 (G)	yes	3	5	204,7	225,3	20,33	92,67	1,808	1,009	1,049
10-6 (G)		3	6	176,7	201,7	13,33	76,67	1,774	1,316	0,64
64-2 (G)	yes	5	2	169	177	23	110	1,326	1,004	1,312
9-4 (p)		5	4	142,8	132,6	11,6	65,8	2,405	1,06	0,842
9-5		5	5	149	148,4	7	43	1,433	1,235	0,441
9-6		5	6	140,4	150	7,2	49,4	1,734	1,472	0,394
58-2		5	2	165,2	162,8	18	95,8	1,226	1,054	1,158
58-3	yes	5	3	146,8	155	12,6	103,8	1,417	1,846	0,707

The measured values allow to compute the value of the residual deformation e_T in the transverse direction, by :

$$e_T = e.k_{yy} = \frac{8.b.e}{l^2 \cos^2 f}$$

The table shows that it is rather constant, about 1.6±0.4 %. The ratio of residual strain in shear to that in transverse bending, given by :

$$\frac{q_{LT}}{q_T} = \frac{c\,l}{b\,h\,2\tan f}$$

is also computed in the table. The value obtained, of about 1.2±0.3, suggests that it could be reasonably assumed q_{LT}_q_T. Fig. F/16 shows that both e_T and the estimated ratio q_{LT}/q_T tend to increase slightly with the veneer thickness.

The deflection a was not measured, since it was estimated visually to be negligible. It can, however, be predicted using the following formula :

$$a = a\frac{q_T}{q_L} = \frac{h^2}{l^2}\tan^2 f.b$$

Assuming that the residual strain in fibre direction does not exceeds that in transverse direction ($q_L/q_T<1$), a can be considered as an upper value of a. However, the table shows that a is about 0.9±0.4 mm, and never exceeds 2 mm. This is quite compatible with the visual estimate of a slight curvature in the axial direction, but with the deflection (a) too small to be measured precisely. Here again, the assumption that q_L_q_T would not contradict the experimental findings.

Thus, the modelling of the final twisting of the wet veneer was done taking into account : (a) the curvature around an oblique axis (14° to the fibre axis) during cutting process, and (b) the anisotropy viscoelastic recovery as generally described in the literature. It appeared, however, that the relative amount of recovery could be considered as isotropic without contradicting the experimental observations. Comparisons with the experimental results on 2-3-4-5-6 mm thick slices manufactured in the preliminary tests shows the soundness of the model with a final residual strain in the tangential direction of 1 to 2%, very slightly increasing with veneer thickness.

If these veneers were left to dry freely, their initial distortion generally increased, by about 20%, which was partially explained by the decrease of thickness. Flat drying under restraint drastically reduced this residual strain except for a small elastic "kick back" effect leaving around 1/10 of the initial residual strain. For a 4 mm thick veneer this made a residual radius of curvature around 1 to 2 m. Experimental results show a high level of variability due to the presence of defects like knots which strongly influence drying deformations of veneers, but they confirm the theoretical predictions with a residual strain around 0.2%.

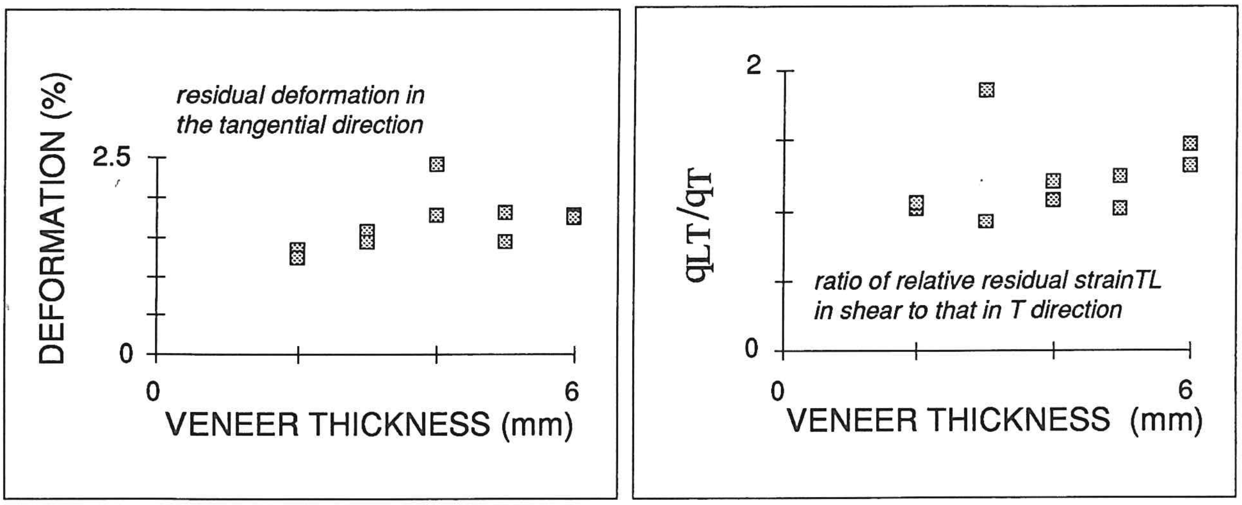
2.2.2.2.3 Specific drying procedure

After the study of TSV global deformation, it was concluded that the best way to recover the final residual deformation, was to dry the TSV under constraint with a counter curvature opposite to the predictable residual curvature observed after drying under flat constraint.

A specific laboratory device was built-up in order to test 5 TSV at a time with the possibility of continuous setting of the curvature, allowing tests on different veneer thicknesses (Fig. F/17). Matched specimens 60 cm long coming from the same TSV (4 mm thick) were dried under constraint in a laboratory oven, 5 by 5, one lot flat (zero curvature), the other lot with a negative oblique (14°) curvature as described before, corresponding to a 2000 mm radius. Although a great dispersion of final global deformation measurements was observed, due to knot occurrence, results clearly showed that TSV dried under oblique negative curvature constraint are globally flat, while simple flat drying under constraint resulted in a small mean apparent residual twisting of the TSV.

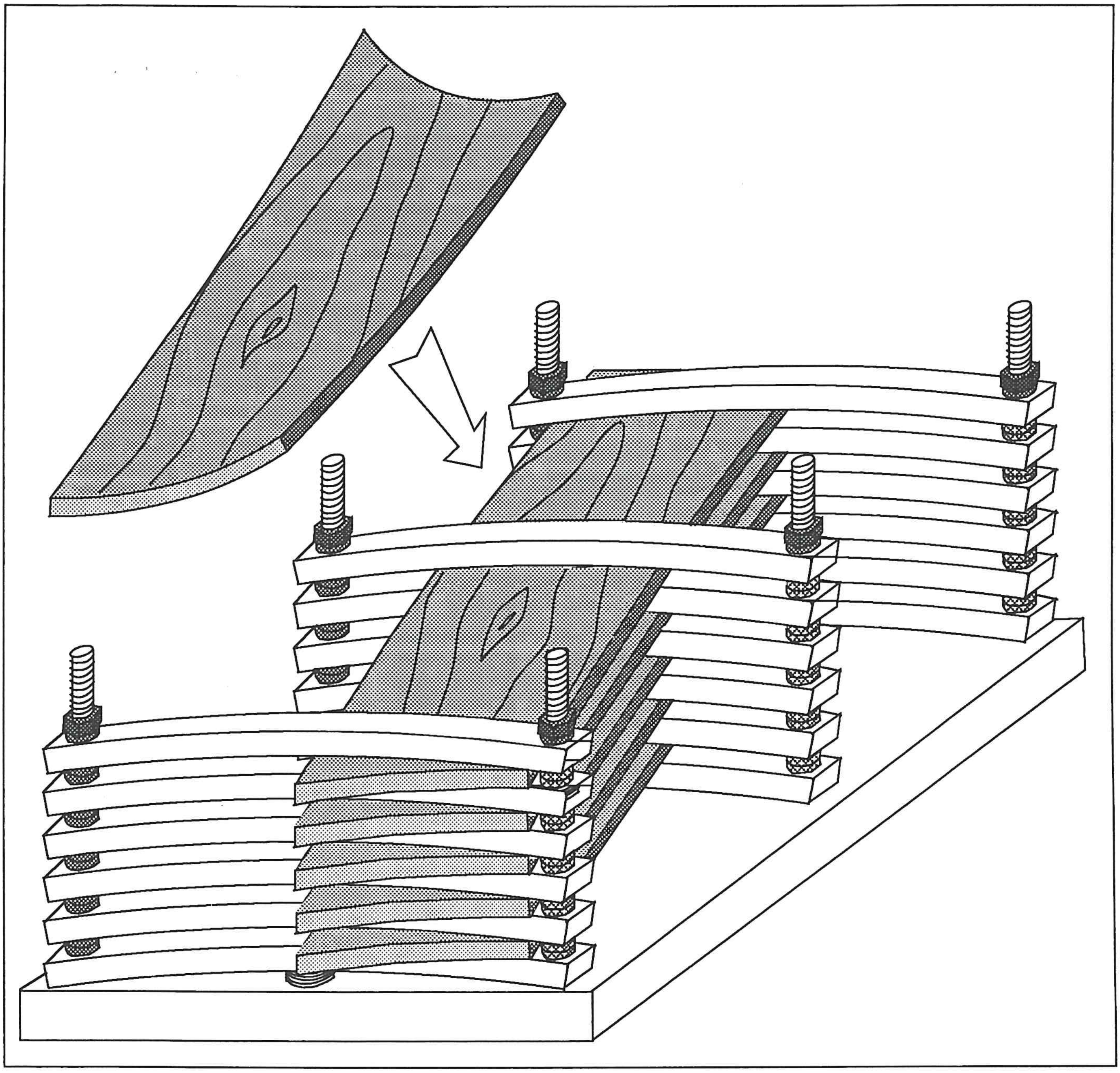
Plans were made to realise a small industrial drying device with fixed oblique negative curvature adapted to the 4 mm thick TSV (negative radius of 2 m). It consists of lower (resp., upper) wood or panel pieces with one convex (resp., concave) upper (resp., lower) face of 2 m curvature radius. Separations between successive TSV layers can be obtained by using the same aluminium rods as those used by the SILD company to flat-dry tropical or walnut veneers manufactured with the MARUNAKA device, because the deformation of these slats remains in the elastic range. This would lead to a very low cost device completely integrated in the usual SILD company process. Two main drawbacks are :

i) an increase of the volume occupied by TSV piles put to dry;



Influence of veneer thickness on the residual deformation

Fig. F/16



Experimental device allowing counter-curvature drying

Fig. F/17

ii) more difficult manual operations to adjust the position of successive TSV layers, because of higher difference of curvature between veneers and the support.

Finally, due to these real but small drawbacks, and mainly because preliminary parquet manufacturing using TSV dried in the hot continuous tunnel (see § 2.2.2.3.1.5) proved to be good enough, the specific drying device was not used at the industrial level.

2.2.2.3 Processing steps for production of prefinished composite parquet strips **[Teams involved: 07,09] (team writing: 07)**

European standards for prefinished parquet are currently being defined. For the time being, reference is made to a resolution of the CEN TC 175/WG3 AHG3 "Wood floorings" of November 2, 1994, which specifies that the outer layer made of heartwood must have a thickness of not less than 2.5 mm.

The Italian standard UNI 8131/80 defines as "prefinished" a parquet strip made up of a number of layers of wooden materials and other materials, in which the outer surface layer consists of heartwood of suitable hardness (and generally belonging to a valuable species) which has undergone a treatment of final sanding and varnishing already in the production phase.

The manufacture of prefinished parquet strips, which is the subject of this research, entailed two distinct processing cycles, developed and carried out in collaboration with two different firms operating in the sector:

production of heartwood veneer sheets for the upper part, i.e., the one in view, of the prefinished strip, by means of lengthwise slicing to form TSV and, on a small sample, by means of vertical-frame multi-blade sawing, using a Gatter-type saw;

gluing of the sheets on a subfloor support consisting of a wood-based panel, and subsequent varnishing and tongue-and-groove edge profiling of the composite obtained.

2.2.2.3.1 Production cycle of sheets by lengthwise slicing (TSV)

2.2.2.3.1.1 Cross cutting

Since the lot of timber of French origin was already supplied in bolts of a definite length, the equalizing operation was carried out only on the Italian material.

The roundwood was cross cutted into lengths which were multiples of those of the finished product (corresponding to 60 cm and 80 cm, plus 10 cm allowance), which made it possible to obtain bolts of lengths ranging from 130 to 330 cm, so that the minimum head diameter was not less than 18 cm. Bolts of varying lengths were deliberately produced in order to check whether bolts of a greater length could enable better processing yields. With this operation, 107 bolts having a mean diameter of 19 cm were obtained for a total volume of 5.151 m^3, equivalent to 76% of the initial volume of the sampled logs.

Considering the two lots, in this phase 141 chestnut bolts, corresponding to a volume of 7.268 m^3, were sent for slicing.

2.2.2.3.1.2 Squaring

Lengthwise slicing calls for previous squaring-off of the roundwood. For this reason, both the Italian and the French bolts were worked using an ordinary band saw until square blocks having faces not less than 12 cm wide were obtained.

2.2.2.3.1.3 Steam treatment

The internal growth stress checks present on the heads of the logs tend to widen and lengthen during steam treatment on account of the high temperature which favours release of the stresses. This phenomenon is known in the literature as Hygrothermal Recovery (HTR) of green wood (Lutz, 1974; Kubler, 1987).

Previous experiments (Gril et al., 1993; Cielo et al., 1994) have shown that it is possible to limit effectively the lengthening of these checks by using steam-treatment temperatures of less than 50-55 °C. However, for reasons linked to the manufacturing organization of the firm at which the processing tests were conducted, a more drastic treatment than the desirable one was carried out; this consisted of an initial steam-treatment phase having a duration ranging from 12 to 18 hours at a temperature of 65-70°C, and of a second phase, of approximately half an hour, at a temperature of 90°C.

2.2.2.3.1.4 Slicing

Slicing was performed using a Marunaka slicer, which works by advancing the square block towards the tool cutter so that the knife cuts into the wood at an angle of approximately 15° to the grain (see Fig. F/18). This type of processing is referred to as lengthwise slicing. Using this type of machine, it is possible to work pieces of small diameter and of varying length with a relatively low outlay of capital. The sheets that are obtained by this process present a deformation of flatness, which results from stresses induced by the cutting tool. This deformation is referred to as "warping" (see Fig. F/19)

2.2.2.3.1.5 Drying

After first carrying out a series of preliminary tests of natural seasoning and of artificial kiln-drying of the sliced veneer, it was deemed more expedient and advantageous to carry out this treatment in a continuous (tunnel), networked, forced-air drier. In the tunnel drier, the sliced veneers are slightly pressed in order to limit and reduce warping. However, no specific measurements were made in this connection.

After artificial drying, the moisture content of the veneers ranged somewhat around a mean value of 15 % m.c. with respect to the kiln-dry weight, with fluctuations of ± 2-3%. Since the veneers must undergo further processing, after a period of storage in closed but not heated environments, this apparently high hygrometric value was deemed satisfactory, even though it is much higher than the value that the finished product should reach when it is to be laid (7±2% m.c.).

2.2.2.3.1.6 Selection and trimming of veneers

On the dried veneers, portions from which sheets free from defects could be obtained were marked out with chalk. For this type of stock, in fact, loose knots, including ones of very small dimensions, are not allowed, nor, obviously, are splits of any type. In the selection stage, instead, sound knots were tolerated, provided that they were perfectly intact and not split by the action of the cutting tool; these requirements were met only by knots having diameters of less than 2 cm.

The sound portions were chosen by visual examination of each veneer. This process was very time-consuming since it was necessary to optimize the trimming of the veneer according to the sizes of the sheets to be obtained and the type of defects present.

2.2.2.3.1.7 Sizing, trimming and final selection

The portions of TSV thus obtained, which were free from defects and had a nominal length of 60 and 80 cm (actual length, 61 and 83 cm) were sized down to a thickness of 3.2 mm. The portions were then trimmed, so as to obtain 10-cm wide sheets with parallel edges. Finally, in the parquet production works, the veneer sheets underwent an additional selection for quality (see Fig. F/20) before undergoing further processing.

2.2.2.3.2 Production of sheets by vertical frame multiblade sawing

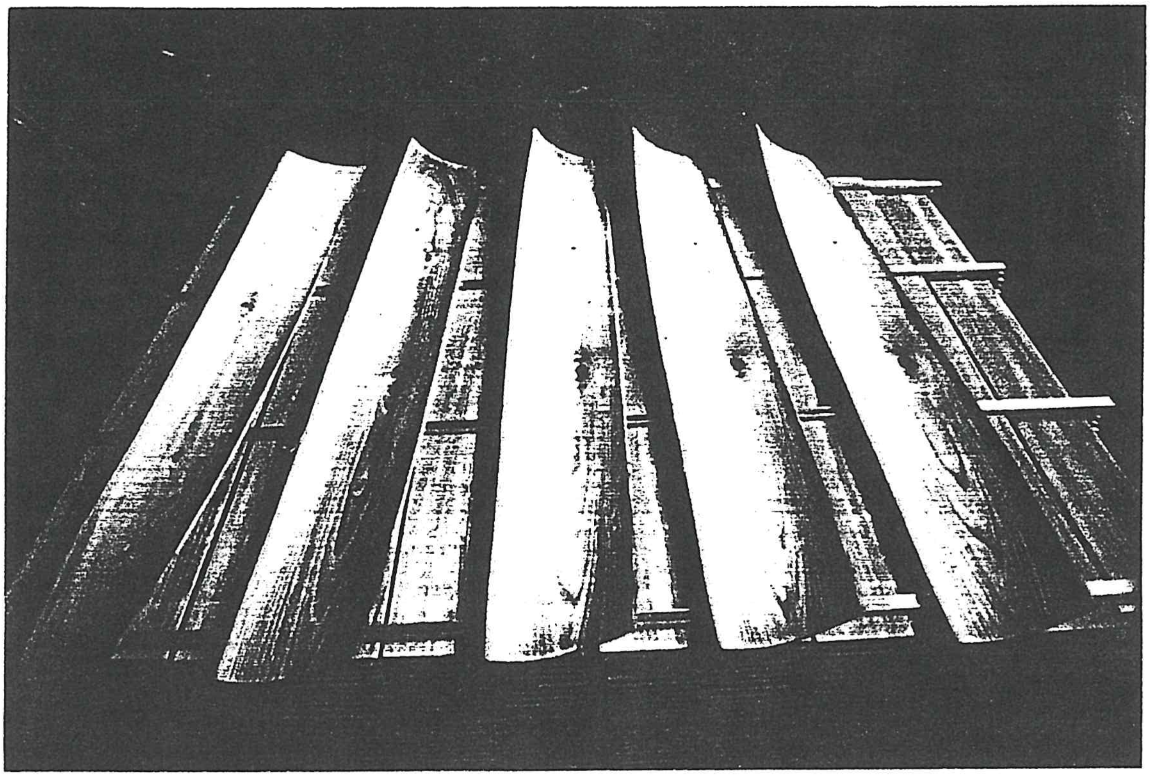


Figure F/19 - Warping of sliced sheets

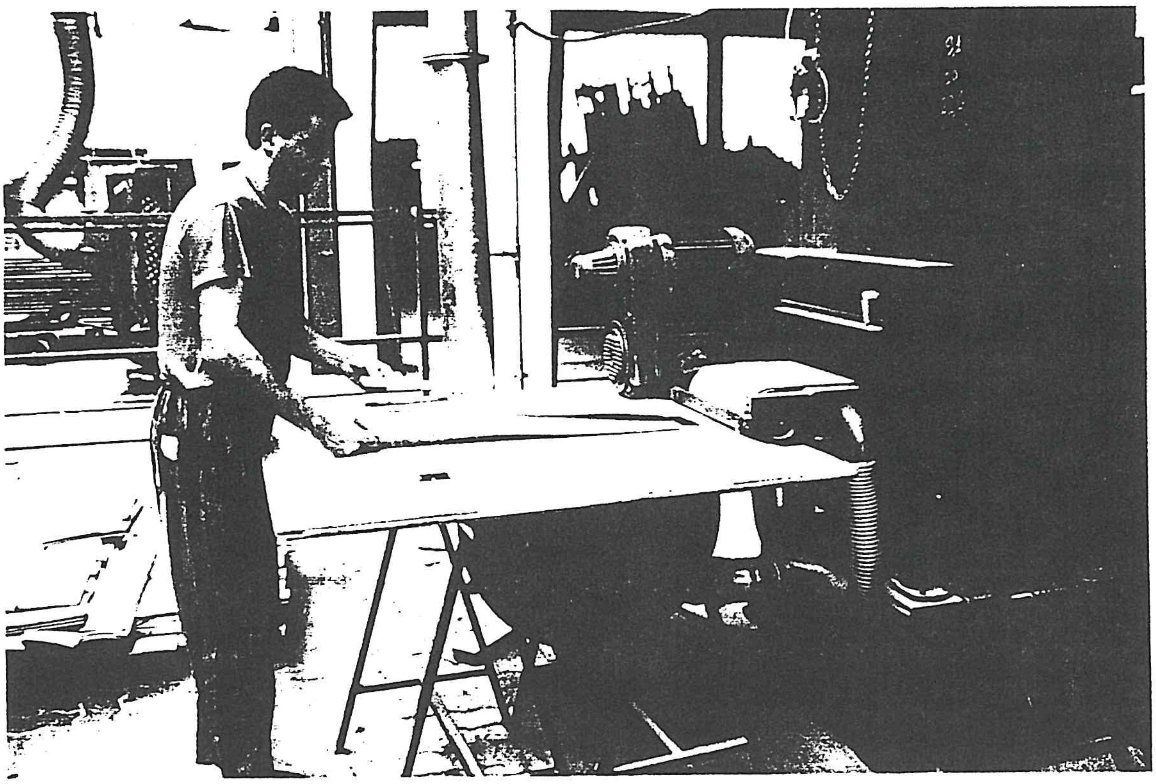


Figure F/20 - Additional selection for quality

In the course of the work, it was decided to evaluate also the possibility of producing sheets using another process, namely with a Gatter-type vertical frame multiblade saw (the set of each individual blade was 1.8 mm) to obtain boards of limited thickness starting directly from the square block (see Fig. F/21).

Even though this type of processing was not contemplated in the research contract, it proved to be of considerable interest in that, as in the case of lengthwise slicing, it enabled production of sheets of limited thickness starting from roundwood of small dimensions, without, however, any need for steam treatment of the wood, and consequently enabled the setting up of a production line at even lower costs.

For this test, 12 small bolts were chosen, taken from the material remaining over from the lot of Italian chestnut, for a total volume of 0.205 m^3. Since the main purpose was to assess the feasibility of the process on chestnut timber, rather than to quantify the yields that can ordinarily be obtained, bolts were very carefully selected that, at least externally, were devoid of knots or other flaws. These were then cross-cutted to lengths between 65 and 70 cm in order to obtain sheets of a nominal length of 60 cm (actual length, 61 cm).

Subsequently, sharp-edged square blocks having a cross section of 11 x 11 cm were sawn following the procedure described above, and from each piece, 19 or 20 sheets of a nominal thickness of 4 mm were obtained.

The sheets were then kiln-dried, sized down to a thickness of 3.2 mm, trimmed and, finally, sorted according to grade.

2.2.2.3.3 Production of prefinished parquet strips

2.2.2.3.3.1 Grading of sheets

The chestnut veneer sheets were divided into two grades (1st and 2nd choice) according to purely visual criteria, such as are normally used in industry for oak (2), as follows:

- 1st choice: this includes sheets with straight or partially patterned grain; a sound, pin-sized, "bird's eye" knot, slight chromatic alterations, and minor deviations in the grain (see Fig. F/22) are tolerated;
- 2nd choice: this includes sheets with sound knots, which are generally pin-sized or, at the most, of 2-cm diameter (beyond this size, it is unlikely to find sound knots that have not been damaged during slicing). Sheets presenting notable chromatic variations or marked grain patterns (see Fig. F/23) are also considered 2nd choice.

(The first choice corresponds to the first grade of the UNI 4376/82 Standard - "Parquet strips for floorings - classification according to defects." The second choice corresponds to the second grade of the same standard, except for knots larger than 5 mm in diameter, which the standard only allows for the third grade).

In the sheets produced by sawing, it was possible to find small loose knots (less than 0.5 cm in diameter) which, owing to the type of cut which subjects the material to less stress and on account of the subsequent varnishing, remained firmly embedded in the surrounding wood. Should production at an industrial level be carried out in future, these sheets could constitute a possible third choice.

2.2.2.3.3.2 Gluing of sheets on subfloor support

Both the 60-cm and the 80-cm veneer sheets were glued side by side, in threes, on a support having the same length and a width of 30 cm, consisting of a poplar or birch 5-layer plywood panel having a thickness of 8 mm.

As subfloor support, the firm normally uses a 7-layer plywood panel made of Finnish birch, 9 mm thick, with the grain of the faces running parallel to that of the sheets, or, vertical framely, an Oriented Strandboard (OSB) panel of the same thickness.

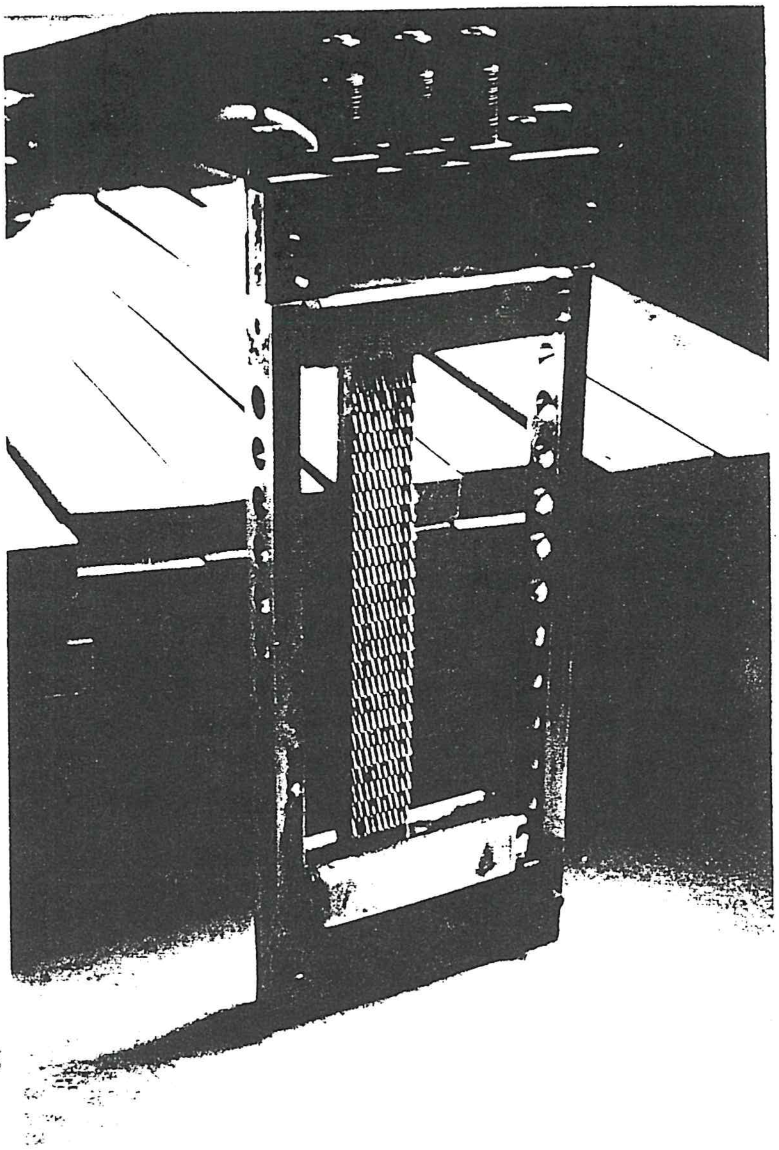


Figure F/21 - Multiblade saw with 1,8 mm spacing

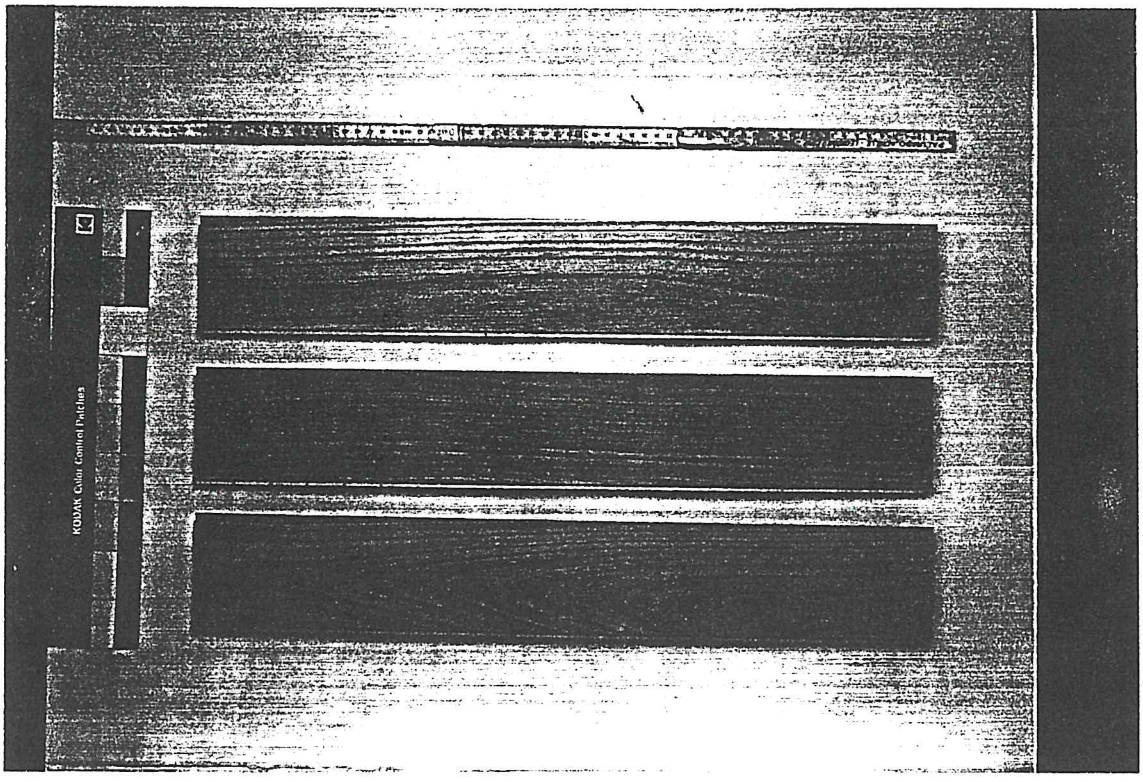


Figure F/22 - First choice sheets

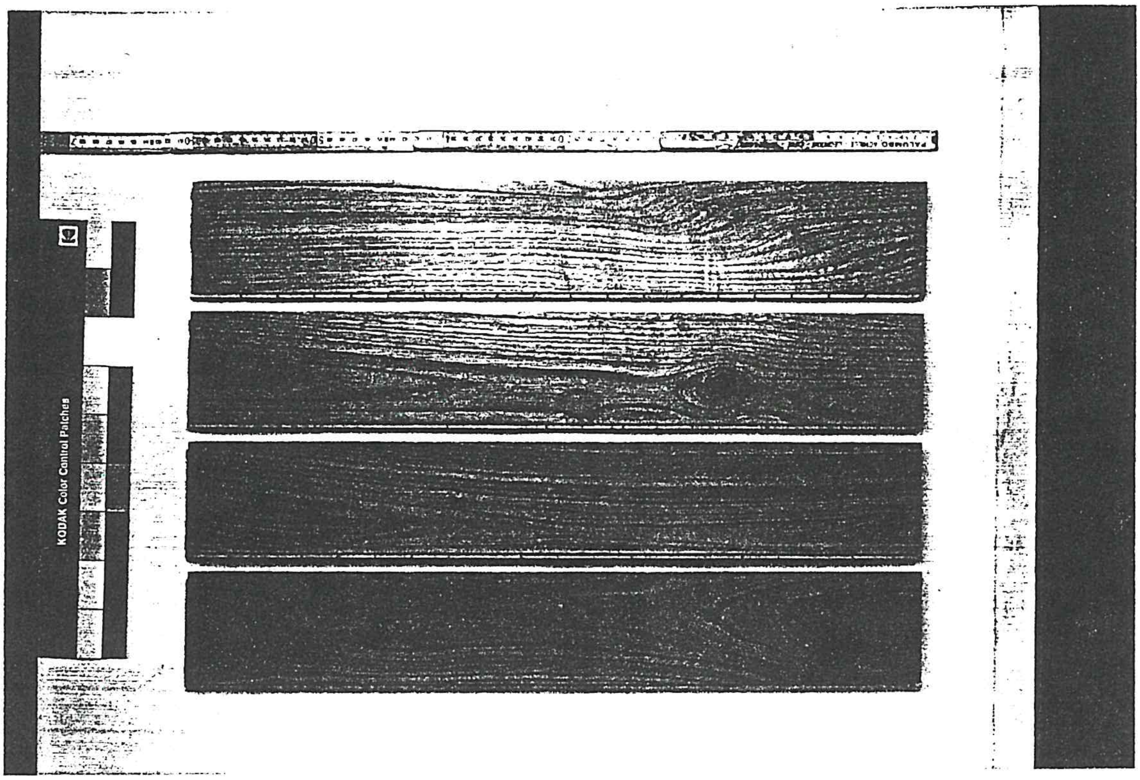


Figure F/23 - Second choice sheets

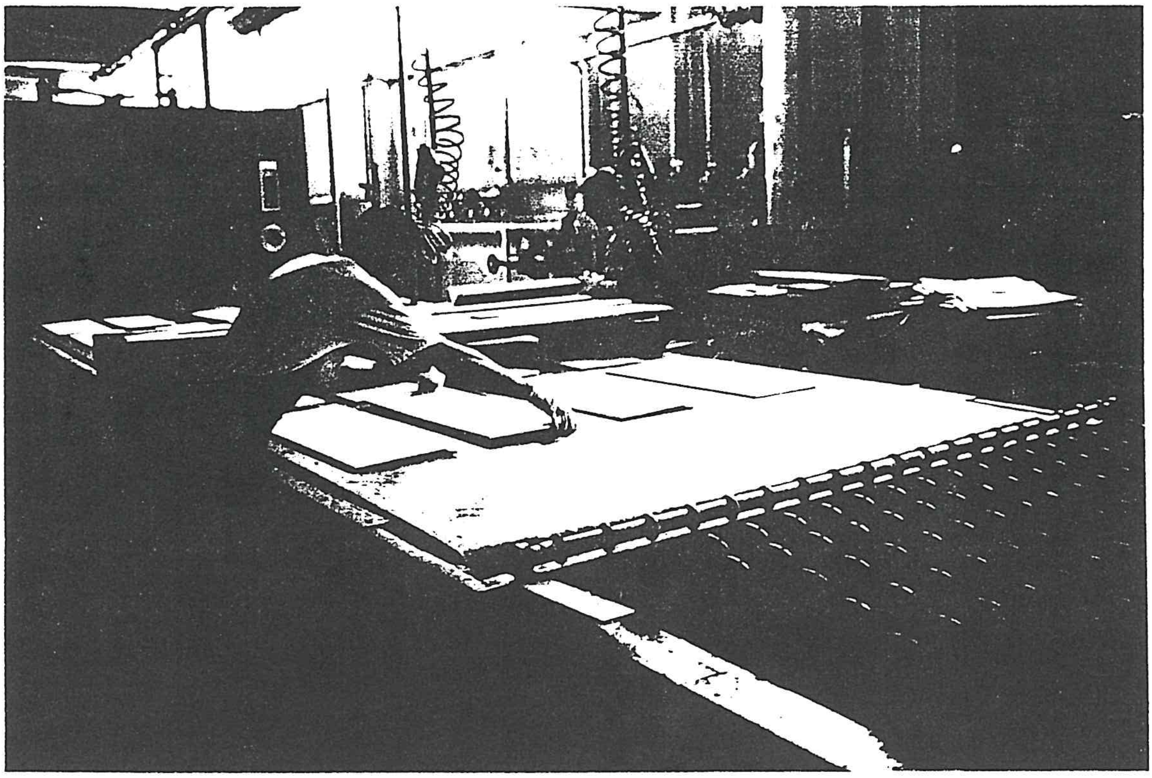


Figure F/24 - Composition before pressing

During the test, the birch plywood panel was glued with the grain of the faces running crosswise to that of the chestnut sheets, whereas the poplar plywood panel was glued with the grain of the faces running parallel.

The purpose of the test with poplar was to make a preliminary assessment on the suitability of poplar plywood panels as subfloor material.

The gluing operation was carried out using a roller spreader to apply a vinyl resin-based two-component adhesive mixture of the D4-type (for indoor structures subject also to high variations in humidity as per UNICHIM 702 and EN 204 standards) on the surface of the support. Three sheets were placed manually on each support, and the composite pieces thus obtained were carried on a conveyor belt into a single-chamber press that exerted a pressure of approximately 0.7 N/mmm^2 for a duration of about 30 minutes (see Fig. F/24).

In order to determine the effect of microsplits on the quality of the finished product, the 80-cm long sheets were glued with the surfaces affected by these splits (stressed faces) outwards, whereas the 60-cm sheets where glued with the faces having microsplits against the support.

2.2.2.3.3.3 Separation of strips and cutting of subfloor support

Upon leaving the press, the semifinished product, consisting of the subfloor panel and the heartwood sheets, was left to cool off and stand for at least 72 hours. It was then cut lengthwise to obtain three single pieces of composite parquet (called strips).

Subsequently, cuts approximately 7 mm deep were made into the underside of the plywood support at right angles to the run of tha sheet grain. These cuts, which left the heartwood sheet and the first layer of the underlying panel intact, serve two purposes: on the one hand, they give the finished product greater flexibility and greater adaptability to any possible irregularities of the floor, and on the other, they limit warping due to imbalanced composition.

2.2.2.3.3.4 Finishing of strips

The finishing cycle was carried out as a single continuous process which, in less than 3 minutes, completed the sanding and varnishing operations on the strips. Altogether four coats of acrylic resin-based light-hardening varnish were applied to form a transparent protective film of 1-2 tenths of a millimetre on the surface of the veneer. The finishing cycle consisted of the following steps:

1 initial sanding to take away about 1/10 mm thickness from the sheet, which was thus reduced to 3.2-mm thickness;
2 brushing of the surface to be varnished;
3 application of a layer of insulating product for U.V. varnishes, and drying in an I.R. oven;
4 application of a first undercoat spread with roller varnisher, and subsequent U.V. drying;
5 application of a second undercoat using a "Reverse" double-roller machine, and U.V. drying. Since the second roller rotates in the opposite direction to the first, a better penetration of the product is achieved;
6 second sanding and brushing;
7 application of finishing varnish coat with double-roller machine, and U.V. drying.

The entire production cycle for parquet strips is shown in the diagram of Fig. F/25.

2.2.2.3.3.5 Profiling of strip's edges

In order to ensure perfect matching of the strips when they are laid down, their edges are worked to obtain a tongue and groove profile both along the sides lengthwise and on the ends. The quality of this process has a marked effect on that of the finished product. In fact, when the grooves of the various strips do not match perfectly, this makes the parquet difficult to lay and tends to make it unacceptable to those who carry out the job of laying it down, as well as to the end customer.

3 RESULTS AND DISCUSSION [Teams involved: 07,09,13] (team writing: 07,09,13)

3.1 Subtask F1 - Laminated Veneer Lumber [Teams involved: 07,09,13] (team writing: 07,09,13)

3.1.1 Step by step yield [Teams involved: 07,09,13] (team writing: 07)

The yields are examined by analysing the waste resulting from each single operation in each step of the panel production cycle.

3.1.1.1 Cross-cutting wastes

The first processing losses occur when cross- cutting the trunks to obtain bolts suitable for rotary cutting. They are due to the presence of curvatures, bifurcations, large branching and portions of the trunk affected by rot, which have to be discarded.

From the analysis of this waste, however, it is not possible to characterise the populations from which the three lots of timber came because it is not known how they were selected or whether they were actually representative of the entire forest complex. Furthermore, only a part of the trunks coming from Isère were made up of whole topped trees, the others being portions of different lengths obtained at different stem heights.

Cross- cutting losses were calculated for the various sources, both as percentage ratio between the waste and the overall volume of the original trunk, and as length of the portion of trunk discarded with respect to the initial length, referred to as the unit. Since frequency distributions for these values are not normal in addition to the values of the mean, which has only an indicative value, those corresponding to the three quartiles were also given.

Table 1 Cross- cutting losses of raw material according to provenance

Provenance	No. Stems	Vol (m^3)	Mean length of stems	Losses in cross- cutting (% of initial volume)				Linear loss (cm/m of initial trunk)			Mean dia. of bolts obtained from stems
				25th percentile	50th percentile	75th percentile	mean	25th percentile	50th percentile	75th percentile	
Isere	33	19.2	9.6	9	16	27	17	10.5	17.5	29.5	28
Cévennes 1	69	18.7	4.4	10	16	30	22	10.0	11.5	32.0	27.5
Cévennes 2	81	19.1	4.1	5	31	43	27	3.0	33.0	48.5	27

From Table 1, it can be noted that for all provenances, 25% of the trunks were of average quality, since cross-cutting waste was found to be lower than 10% of the initial volume, with a maximum waste of 10.5 cm per metre of trunk (i.e., approx. 16 cm for each bolt having a length of 1.5 m); a further 50% of the round-section portions gave losses of between 10% and 30% of the initial volume in the case of specimens coming from the Isère and Cévennes 1 areas, and between 5% and 43% for Cévennes 2, the material of which was less uniform. Finally, the remaining 25% of stems presented cross- cutting losses higher than the above values.

It should be noted that, with cut bolts of greater length (for example, to produce door jambs or window posts, panels, and hence equalised pieces, having lengths of over 2 m would be necessary), the cross- cutting waste would certainly have been greater. In the event of future

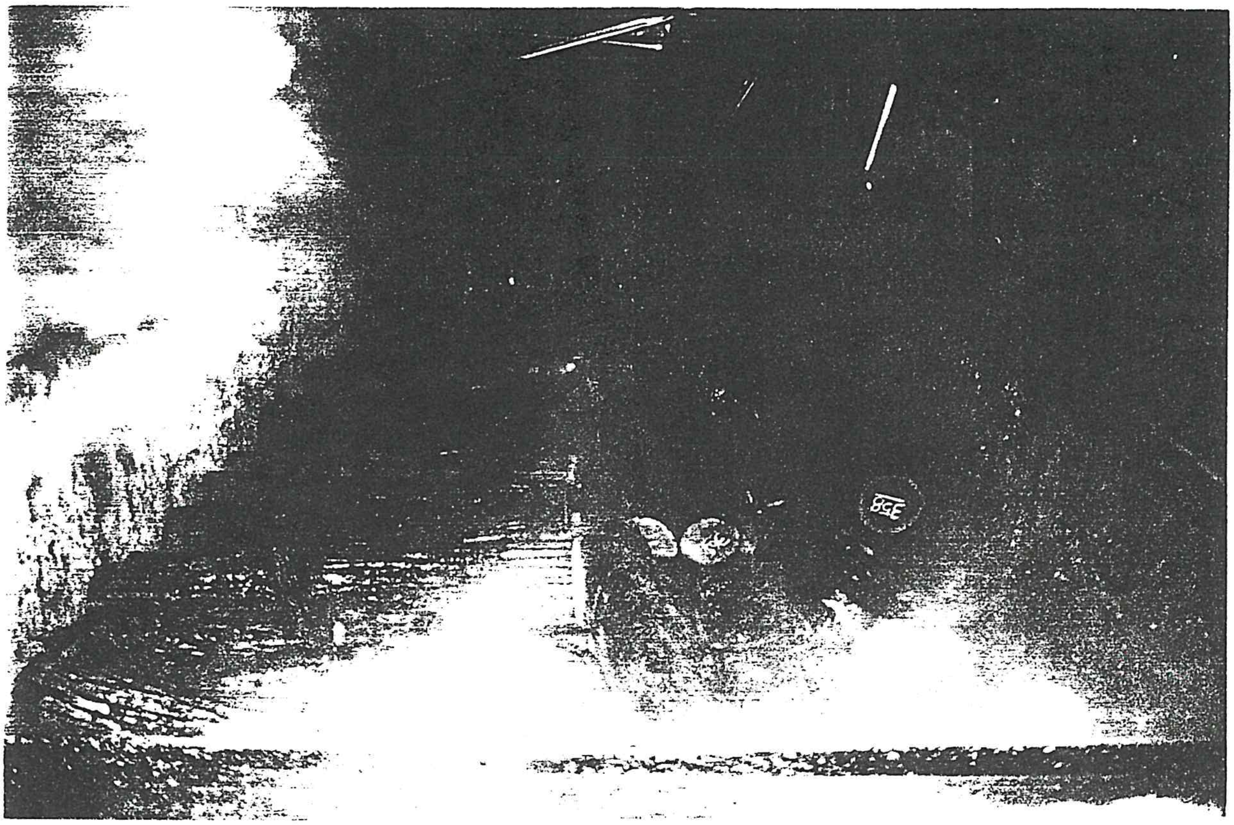


Figure F/26 - Steaming of bolts

industrial use of chestnut stems by rotary cutting, it will therefore be convenient to carefully assess whether to carry stem cross- cutting and selection at the felling point, so as to use to the greatest profit each portion suitable for such a transformation, thus limiting transportation costs to the actually used raw material, or to put such operations off to the material arrival at the plant yard, where they can at least in part be mechanised, and the waste utilised for chip production or as an energy source.

The cross- cutting operation yielded 169 bolts from the Isère lot, 166 from the Cévennes 1 lot, and 117 from the Cévennes 2 lot. that added to the 42 ones from the Piemonte lot, gave a total of 494 bolts for an overall volume of 49.3 m³ of timber for rotary cutting.

3.1.1.2 Losses during steam treatment

End checks often already visible since cross cutting can increase if a release of residual growth stresses is brought about by steaming.

In the steaming phase alone, as a result of the above referred stress release, 2 bolts of the Isère lot (for a volume of 0.109 m³ corresponding to 2% of the global volume of timber that underwent steam treatment) were irrecoverably split and were consequently unusable for further processing. See steam treating in the Fig. F/26.

3.1.1.3 Losses due to bark-peeling

Barking was carried out after steam-treatment. During this operation, 4 bolts had to be completely discarded, and on the remaining 10, damage was caused that led to greater rounding-off operation losses. Altogether, barking damage meant a loss estimated at 0.903 m³, corresponding to 1.9% of the total amount of timber processed.

Damage caused by barking was caused by the fact that the some bolts did not move through the rotor exactly coaxially with respect to the rotor axis, so that one or more knives cut the wood beyond the bark. This occurred both because these bolts had a limited diameter (i.e., smaller than the adjustment possibilities of the barker), and presented exceedingly irregular shapes.

3.1.1.4 Yield and waste during rotary cutting

For each bolt, veneer yield was expressed as the percentage of veneer volume (green or dried according to the operation) obtained and its initial volume. The veneer consists of whole sheets (1.50 x 1.59 m, when green, and 1,50 x 1,52 m at 10% m.c.) and strips of different widths.

The global veneer-cutting yield was calculated over 304 of the 494 bolts sent for processing, since a part of these were damaged during the initial processing phases and the rest were processed when choosing the cutting and panelling parameters. Table 2 gives the global processing yield and the waste divided as follows:

Rounding-off waste. In order to produce a continuous veneer ribbon , the bolt being processed must be perfectly cylindrical. The operation is referred to as "rounding-off" and entails waste of wood, which is the higher, the more irregular is the initial shape of the bolt (because of the presence, for instance, of tapering, non-circular sections, curvatures, knots). Rounding-off losses ought therefore to depend exclusively on the irregularity of shape of the bolt and not on the quality of the wood making it up. Since, on the account of the close succession of the phases of operation, it is not possible to measure the diameters of the barked bolts, the waste due to rounding-off includes also the volume of bark (see Fig. F/27 and Fig. F/28).

Core waste To prevent the knife from coming into contact with the chuck that grips the bolt, rotary cutting was automatically stopped at the diameter of 8.5 - 9 cm. The result was an unutilized central core, which constituted a processing waste that, percentagewise, was the greater, the smaller the initial diameter of the bolt. However, owing to the presence of flaws in the wood, in particular ring shake, checks due to release of internal growth stresses and heartwood rot, in many bolts the peeling had to be stopped at a diameter greater than the one mentioned above.

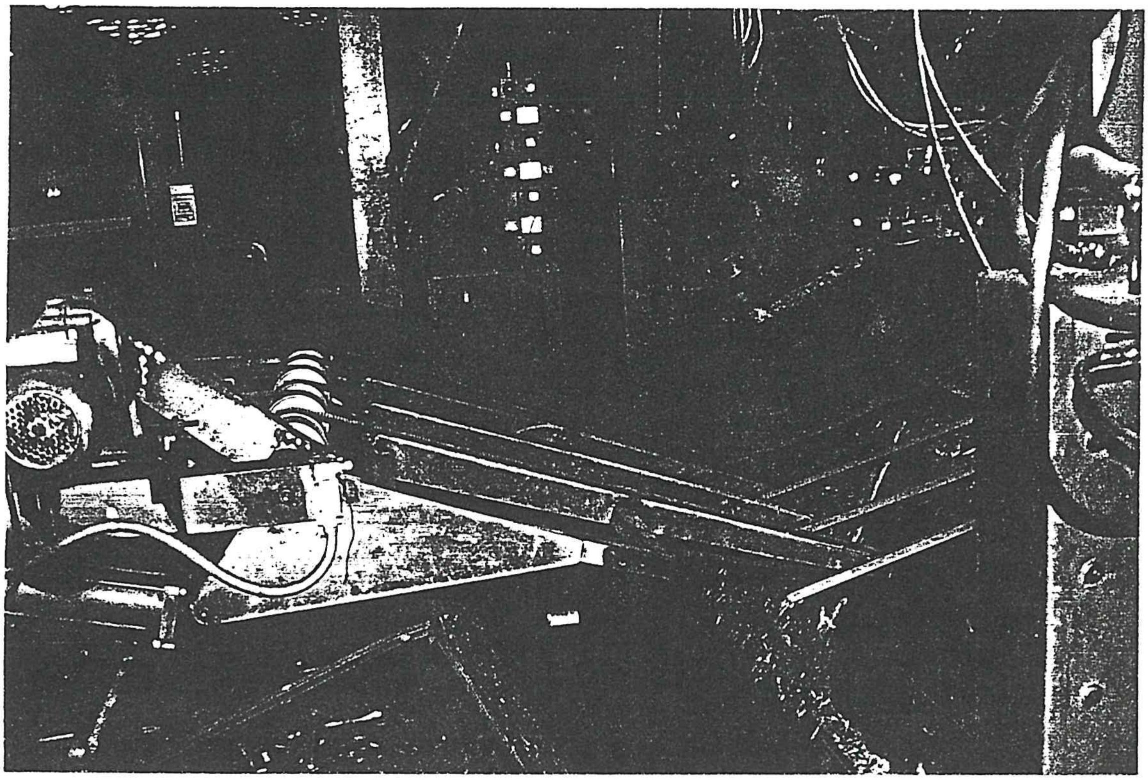


Figure F/27 - Example of continuous veneer ribbon

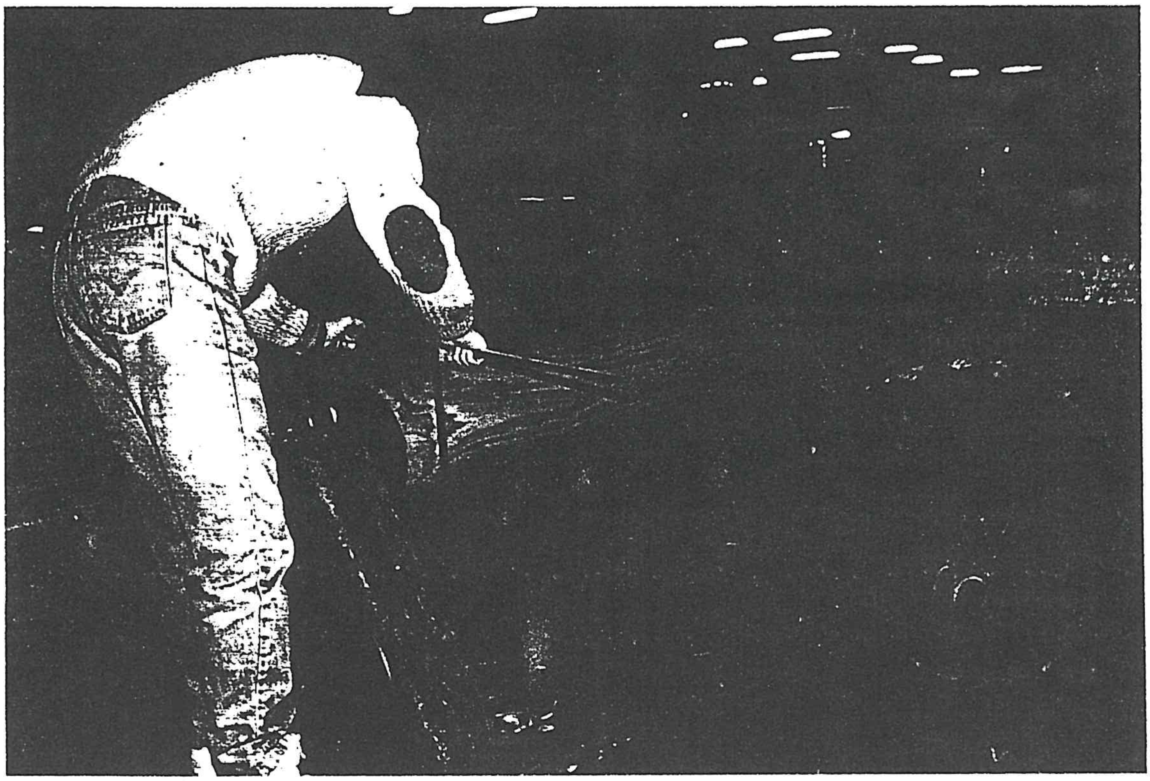


Figure F/28 - Measurement of diameter after rounding-off

Trim waste. This type of waste consists of portions of veneer of different area that present such wood connected or process induced flaws to rule out their subsequent use even for the internal layers of the panels or similar products. The amount of irrecoverable waste of veneer is above all linked to the presence of serious flaws in the wood, such as, in particular, splits and checks (which seriously jeopardise the integrity of the veneer), large knots or rot. In these losses are also included portions of wood of irregular thickness discarded when rotary cutting is resumed after any break in processing.

Drying loss. Wastage of material as the result of shrinkage and the subsequent conditioning of sheets and strips up to about 10% of stabilising moisture content. The calculation was made on the basis of the data available from literature on the average tangential shrinkage of chestnut wood (Giordano, 1986); longitudinal and radial shrinkage were considered negligible.

Jointing waste. Since the thicker LVL panels, for which is indicated the employment for the production of casing frames, will be processed by a milling machine that will make the inner layer to show, it is necessary that there are not solutions of continuity excessively big inside the panel, that means not only loosing knots, but also opened checks or bad juxtapositions of the strips. From these initial requirements and the qualitative characteristic of the obtained sheets, generally rather defective, 4 quality classes of the sheets have been established with visual criteria; 3^ and 4^ grades sheets were trimmed to produce firstly clean strips without defects and then jointed sheets; also the strips obtained directly from rotary cutting have been jointed together to produce sheets. All the losses are expressed in percentages and with reference to the initial volume of the bolts of different provenances.

Table 2 Global processing yield and waste subdivision by type

Provenance	Parameters	Mean diameter (cm)	Core waste (%)	Rounding off waste (%)	Trimming waste (%)	Drying loss (%)	Jointing waste (%)	Yield in sheet volume (%)
Cévennes 1	mean	**28.02**	**15.80**	**33.38**	**21.35**	**1.30**	**4.91**	**23.20**
	std.dev.	5.3	8.26	7.25	11.23	0.72	3.88	14.12
	n° of bolts	46						
	volume (m^3)	4.41						
Isère	mean	**27.95**	**10.03**	**30.99**	**11.43**	**2.09**	**4.31**	**41.03**
	std.dev.	5.4	4.41	8.19	7.73	0.52	3.18	10.98
	n° of bolts	119						
	volume (m^3)	11.36						
Piemonte	mean	**35.28**	**10.84**	**32.50**	**24.53**	**1.41**	**5.42**	**25.26**
	std.dev.	7.5	5.58	7.44	13.83	0.58	4.42	12.02
	n° of bolts	27						
	volume (m^3)	4.14						
Cévennes 2	mean	**28.28**	**9.93**	**42.01**	**13.32**	**1.53**	**5.73**	**27.30**
	std.dev.	4.1	3.01	8.59	7.32	0.47	5.49	9.57
	n° of bolts	112						
	volume (m^3)	10.76						
Global	mean	**28.73**	**10.93**	**35.41**	**15.29**	**1.69**	**5.02**	**31.52**
	std.dev.	5.6	5.22	9.38	9.63	0.60	4.41	12.85
	n° of bolts	304						
	volume (m^3)	30.67						

In the data processing that follows, only two of the mentioned defects will be taken into account: ring shake, (which involved 53 bolts) and diametral checks resulting from growth stresses release (19 bolts). Rot was reported in only 6 cases.

In general it may be noted that the highest yield came from the Isère lot, which was, as already pointed out in the preliminary description, the one featuring the best-shaped trunks and those of greatest length and with fewer defects.

As far as the types of waste are concerned, it is important to emphasise that the greatest waste is linked to rounding-off, during which, as an average, one third of the total volume of bolts is removed; in the case of the Cévennes 2 lot, which was the one presenting the greatest irregularities of trunk shape, this proportion rose over 40%.

3.1.1.4.1 Rounding-off losses

By analysing the different waste types it can be seen that even with a considerable variability of the bolts mean diameter and henceforth of their volumes, rounding off waste keeps about constant. The difference between each bolt diameter and its rounded off diameter, expressed in cm, has shown to increase along with the bolt diameter, as it may be seen from the graph of Fig. F/1. This pattern may be linked both to the increase in bark thickness and to a greater irregularity of shape of bolts having a larger diameter.

Consequently, considering percentage rounding-off losses alone, no advantage in peeling of larger-sized bolts was found, ring shake and checks due to release of internal stresses do not appear instead to have any effect on rounding-off losses (see Fig. F/29).

3.1.1.4.2 Core losses

In the absence of defects, core losses, expressed as a percentage of the bolt volume, present a decreasing pattern as the diameters of the bolts increase. (see Fig. F/30) Fig. F/2 shows that, in the case under examination, this pattern was not respected for a certain number of bolts. This is due to the presence of defects that brought processing to a halt at a core diameter higher than the one technically allowed, so leading to higher losses.

Table 3 - Percentage waste due to core and trimming losses, subdivided according to presence of defects (CIP = 0: bolts free from ring shake; CIP = 1: bolts with ring shake; CRT = 0: bolts free from stress checks; CRT = 1: bolts with internal stress checks).

	CIP = 0 CRT = 0	**CIP = 0 CRT = 1**	**CIP = 1 CRT = 0**	**CIP = 1 CRT = 1**
Number of bolts	235	16	50	3
Core waste (%)	9.9	12.23	14.07	16.7
Mean core diameter (cm)	8.9	10	12.5	12.2
Expected core waste (%)	9.3	9.1	6.8	6.3
Actual waste minus expected waste (%)	0.6	3.08	7.3	10.43
Mean diameter of bolts (cm)	27.9	28.1	32.6	34
Trimming waste (%)	12.5	10.7	25.9	15.97

Table 3 shows the increase in core waste with reference to the presence of the defects taken into account, over all the processed bolts. From the obtained data it can be seen that bolts affected by ring shake have much greater wastes than those expected and than those found in bolts without this defect. Ring shake has caused peeling to be interrupted at an average diameter of 11 - 12 cm. This led to a 4 % increase of core losses in the 53 bolts affected by ring shake.

The presence of checks did not seem to adversely affect the possibility of rotary cutting of the innermost parts of bolts, nor to increase the percent core losses.

Table 4 shows instead the percent core losses referring to the bolts of different provenances. It stresses a different effect of ring shake, that induced a statistically significant (according to the Student test) higher core loss in the samples from the most faulty provenances (Cévennes 1 and Piemonte), and a core loss almost twice as big as the expected one.

Table 4 Absolute and percent frequency of ring shake and check affected bolts by provenance, and percent core waste; expected residual core loss by mean diameter is given in parentheses.

Provenance	No. of bolts with ring shake	No. of bolts with checks	Core losses (%)	Residual core diameter (cm)
Cévennes 1	19 (40%)	1 (2%)	15.7(8.6)	11.3
Isere	1 (1%)	8 (7%)	10.0 (9.3)	9.0
Piemonte	19 (70%)	4 (15%)	10.8 (5.6)	11.9
Cévennes 2	14 (13%)	6 (5%)	9.9 (9.0)	9.0

3.1.1.4.3 Trim losses

Also as far as trim losses are concerned, ring shake seems to have a marked influence. Indeed, it clearly emerges from Tables 2 and 3 that the highest trimming losses come from ring shake affected bolts and in lots where this defect is more frequent, namely Cévennes 1 and Piedmont.

Moreover, the positive correlation between this waste and the core diameter proved more than significant, which stresses the fact that the link between trim losses and core losses is to be sought in ring shake: the peeling breaks, mostly linked to the presence of this defect (it caused 45 interruptions out of 51), may be correlated to a veneer ribbon presenting a lot of waste. On the basis of the findings of Table 5, ring shake accounted for an increment in trim losses of 11% of the volume of the bolt.

Also in the case of this type of waste, checks due to internal stresses do not seem to adversely affect processing yields.

3.1.1.4.4. Jointing losses

Selection, trimming and jointing of the veneer has been made on the sheets dried at 4% m.c., then conditioned in the factory to about 10% m.c.. The shrinkage caused by the two processes was calculated on the basis of data available in the literature and by considering as relevant only shrinkage in the tangential direction, that is in the breadth of the sheets and the strips. This loss of volume has consequently proved to be most relevant for the source that provided the highest yield in the form of sheets and strips, i.e. Isère.

The selection of the veneer into 4 quality classes, already mentioned under point 3.1.1.4, was made on the basis of the following criteria:

1^ quality: loosing knots are admitted provided that the add of their diameter doesn't overcome 30 mm/m^2, checks on the edge of the sheets must be not opened and less than 5 mm long.
2^ quality: loosing knots are admitted provided that the add of their diameters doesn't overcome 70 mm/m^2, checks on the edges of the sheet must be less than 20 mm long and opened less than 5 mm.
3^ quality: includes venners or portions of venners, that contain serious isolated defects (whorls of big loosing knots, rot pockets), with their elimination it is possible to obtain wide strips without defects.
4^ quality: includes veneers with defects distributed all over the surface and particularly with more than 70 mm/m^2 of loosing knots, checks on the edges more than 20 mm long or opened more than 5 mm.

Subsequently the veneers of the 2 inferior qualities underwent trimming in order to obtain flawless strips that were then jointed to obtain entire "jointed" veneers. The strips obtained directly from rotary cutting were also cut to size and jointed (see Fig. F/31 and Fig. F/32).

Table 5 Yields of different provenance divided by quality classes of dried veneers, referred to the green volume of bolts

Provenance	Mean diam. (cm)	1^quality class veneers yield (%)	2^ quality class veneers yield (%)	jointed veneers yield (%)	ring shaked bolts (%)
Cévennes 1	28.02	1.2	4.6	17.4	40
Isère	27.95	6.5	15.3	19.3	1
Piemonte	35.28	1.7	4.4	19.1	70
Cévennes 2	28.28	2.7	9.7	14.6	13
Total	28.73	3.7	10.4	17.4	17

3.1.1.5. Production of the LVL panels

According to the program, 40 LVL panels of the thickness of 56 mm and 42 panels of the thickness of 27 mm have been manufactured; each 56 mm panel is 1.45 m long and 1.45 m large and 27 mm panels are 1.4 m x 1.4 m, hence the total volume is 6.9 m^3. A quantity of about 3.3 m^3 of dried veneer is still available for further testing.

The production technique are described in the section 2.2.1.2. (see also Fig. F/33 and Fig. 34)

The 56 mm thick panels have been composed as follows:

Comp.1: 2 exterior layers with veneers of 1^ quality class and inner layers of jointed veneers without defects (see Fig. 35);

Comp.2: 2 exterior layers with veneers of 1^ quality class and 21 inner layers of 2^ quality class with a permissible number of loosing knot and/or open splits (see Fig. 36).

based on the availability of the dried veneers the panels have been produced conforming to the following table which reports the number and type of composition for each lot of origin:

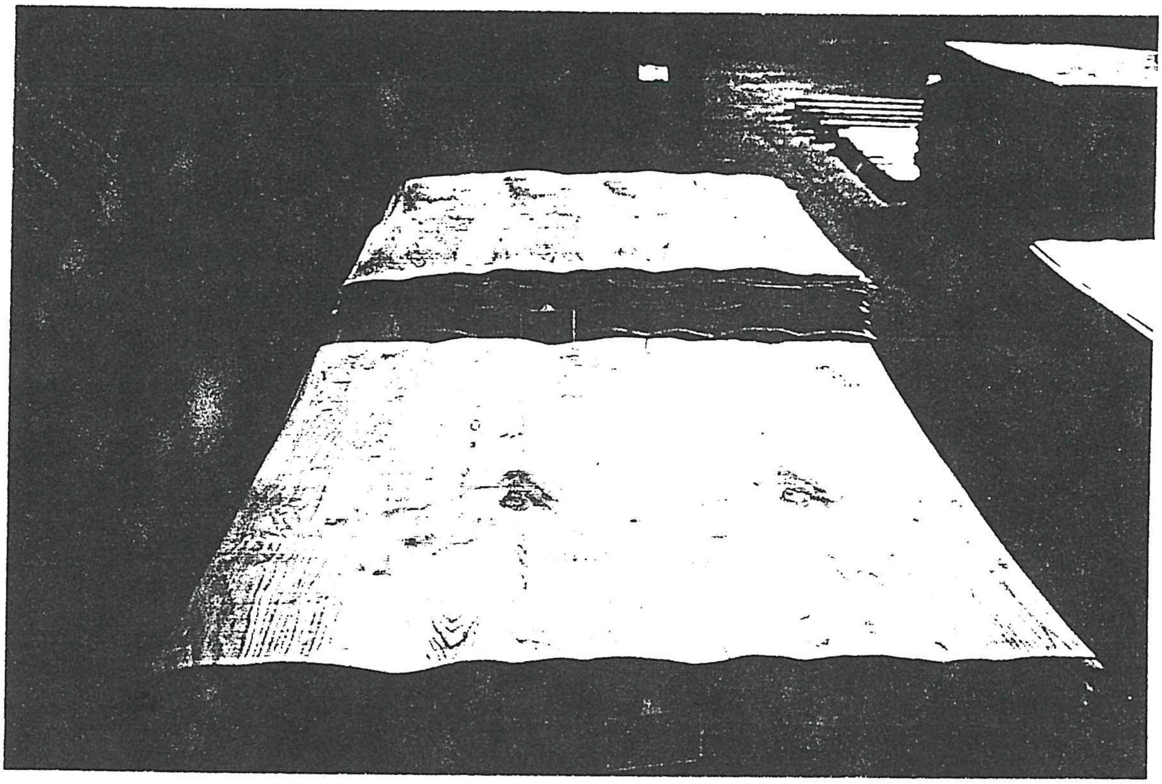


Figure F/31 - Dried veneers

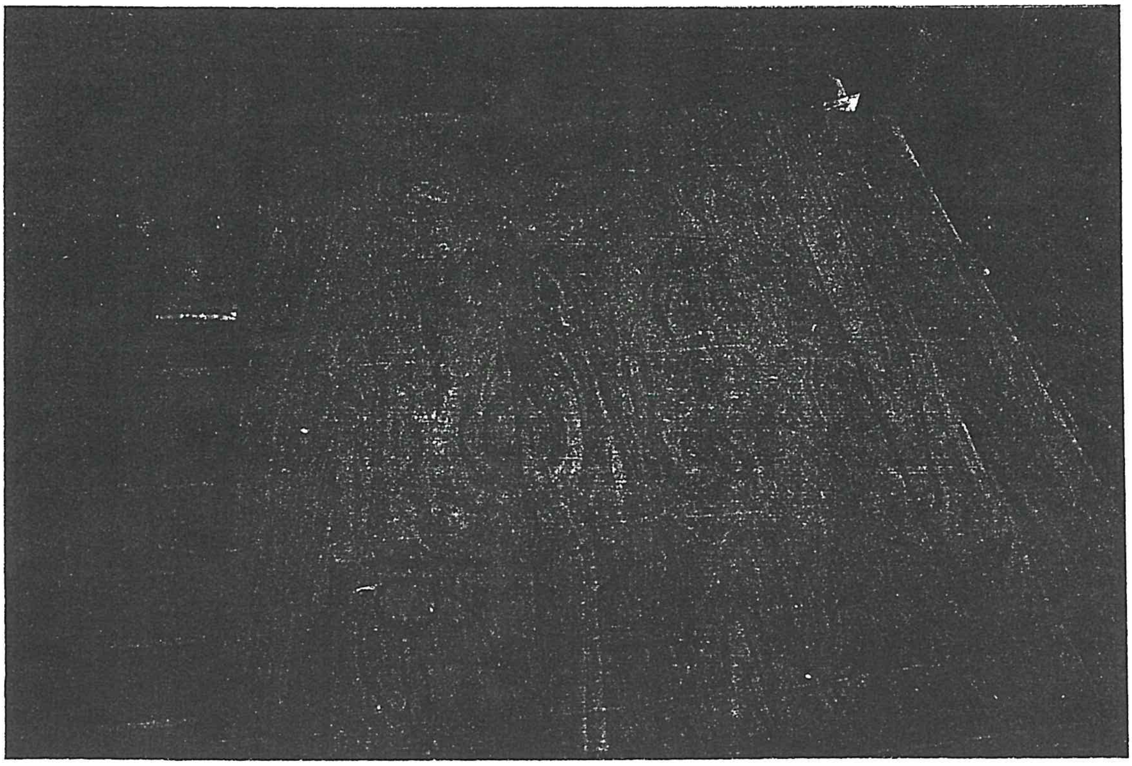


Figure F/32 - Jointed veneers

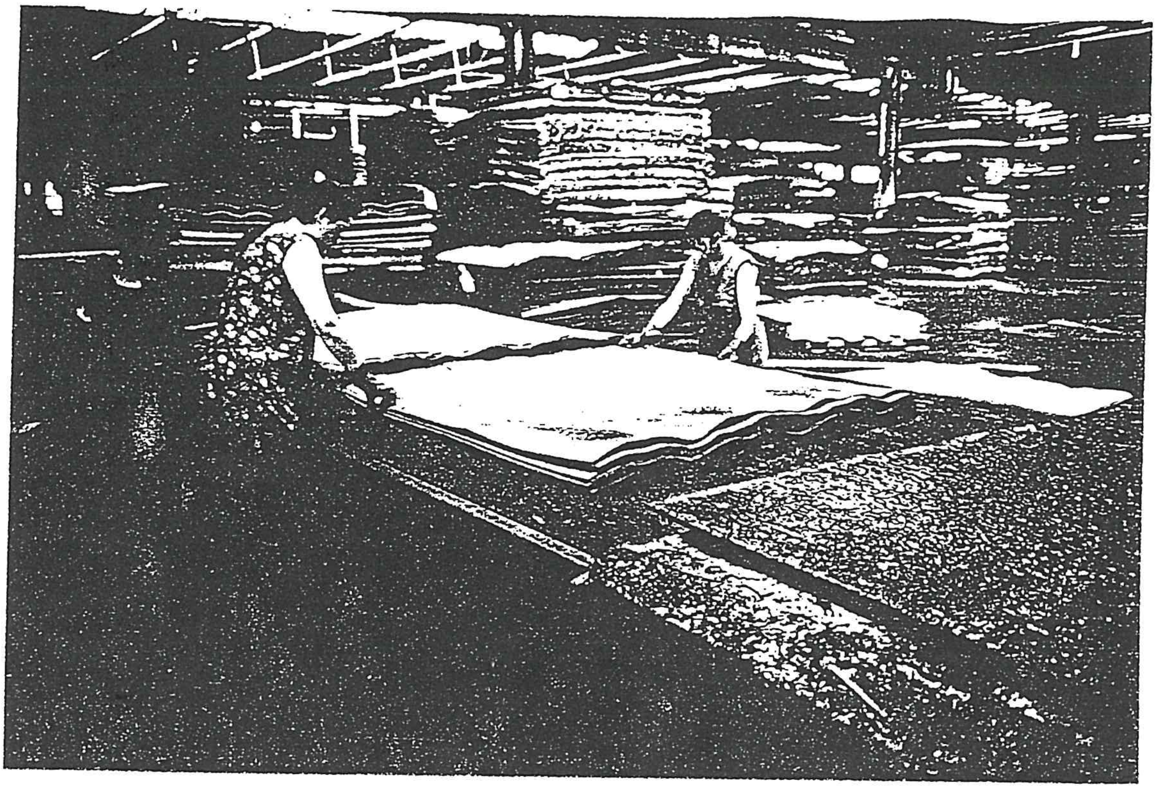


Figure F/33 - Composition of panels before pressing

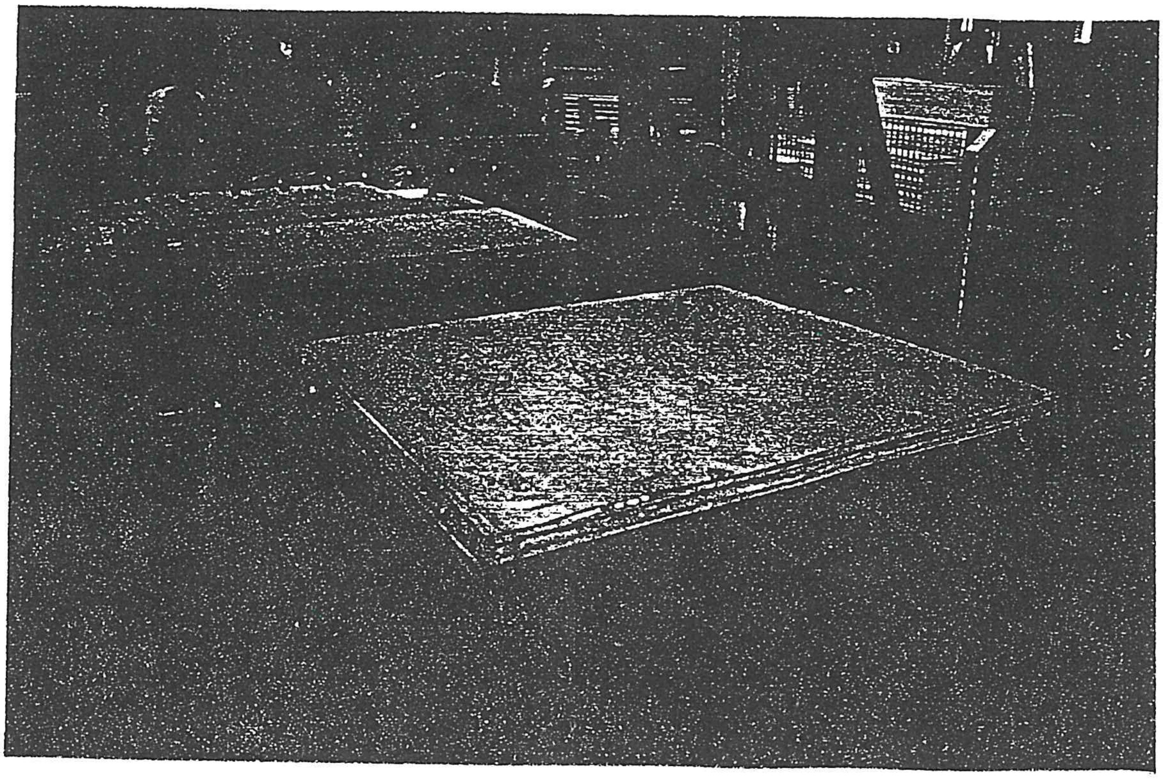


Figure F/34 - LVL panels at the cooling phase, just after pressing

Table 6 - LVL panels, thickness 56 mm

	Cévennes 1	Isère	Piemonte	Cévennes 2	Total
Comp. 1	3	6	3	6	18
Comp.2	3	8	3	8	22
Total	6	14	6	14	40

The criteria of composition have been choose in order to optimise the use of the veneers and to produce LVL panels of different quality (in this context composition n° 1 should be better than n°2).

The LVL panels of the thickness of 27 mm were manufactured using exclusively the veneers of Cévennes 1 and Isère.

In the case of Isère provenance, 3 different composition have been adopted (for a total number of 12 panels) in order to study the shape stability and to select the best lay-up which could avoid the development of warp and distortion of the panel. The composition 1, 2 and 3 foresee all that panel faces are composed of 1^ and 2^ choice veneers, the central layer is a jointed veneer and the other 10 inner layers are of 2^ quality class. They differ the way the loose faces (which presents peeling checks) and those compressed of the inside veneers are arranged. Other 20 panels were produced using veneers of 1^ quality class for the exterior layers and jointed veneers for the inner layers; the above mentioned lay-ups are referred in the tab. 7.

Table 7 - LVL panels, thickness 27 mm

	Cévennes 1	Isère	Total
Comp.1		4	4
Comp. 2		4	4
Comp. 3		4	4
Jointed inner layers	20	10	30
Total	20	22	42

The 82 produced panels needed 1382 dried and conditioned veneers, for a total volume of 8.2 m^3; so the waste due to pressing, edging and sanding of the panels is equal to the 16% of the volume of dried sheets.

Then the mean yield is (31.5 * (1- 0.16))% = 26.5 % of the volume of bolts, considering that in the case in which we produce panels of 56 mm at least 9% in number of venners of 1^ quality (equivalent in the advised case, to the 3% of the volume of bolts) is needed, while if 27 mm are produced the aforesaid percent doubles. Employing gluing jointing machine may be we can use the jointed veneers also for the panels faces, providing so for the need of complete veneers of 1^ quality class.

3.1.2 Relation between raw material and yield [Teams involved: 07] (team writing: 07)

Knots

The positions, number and types of knots visible from the outside were noted on a sample of 29 bolts in order determine any correlations between these flaws and the veneer yields.

The knots were classified as sound, loose, pin knots and covered knots. The diameters of live and dead knots were measured, whereas all the covered and pin knots were attributed with equal diameters of 10 and 5 mm respectively.

The majority of covered knots can be considered dead as pruning is not normally practised in chestnut coppices (see Fig. F/37 F/38).

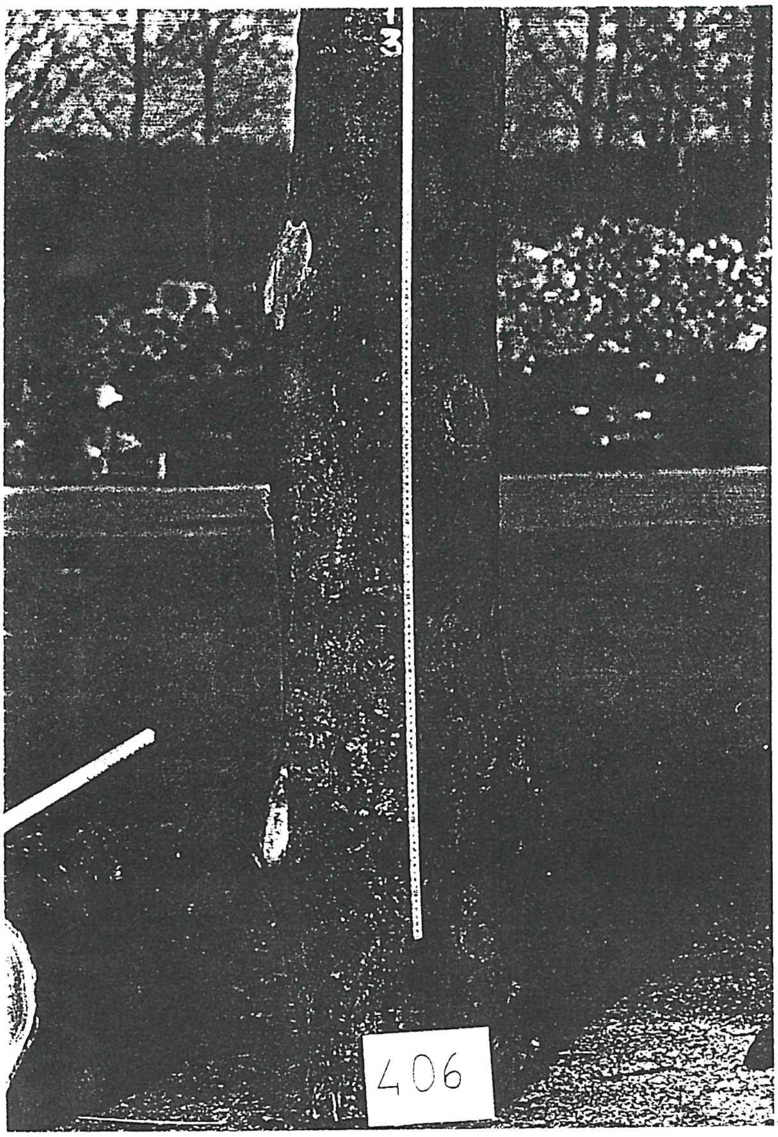


Figure F/37 - Sound knots

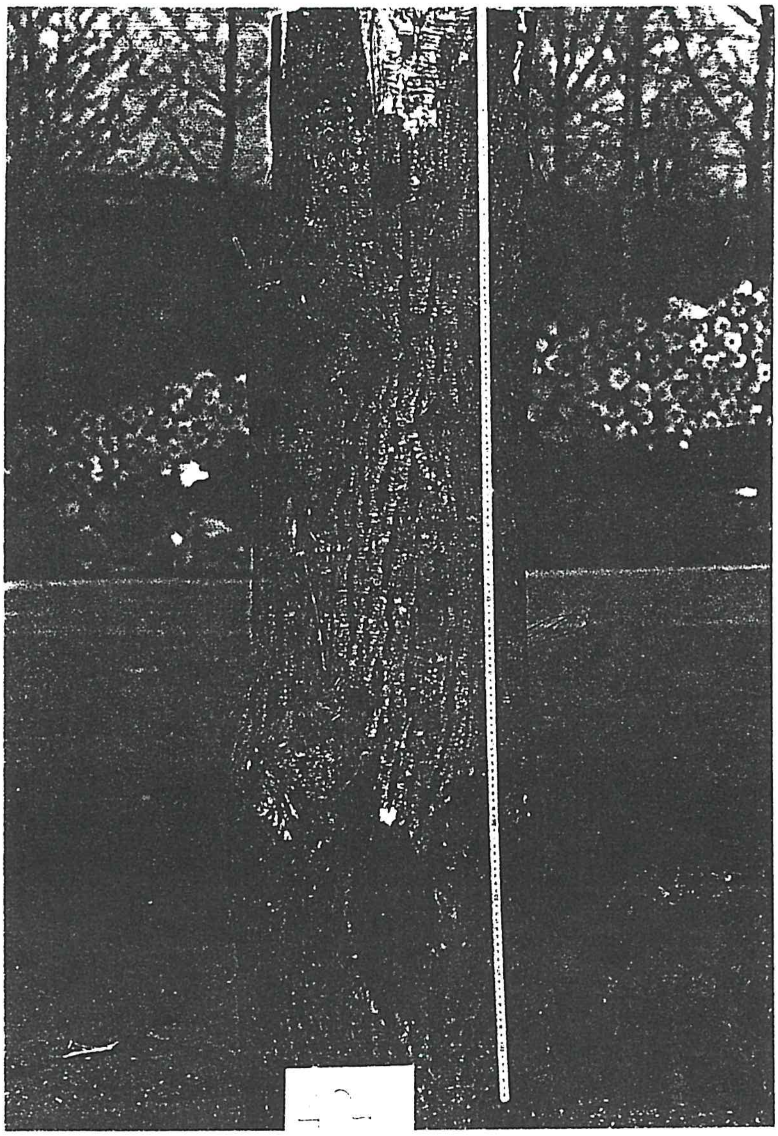


Figure F/38 - Dead knots

For each bolt and for each type of knot, the number of knots, the sum of their diameters and their total surface area were calculated. The principal results are given in table 8.

Table 8 - Principal data concerning the nodosity of the 29 sample bolts from Cevennes 2. Length of bolts 1.5 m

	sound	loose	pin	covered	total
Average no. of knots	1.9	3.2	2.7	5.1	12.9
Average diameter of knots (mm)	46	25	5*	10*	33

* = value not measured, but based on an estimate.

The data in the table confirms the abundance of knots in the Cevennes 2 lot and it can be inferred that at least 50% of the knots (loose and covered) will give rise to solutions of continuity in the veneer.

However, no significant correlations emerged between the processing yields and the presence of knots. Of the process wastes, only those from rounding off show a significant, though weak, relation to the total number of knots, and this can be explained by the fact that as the nodosity increases so does the irregularity of the shape of the stem. Even the partial yields of first and second quality class and jointed veneers did not show any connection with their presence. The absence of any quantitative correlations should not however lead to the conclusion that the knots do not in fact limit the processing yields, especially those of the face veneers; in the Cevennes 2 lot the knots do not play a decisive role that is easily distinguishable from the many factors influencing the veneer yield. The negative effect of knots probably combines with and is hidden by that caused by defects in shape. Moreover, the limited number of bolts considered prevents any application of the results obtained to the other lots.

A lot of timber with less knots have probably yields higher than a lot with more knots, but it cane be affirmed that among the stems of the same origin, i.e. from Cevennes 2, differences of nodosity have not significantly influenced the yield of individual pieces.

Irregularity of shape

Over the entire production process the most incisive waste occurs during the cutting of the material acquired as stems or trunks. The most significant defect therefore concerns the actual shape of the trunks. The problem can be viewed from two angles: in the first place the processed material can be considered as representative of the typical population of mature coppices, and hence the waste produced can also be evaluated as representative. It can thus be calculated that in general only 2/3 of the best material derived from a mature chestnut coppice can be selected for veneer processing. On the other hand, it could be concluded that by improving the organisation of work in the forests, equalising could be carried out at the felling site so that the transport costs and work times in the mill could be restricted.

Even in the actual rotary cutting process, the major processing losses occurred during rounding-off operations (bark-peeling and rounding-off); hence, the defects that most affect yield are those related to the shape of the bolts (see Fig. F/39).

Ring shake

All the categories of waste and the final yield give very significantly different results for according to the presence or absence of ring shake on the bolts, except for wastes due to rounding off and to jointing the sheets, that do not provide significance for the Student t test where ring shake is present, which was altogether responsible for an increase in losses of 17 % of the initial bolt volume (Tables 9 and 10).

Table 9 - Mean yield and waste of bolts without ring shake (251)

	Mean (cm)	**Volume (m^3)**	**Rnd-off loss (%)**	**Core loss (%)**	**Exp.core loss (%)**	**Trim loss (%)**	**Drying loss (%)**	**Jointing loss (%)**	**Yield (%)**
Mean	27.90	23.69	35.22	10.03	9.28	12.34	1.87	5.2	35.21
Max.	53.50	0.34	64.36	36.84		44.00	3.29	23.9	70.33
Min	19.50	0.04	6.25	1.23		0.38	0.00	0	0.00
Std. dev.	4.75	0.04	9.11	3.87		7.69	0.52	4.5	11.45

Table 10 - Mean yield and waste of bolts with ring shake (53)

	Mean (cm)	**Volume (m^3)**	**Rnd-off loss (%)**	**Core loss (%)**	**Exp. core loss (%)**	**Trim loss (%)**	**Drying loss (%)**	**Jointing loss (%)**	**Yield (%)**
Mean	32.67	6.99	36.04	13.99	6.77	25.28	1.09	4.3	18.99
Max.	53.50	0.34	73.31	41.87		53.92	3.06	17. 3	56.81
Min	21.00	0.05	18.14	2.83		0.34	0.00	0	0.00
Std. dev.	7.19	0.06	10.40	8.41		12.14	0.57	3.7	10.90

Regarding the qualitative yield, the presence of ring shake caused a sharp reduction in the production of 1st and 2nd *choice* sheets. Very significant differences result in the yields of 1st and 2nd *choice* sheets between bolts with ring shake and those without (see table 11). Moreover, it is interesting to note that the percentage yields of 1st and 2nd *choice* sheets show a negative correlation with the yield of jointed sheets. Therefore, as a general rule, the bolts that supply more higher quality sheets also produce less lower quality sheets for further trimming and jointing (see Fig. F/40).

Table 11 - Differences in qualitative yields between bolts with and without ring shake

	1^	**2^**	**jointed**
Bolts without ring shake	4.5	12.6	18.1
Bolts with ring shake	1.2	3.1	14.7

Growth stresses checks

The checks due to release of internal growth stresses did not cause any statistically appreciable difference in processing losses, probably also on account of the steam treatment technique that has been developed, which makes it possible to restrain the effects of HTR, and hence to limit the evolution of this defect (see Fig. F/40).

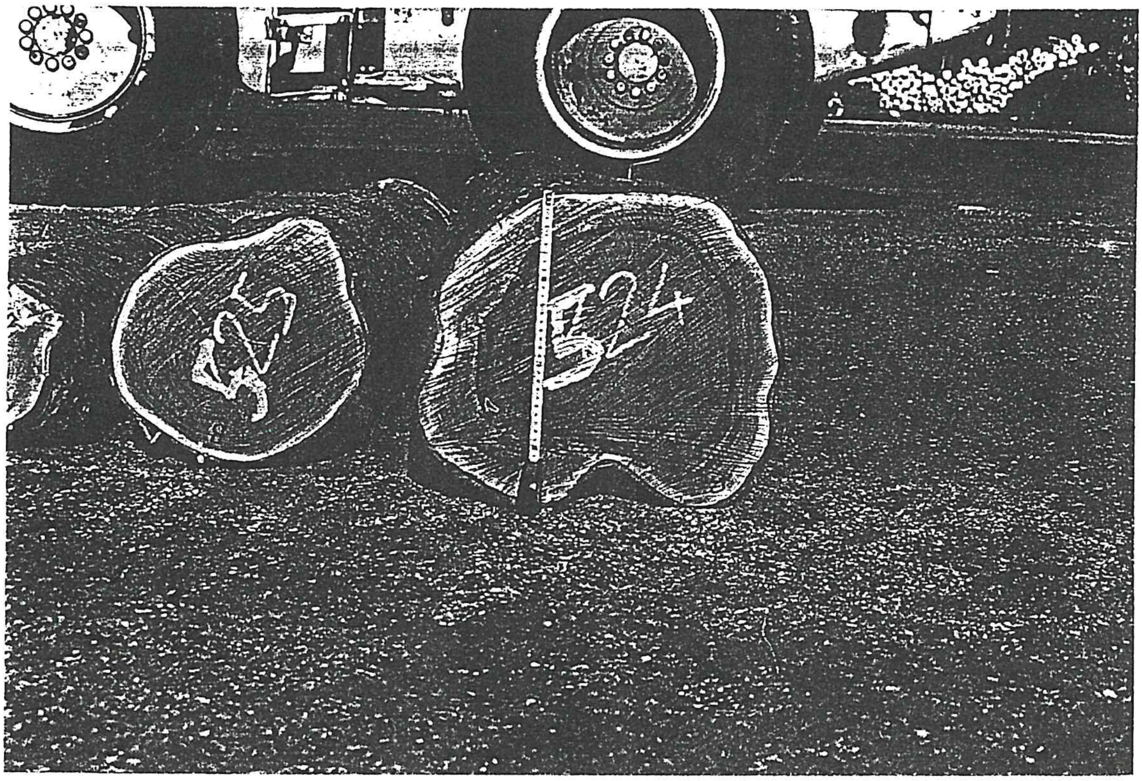


Figure F/39 - Irregularity of shape

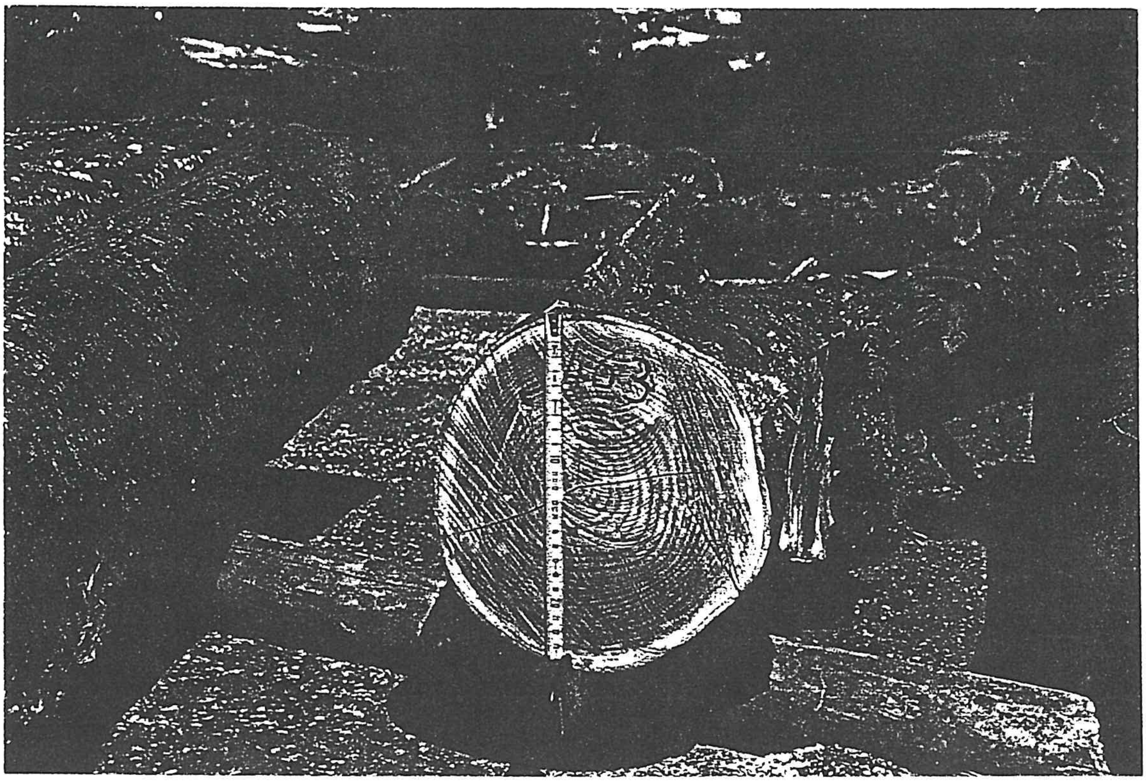


Figure F/40 - Growth stress checks

Table 12 - Different yields and losses between bolts with and without diametral checks

		Mean (cm)	Core loss (%)	Rnd-off loss (%)	Trim loss (%)	Drying loss (%)	Jointing loss (%)	Yield (%)
Bolts without	**Mean**	28.71	10.84	35.49	15.52	1.68	5.15	31.31
	Std. dev.	5.59	5.07	9.50	9.67	0.61	4.49	12.90
diametral checks	**Count**	285						
Bolts with	**Mean**	29.07	12.31	34.15	11.79	1.84	5.38	34.54
	Std. dev.	5.09	6.98	7.32	8.71	0.56	3.01	12.00
diametral checks	**Count**	19						

In the stands investigated, the incidence of shape defects, of ring shake and of checks due to release of internal stresses, increases with the diameter of the bolts. Hence, the expected increase in yield in bolts of larger diameter as a consequence of the lower theoretical incidence of the waste due to the residual core and to rounding-off did not materialise (Giordano, 1983).

3.1.3 Proposition for roundwood assessing [Teams involved: 07,09,13] (team writing: 07)

On the basis of the yields obtained, and assuming that the aesthetic and practical qualities of the LVL produced can satisfy the needs of window manufacturers, some indications are given of the dimensional and qualitative requirements that bolts destined for this type of production must meet.

The minimum diameter at the top must be 22 cm, for bolts that are 1.5 m in length. It should be borne in mind that bolts with larger diameters do not give higher yields because they tend to have more prominent defects and more serious flaws in the wood. It would seem difficult to use bolts longer than 2 m again because of the irregular shapes of the original trunks. Unless butt jointing is adopted, such lengths would exclude the use of chestnut LVL for the production of doors and French windows.

The presence of ring shake imposes no technical limits on rotary cutting, but it reduces its yield by more than 15% of the volume of the bolt and makes the number of 1^ quality class sheets very low.

Cracks due to the release of internal stress do not seem to impose a limit on this type of processing, as long as a suitable steam treatment cycle is adopted.

The presence of feather rot prevents regular rotary cutting. Moreover this defect is quite rare in chestnut stems of small diameters.

The presence of knots, abundant in the raw material, does not seem to have any direct influence on quantitative yields. Sound knots present a problem only if their dimensions (5-6 cm in diameter) are such as to result in an accentuated irregularity of the shape of the trunk or in coarsening of the surface of the veneer. The loose knots prevent a sufficient quantity of sheets from being obtained for face layers and cannot be completely eliminated by trimming because they are too abundant. Sometimes they will damage the cutting edge of the veneer-cutter. Pin knots are very frequent are also loose in chestnut stems from coppice stands. They are caused by epicormic shoots resulting from attacks of canker. They give rise to solutions of continuity and alterations in the colour of the wood. Regarding the selection of the raw material, it is generally advisable to discard bolts with knots whose diameters are more than 6 cm, whereas it is more difficult to quantify the maximum number of knots admissible on each bolt. In fact the number of knots per metre of sheet depends on the number of knots on the bolt and on the diameter at which the veneer is cut. For example a bolt that is 1.5 m long with three loose knots with diameters of 1 cm and a diameter with the bark on of 25 cm, that is reduced to 21 cm after rounding off, provides firstly 1^ quality class veneers, and then, when the rotary cutting diameter is reduced to 15 cm, it produces 2^ quality veneers.

It is to be concluded that, by selecting regularly shaped stems that are free of ring shake, yields of dried veneer can be obtained, that are equal to about 40% of the original volume, together with a sufficient percentage of veneers for face layers (characteristics that were found in the lot from Isère). If a proportion of bolts with ring shake (never more than 20%) are accepted together with irregularly shaped bolts, yields of around 30% can be obtained with a percentage of face veneers that is sufficient only for the production of very thick panels (average characteristics of the set of lots examined). Lots with inferior characteristics do not seem suitable for this type of processing.

3.1.4 Main properties of LVL [team: 06] (writing: 06) [mn]

3.1.4.1 Properties of 56 mm squared pieces [team involved: 06](writing: 06) [mn]

3.1.4.1.1 Mechanical properties: bending and shear [team involved: 06] (writing: 06) [mn]

In the following Tables, the main physical and mechanical properties, such as the mass density, the moisture content, the bending modulus of elasticity, the shear modulus and the bending strength, are reported.

Preliminary sample

In order to give the preliminary information to the other Teams involved and to check the test methodologies, basic tests were performed on a preliminary 27 mm and 56 mm thick panels production, obtained by Chestnut log from France and Italy: Cévennes, Isère (France) and Torre Canavese (Italy).
From the 56 mm thick panels, squared pieces 56 by 56 mm by 1,45 m length were sawn; on that sample the shear modulus was not carried out.
The final results are reported in the following Tables:

- /3.1.4/ 1 shows the properties of the whole set of specimens tested flatwise, that is with the glue layers perpendicular to the load;
- /3.1.4/ 2 shows the properties of the whole set of specimens tested edgewise, that is with the glue layers parallel to the load;
- /3.1.4/ 3 shows the properties of whole set of squared pieeces of that sample.

That last Table shows that the specimens tested were 34; referring to mean properties of solid Chestnut, this LVL sample results characterised by an high density (642 kg7m^3) and an high mean value of bending strength (f_m mean: 73,1 N/mm$_2$); note that also the minimum value of strength is to be considered quite high (f_m minimum: 59,8 N/mm$_2$). The bending modulus of elasticity (13700) is comparable to high quality solid Chestnut.
The good mean results, as well as the small Coefficient of Variation (CoV%), indicate that the pieces showed to have homogeneous and reliable properties.
In the subsequent pages, the Tables report the properties of each provenance, divided into flat- and edgewise setting.
In the subsequent pages, the Tables report the properties of each provenance divided into flat- and edgewise setting:

- /3.1.4/ 4 and 5: Cévennes
- /3.1.4/ 6 and 7: Isère

- /3.1.4/ 8 and 9: Torre C.se

Referring to the source, the higher mean mechanical performances are reached by Torre C.se provenance, then by Cévennes and finally by Isère provenances.

__**Preliminary sample**__: whole set of specimens from **Cévennes, Isère, Torre Canavese** provenances

All provenance Flatwise				
Property	**Em**	**fm**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kg/m^3)	(%)
n	19	19	19	19
Average	**13600**	**72,6**	**640**	**11,8**
StDev	1177	7,5	21	0,41
min	12052	59,8	579	11,1
Max	15783	87	665	12,4
CoV (%)	9	10,3	3	3,48

Table /3.1.4/ 1 - *Bending properties of whole set of squared pieces tested flatwise: all provenance, preliminary sample*

All provenance Edgewise				
Property	**Em**	**fm**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kg/m^3)	(%)
n	15	15	15	14
Average	**13700**	**73,8**	**644**	**12**
StDev	1112	5,78	14,1	0,35
min	12044	64,3	624	11,4
Max	15400	84,3	668	12,6
CoV (%)	8,09	7,84	2,19	2,9

Table /3.1.4/ 2 - *Bending properties of whole set of squared pieces tested edgewise: all provenance, preliminary sample*

Preliminary sample **Whole set**				
Property	**Em**	**fm**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kg/m^3)	(%)
n	34	34	34	33
Average	**13700**	**73,1**	**642**	**11,9**
StDev	1134	6,7	18	0,39
min	12044	59,8	579	11,1
Max	15783	87	668	12,6
CoV (%)	8,31	9,17	2,81	3,29

Table /3.1.4/ 3 - *Bending properties of squared pieces whole set: all provenance of the preliminary sample*

Preliminary sample: whole set of specimens from **Cévennes** provenance (noted **C56/TL/G)**)

Cévennes Flatwise				
Property	**Em**	**fm**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kg/m^3)	(%)
n	6	6	6	6
Average	**13500**	**72,2**	**621**	**11,6**
StDev	1446	7,2	22	0,3
min	12052	59,9	579	11,2
Max	15783	80,2	645	11,9
CoV (%)	10,7	10	3,55	2,2

Table /3.1.4/ 4 - *Bending properties of squared pieces tested flatwise: provenance Cévennes, preliminary sample (noted C56/TL/G)*

Cévennes Edgewise				
Property	**Em**	**fm**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kg/m^3)	(%)
n	5	5	5	5
Average	**13000**	**72,3**	**641**	**11,7**
StDev	1152	3,7	8	0,2
min	12044	69,8	631	11,4
Max	14748	78,9	653	12
CoV (%)	8,85	5,2	1,3	1,9

Table /3.1.4/ 5 - *Bending properties of squared pieces tested edgewise: provenance Cévennes, preliminary sample (noted C56/TL/G)*

Preliminary sample: whole set of specimens from **Isère** provenance (noted **Is56/TL/G**)

Isère Flatwise				
Property	**Em**	**fm**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kg/m^3)	(%)
n	7	7	7	7
Average	**13600**	**68,9**	**638**	**11,7**
StDev	1123	7,1	6	0,4
min	12378	60,9	630	11,1
Max	15393	80,3	649	12,3
CoV (%)	8,27	10,2	1,02	3,5

Table /3.1.4/ 6 - *Bending properties of squared pieces tested flatwise: provenance Isère, preliminary sample (noted Is56/TL/G)*

Isère Edgewise				
Property	**Em**	**fm**	**ρ**	**ω**
Unit	(N/mm²)	(N/mm²)	(kg/m³)	(%)
n	5	5	5	5
Average	**14400**	**70,3**	**632**	**12,1**
StDev	740	4,2	11	0,4
min	13748	64,3	624	11,6
Max	15400	74,8	649	12,6
CoV (%)	5,12	5,9	1,67	7,7

Table /3.1.4/ 7 - *Bending properties of squared pieces tested edgewise: provenance Isère, preliminary sample (noted Is56/TL/G)*

<u>Preliminary sample</u>: whole set of specimens from Torre Canavese provenance (noted T56/TL/G)

Torre C.se Flatwise				
Property	**Em**	**fm**	**ρ**	**ω**
Unit	(N/mm²)	(N/mm²)	(kg/m³)	(%)
n	6	6	6	6
Average	**13700**	**77,4**	**662**	**12,1**
StDev	1166	6,4	2	0,4
min	12306	70,4	659	11,6
Max	14989	87	665	12,4
CoV (%)	8,52	8,3	0,34	3,2

Table /3.1.4/ 8 - *Bending properties of squared pieces tested flatwise: provenance Torre Canavese, preliminary sample (noted T56/TL/G)*

Torre C.se Edgewise				
Property	**Em**	**fm**	**ρ**	**ω**
Unit	(N/mm²)	(N/mm²)	(kg/m³)	(%)
n	5	5	5	4
Average	**13800**	**78,7**	**659**	**12,1**
StDev	1092	6,2	8	0,4
min	12403	69,9	650	11,6
Max	14879	84,3	668	12,4
CoV (%)	7,93	7,8	1,18	3

Table /3.1.4/ 9 - *Bending properties of squared pieces tested edgewise: provenance Torre Canavese, preliminary sample (noted T56/TL/G)*

Main sample

The 56 mm thick panels main sample was manufactured using Chestnut log from France and Italy: 2 lots from Cévennes -France - (noted C1 and C2), 1 from Isère - France - (noted I) and 1 from Torrazzo - Italy.
Looking at the previuos experience with the preliminary sample, from 56 mm thick panels squared pieces 56 by 56 mm by 1,45 m length were sawn.
The final results of the whole set of specimens (all provenances) are reported in Table /3.1.4/ 10.
The mechanical tests - bending modulus of elasticiticity, bending strength and shear modulus - were carried out on 131 specimens; referring to mean properties of solid Chestnut, this LVL sample results characterised by a quite high density (624 kg/m^3) and a bending strength high value (f_m: 69,3 N/mm_2); the bending modulus of elasticity (E_m: 12500 N/mm_2) is comparable to mean quality solid Chestnut, while the shear modulus (G: 0,90 k N/mm_2) results not higher than solid Chestnut (G = 1,01 k N/mm_2, from tests carried out for different purposes on a different sample by team 06, in the framework of a research on solid Chestnut); it should be noted the wide range of G modulus (Coefficient of Variation: 27,7%). The mean results are generally lower than the previous sample.
In the subsequent pages the Tables report the properties of each provenance divided into flat- and edgewise setting:

- /3.1.4/11 shows the properties of the set of specimens from Cévennes1 tested edgewise, /3.1.4/12 flatwise and /3.1.4/13 the of whole set;
- /3.1.4/14 shows the properties of the set of specimens from Cévennes2 tested edgewise, /3.1.4/15 flatwise and /3.1.4/16 the of whole set;
- /3.1.4/17 shows the properties of the set of specimens from Isère tested edgewise, /3.1.4/18 flatwise and /3.1.4/19 the of whole set;
- /3.1.4/20 shows the properties of the set of specimens from Torrazzo tested edgewise, /3.1.4/21 flatwise and /3.1.4/22 the of whole set.

A limited number of specimens were not conditioned at 20°C - 65° HR, but at uncontrolled (dryer) conditions.
Referring to the source, the higher mechanical performances are reached by Isère provenance, then by Torrazzo provenance and finally by the two Cévennes lots.

Main sample **Whole set**				
Property	**Em**	**fm**	**G**	**ρ**
Unit	(N/mm^2)	(N/mm^2)	(kN/ mm^2)	(kg/m^3)
n	131	127	128	127
Average	**12500**	**69,3**	**0,90**	**624**
StDev	1803	8,7	0,25	29
min	9584	47,1	0,56	567
Max	15138	94,9	1,84	693
CoV (%)	14,5	12,6	27,7	4,7

Table /3.1.4/ 10 - *Bending and shear properties of whole set of specimens from Cévennes, Isère and Torrazzo*

Main sample: specimens from **Cevennes1** provenance (noted **C1**)

Cevennes 1 Flatwise					
Property	**Em**	**fm**	**G**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kN/mm^2)	(kg/m^3)	(%)
n	11	9	10	9	10
Average	**12600**	**61,6**	**0,95**	**631**	**11,4**
StDev	1941	7,43	0,13	23	0,34
min	13419	48,5	0,81	608	10,9
Max	15138	71,5	1,15	671	11,9
CoV (%)	15,3	12,1	13,7	3,72	3,02

Table /3.1.4/ 11 - *Bending and shear properties of squared pieces tested flatwise: provenance Cevennes 1 (noted C1)*

Cevennes 1 Edgewise					
Property	**Em**	**fm**	**G**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kN/mm^2)	(kg/m^3)	(%)
n	11	9	11	9	11
Average	**11800**	**67,2**	**0,89**	**639**	**11,6**
StDev	1439	4,7	0,36	23	0,47
min	9584	61,3	0,57	614	10,8
Max	14207	72,8	1,84	679	12,3
CoV (%)	12,2	6,9	40,5	3,6	4,07

Table /3.1.4/ 12 - *Bending and shear properties of squared pieces tested edgewise: provenance Cevennes 1 (noted C1)*

Cevennes 1 Whole set					
Property	**Em**	**fm**	**G**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kN/mm^2)	(kg/m^3)	(%)
n	22	18	21	18	21
Average	**12200**	**64,4**	**0,92**	**635**	**11,5**
StDev	1723	6,69	0,27	23	0,42
min	9584	48,5	0,57	608	10,8
Max	15138	72,8	1,84	679	12,3
CoV (%)	14,1	10,4	29,5	3,6	3,67

Table /3.1.4/ 13 - *Bending and shear properties of whole set of specimens from Cevennes 1 (noted C1)*

Main sample: specimens from **Cevennes2** provenance (noted **C2**)

Cevennes 2 Flatwise					
Property	**Em**	**fm**	**G**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kN/mm^2)	(kg/m^3)	(%)
n	25	24	25	24	26
Average	**11000**	**65**	**1,21**	**619**	**11,8**
StDev	883	10	0,25	15	0,72
min	9745	47	0,86	588	10,6
Max	12479	82	1,6	643	13,2
CoV (%)	8	15	20,3	2,5	6,12

Table /3.1.4/ 14 - *Bending and shear properties of squared pieces tested flatwise: provenance Cevennes 2 (noted C2)*

Cevennes 2 Edgewise					
Property	**Em**	**fm**	**G**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kN/mm^2)	(kg/m^3)	(%)
n	25	25	23	25	25
Average	**10600**	**63,8**	**0,73**	**622**	**11,8**
StDev	483	3,98	0,11	14	0,77
min	9675	57,4	0,56	590	10,6
Max	11488	74,9	0,99	648	13,2
CoV (%)	4,5	6,2	15,4	2,3	6,6

Table /3.1.4/ 15 - *Bending and shear properties of squared pieces tested edgewise: provenance Cevennes 2 (noted C2)*

Cevennes 2 Whole set					
Property	**Em**	**fm**	**G**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kN/mm^2)	(kg/m^3)	(%)
n	50	49	48	49	51
Average	**10800**	**64,2**	**0,98**	**621**	**11,8**
StDev	733	7,28	0,31	15	0,74
min	9675	47,1	0,56	588	10,61
Max	12479	82,1	1,6	648	13,24
CoV (%)	6,76	11,3	31,3	2,36	6,28

Table /3.1.4/ 16 - *Bending and shear properties of whole set of specimens from Cevennes 2 (noted C2)*

Main sample: specimens from **Isère** provenance (noted I)

Isère Flatwise					
Property	**Em**	**fm**	**G**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kN/mm^2)	(kg/m^3)	(%)
n	22	22	22	22	22
Average	**14200**	**75,7**	**0,88**	**603**	**11,1**
StDev	1233	7,38	0,13	20	0,52
min	11492	65,3	0,66	567	10,1
Max	16045	94,9	1,15	637	12
CoV (%)	8,68	9,74	15	3,31	4,68

Table /3.1.4/ 17 - *Bending and shear properties of squared pieces tested flatwise: provenance Isère (noted I)*

Isère Edgewise					
Property	**Em**	**fm**	**G**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kN/mm^2)	(kg/m^3)	(%)
n	22	22	22	22	22
Average	**14000**	**76,6**	**0,75**	**606**	**11,5**
StDev	997	5,8	0,11	23	0,63
min	11645	62,8	0,59	569	10,3
Max	15829	85	0,96	664	12,5
CoV (%)	7,14	7,57	14,7	3,86	5,52

Table /3.1.4/ 18 - *Bending and shear properties of squared pieces tested edgewise: provenance Isère (noted I)*

Isère Whole set					
Property	**Em**	**fm**	**G**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kN/mm^2)	(kg/m^3)	(%)
n	44	44	44	44	44
Average	**14100**	**76,2**	**0,81**	**604**	**11,3**
StDev	1114	6,58	0,14	22	0,61
min	11492	62,8	0,59	567	12,1
Max	16045	94,9	1,15	664	12,5
CoV (%)	7,9	8,63	16,9	3,6	5,35

Table /3.1.4/ 19 - *Bending and shear properties of whole set of specimens from Isère (noted I)*

Main sample: specimens from **Torrazzo** provenance (noted **T1**)

Torrazzo Flatwise					
Property	**Em**	**fm**	**G**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kN/mm^2)	(kg/m^3)	(%)
n	8	8	8	8	8
Average	**14100**	**73,7**	**0,91**	**682**	**10,6**
StDev	998	5,54	0,24	6,9	0,86
min	12833	65	0,56	676	9,84
Max	15482	80,4	1,36	693	12
CoV (%)	7,1	7,52	26,2	1,01	8,17

Table /3.1.4/ 20 - *Bending and shear properties of squared pieces tested flatwise: provenance Torrazzo (noted T1)*

Torrazzo Edgewise					
Property	**Em**	**fm**	**G**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kN/mm^2)	(kg/m^3)	(%)
n	7	8	7	8	8
Average	**13000**	**69,4**	**0,85**	**673**	**11,1**
StDev	608	5,64	0,13	18,8	1,03
min	11824	60,3	0,66	629	9,4
Max	13649	77,6	1,02	686	12,3
CoV (%)	4,7	8,14	14,9	2,32	9,3

Table /3.1.4/ 21 - *Bending and shear properties of squared pieces tested edgewise: provenance Torrazzo (noted T1)*

Torrazzo Whole set					
Property	**Em**	**fm**	**G**	**ρ**	**ω**
Unit	(N/mm^2)	(N/mm^2)	(kN/mm^2)	(kg/m^3)	(%)
n	15	16	15	16	16
Average	**13500**	**71,5**	**0,88**	**678**	**10,8**
StDev	992	5,85	0,19	14	0,95
min	11824	60,3	0,56	629	9,4
Max	15482	80,4	1,36	693	12,3
CoV (%)	7,32	8,17	21,7	2,13	8,8

Table /3.1.4/ 22 - *Bending and shear properties of whole set of specimens from Torrazzo (noted T1)*

3.1.4.1.2 Mechanical properties: strength of glue lines[team involved: 06] (writing: 06) [mn]

Even if this tests procedure would not be intended for testing manufactured products, the reliability of the method (procedure and shear device), as well as the relatively easiness for manufacturing the specimens from the squared pieces of LVL suggested to adopt it with some modifications, previously specified.
Due to the unfavourable orientation of wood layer (tangential), wich is mainly stressed along the porous ring, the failure was located more frequently in the wood layer than along the glue bond; thus the shear strength reported in Table /3.1.4/23 is to be intended as a minimum value of resistance of the LVL (wood layer + glue line) along the glue line.

τ	**C1**	**C2**	**I**	**T1**	**Whole set**
Unit	(N/mm^2)	(N/mm^2)	(N/mm^2)	(N/mm^2)	(N/mm^2)
n	28	12	78	72	178
Average	**9,55**	**12**	**11,3**	**9,84**	**10,5**
StDev	2,12	1,11	1,73	1,45	1,85
min	4,48	10,3	7,6	6,24	4,48
Max	13,1	13,8	15	13,5	15
CoV (%)	22,2	9,23	15,3	14,8	17,6

Table /3.1.4/ 23 - *The shear strength of wood-to-wood adhesive bond, divided into the provenances*

3.1.4.1.3 Dimensional stabilty [team involved: 06] (writing: 06) [mn]

The dimensional stability under change of environmental conditions is one the most important properties, particularly for pieces intended to be used for joinery.
The position - referred to a mesurement bar - of a chosen point located on the surface of the test piece was measured both at the conditions of 20 °C - 65 % RH and at 20 °C - 80 % RH. The deformation measured was the bow (ε_0) expressed in Table /3.1.4/2 as ‰; the average of the bow expressed as ratio on the basis of 1000 mm length, is 0,1/1000 mm. C2 showed a wide range of variation and the larger deformation ratio, while T1 and C1 showed lower deformability (and a smaller variation).

Longitudinal deformation of sq. pieces	**C2**	**I**	**T1**	**C1**	**All**
ε_0	(‰)	(‰)	(‰)	(‰)	(‰)
n	3	3	3	3	12
Average	**0,172**	**0,138**	**0,076**	**0,033**	**0,105**
StDev	0,121	0,055	0,017	0,006	0,08
CoV(%)	70,1	39,9	22,6	17,3	76,53

Table /3.1.4/ 24 - *Longitudinal deformation of the 56 mm squared pieces, expressed as a ratio on the basis of 1000 mm length*

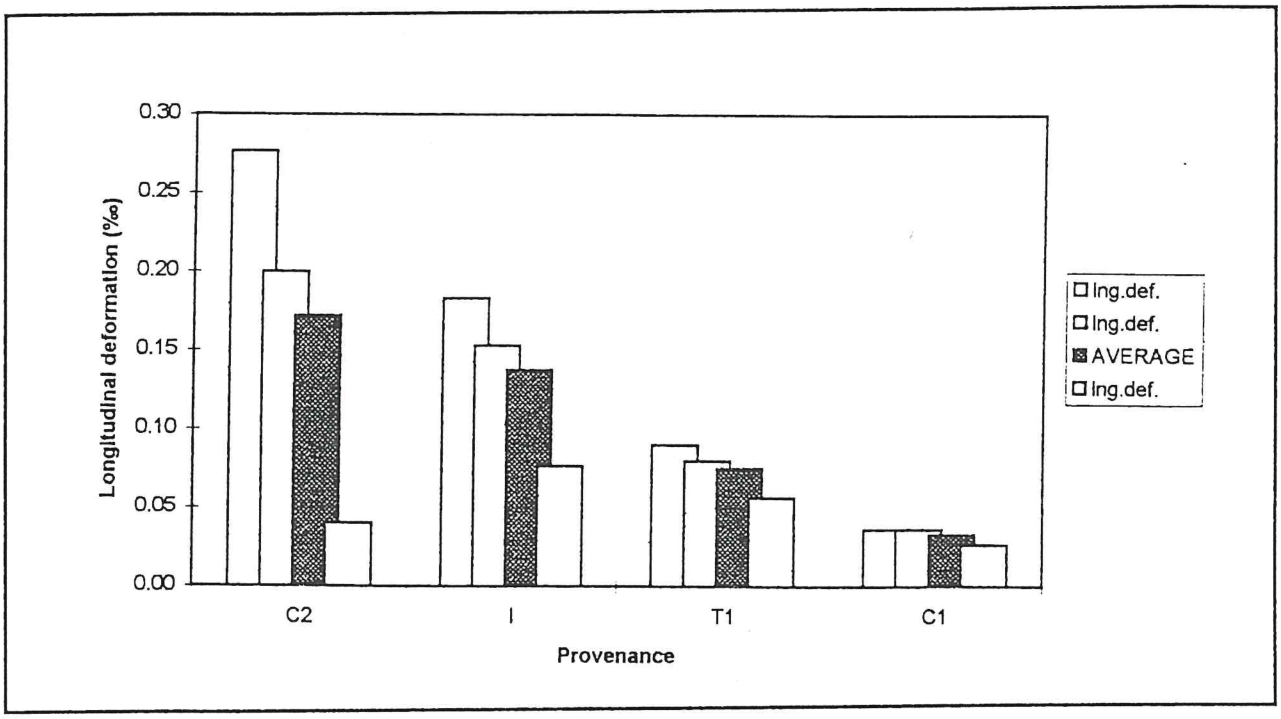


Figure /3.1.4/ 1- *Longitudinal deformation of the 56 mm squared pieces, expressed as a ratio on the basis of 1000 mm length*

3.1.4.1.4 Industrial machining [team involved: 06] (writing: 06) [mn]

A small lot of squared pieces of the preliminary sample were machined by a joinery manufacturer (PB Finestre, also strongly co-operating in TaskE, Non-structural Glulam). The LVL pieces, machined with the same wood-working machines used for the normal production and HSS steel tools suitable both for solid and Gluam timber, showed that:

- generally good quality of the surfaces;
- some defects due the vessels cut by a tangential plane (unavoidable defect);
- some defects due to the occurrence of internal vacuum (avoidable defect).

The last defect was judged the most dangerous for the quality of the panel and of the subsequent squared pieces; these informations with some suggestion regarding the other visual aspect (such as the colour of the glue line and the quality of the external slice) were given to the teams involved in LVL manufacturing.

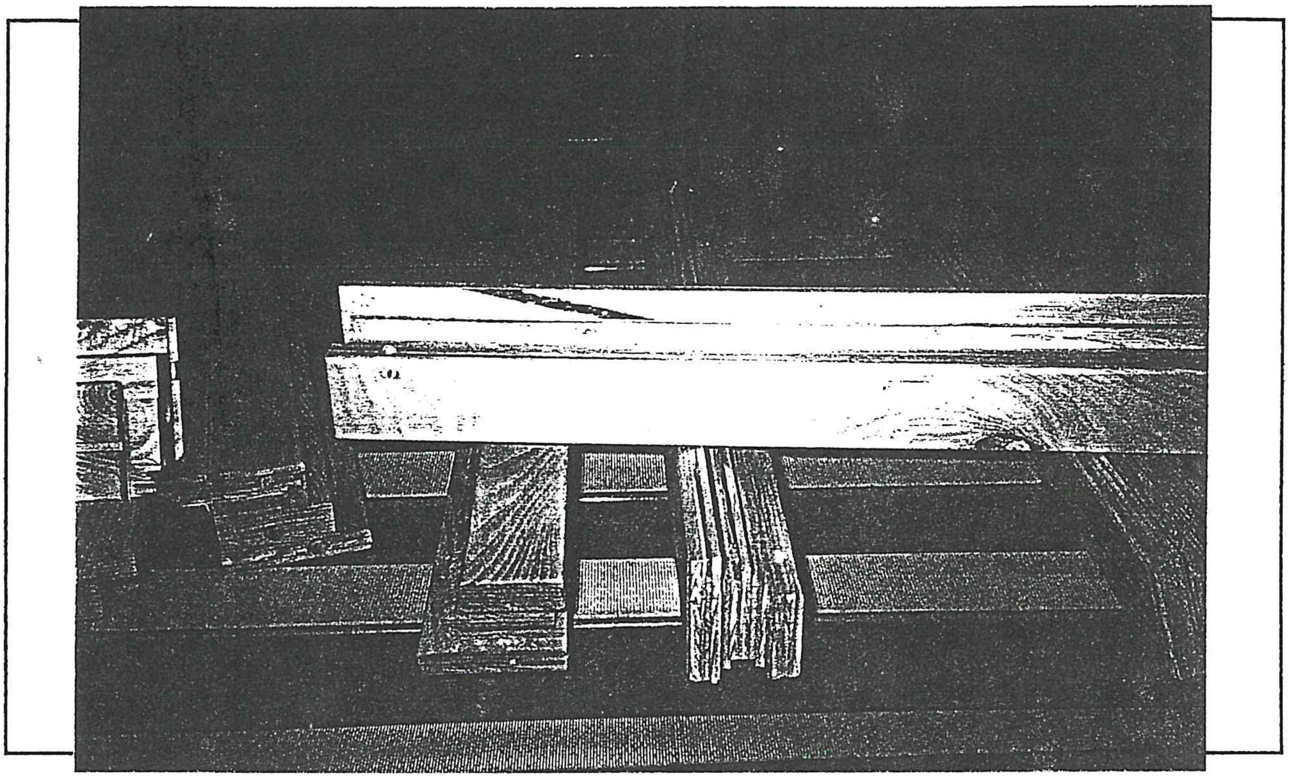


Photo /3.1.4/ 1 - *Defect due to the occurrence of internal vacuum (avoidable defect)*

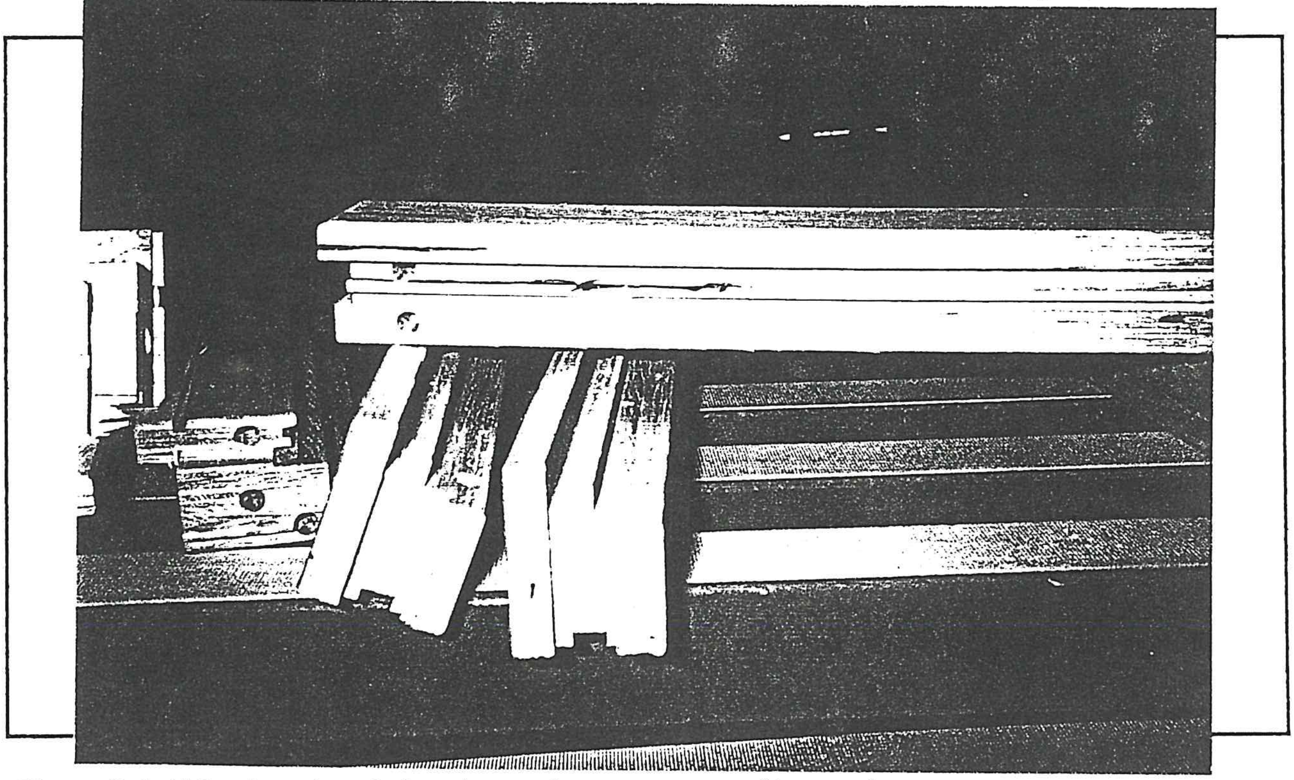


Photo /3.1.4/ 2 - An other d*efect due to the occurrence of internal vacuum*

3.1.4.2 Properties of 27 mm thick panels [team involved: 06] (writing: 06)

3.1.4.2.1 Bending properties [team involved: 06] (writing: 06) [mn]
The 27 mm panels were tested both parallel to grain and perpendicular to grain on only two provenances (C1 and I), according to the other teams involved; in fact from each panel few specimens were obtained. The methodology for testing the panels doesn't foresee the G modulus; by contrast bending stiffness EmI (GNmm2) and moment capacity Mmax (MNmm) are reported. Provenance Isère showed higher performances than Cévennes.

> The Isère specimens were not conditioned at 20°C - 65° HR, but at uncontrolled (dryer) conditions; thus the strength properties are supposed to be incresed; nevertheless it should be noted that also in the case of 56 thick squared pieces Isère provenance showed the best performances.

The average density of 27 mm panels (both provenances, 27 panels) is around 600 kg/m^3 (whole set density [kg/m^3]: average = 603; standard deviation = 16,6; CoV% = 2,75) while the density of 56 mm panels (from which the squared pieces were sawn) is higher, probably due to the manufacturing processes.
The tests carried out perpendicular to grain were soon interrupted due to the so low ultimate loading values (less than 50 kg); the strength parallel to grain resulted 25 times the strength perpendicular; the failures seemed to be occurred due to a tension stress (perpendicular to the grain).

Whole set parallel to grain						
Property	**Em_0**	**EmI_0**	**fm_0**	**$Mmax_0$**	**ρ**	**ω**
Unit	(N/mm^2)	(GNmm^2)	(N/mm^2)	(MNmm)	(kg/m^3)	(%)
n	19	19	21	21	21	21
Average	**11800**	**5,96**	**63,4**	**2,35**	**596**	**10,6**
StDev	2024	0,86	10,5	0,34	15	1,4
min	8964	4,71	49,4	1,87	561	9
Max	15449	7,6	86,1	3,12	629	12,6
CoV (%)	17,1	14,5	16,6	14,6	2,6	12,5

Table /3.1.4/ 25 - *Bending and stiffness properties of whole set of panels tested parallel to grain*

F 4

Cévennes 1 parallel to grain						
Property	**Em_0**	**EmI_0**	**fm_0**	**$Mmax_0$**	ρ	ω
Unit	(N/mm^2)	(GNmm^2)	(N/mm^2)	(MNmm)	(kg/m^3)	(%)
n	12	12	14	14	14	14
Average	**10500**	**5,45**	**56,9**	**2,15**	**598**	**11,9**
StDev	1123	0,63	4,6	0,18	15	0,6
min	8964	4,71	49,4	1,87	576	10,3
Max	13249	7,04	65,1	2,49	629	12,6
CoV (%)	10,7	11,5	8,1	8,2	2,5	4,8

Table /3.1.4/ 26 - *Bending and stiffness properties of panels from Cévennes tested parallel to grain (noted C1)*

Isère 1 parallel to grain						
Property	**Em_0**	**EmI_0**	**fm_0**	**$Mmax_0$**	ρ	ω *
Unit	(N/mm^2)	(GNmm^2)	(N/mm^2)	(MNmm)	(kg/m^3)	(%)
n	7	7	7	7	7	7
Average	**14100**	**6,82**	**76,3**	**2,75**	**592**	**9,2**
StDev	708	0,36	5,4	0,21	17	0,1
min	13356	6,57	70,2	2,48	561	9
Max	15449	7,6	86,1	3,12	615	9,4
CoV (%)	5	5,4	7,1	7,7	2,8	1,6

* That sample, due to a technical problem on the climatic chamber, was equilibrated under uncontrolled environmental conditions.

Table /3.1.4/ 27 - *Bending and stiffness properties of panels from Isère tested parallel to grain (noted I)*

Whole set perpendic. to grain						
Property	**Em_{90}**	**EmI_{90}**	**fm_{90}**	**$Mmax_{90}$**	ρ	ω
Unit	(N/mm^2)	(GNmm^2)	(N/mm^2)	(MNmm)	(kg/m^3)	(%)
n	6	6	6	6	6	6
Average	**399**	**0,22**	**2,4**	**0,09**	**616**	**12,2**
StDev	29	0,02	0,2	0,006	10	0,4
min	356	0,19	2,2	0,09	601	11,7
Max	435	0,23	2,7	0,1	624	12,7
CoV (%)	7,2	7,7	7,4	7	1,6	2,9

Table /3.1.4/ 28 - *Bending and stiffness properties of a limited set of panels tested perpendicular to grain*

3.1.4.2.2 Dimensional and shape stability [team involved: 02, 06] (writing: 06) [mn]

The shape of the panels was evaluated both as planarity and as total deformation under change of moisture conditions. The panel can be considered straight along the grain ($\varepsilon < 1‰$); across the grain wide cup were found even without any change of hygrothemal conditions.

According to the first manufacturing process, adopted with the preliminary sample, the test pieces were divided following the three different composition, related to the orientation of the grain layer:

- composition *a*, noted ///////: the grain layers was oriented along the same direction (all provenances of preliminary sample);
- composition *b*, noted ///⊥///: the grain layers was oriented along the same direction, eccept the grain direction of central layer (only Isère provenance);
- composition *c*, noted /⊥///⊥/: the grain layers was oriented along the same direction, eccept the grain direction of 2° and 10° layers (only Isère provenance).

In order to avoid some layers with the grain direction perpendicular to the other layers grain direction, a different technique was tested on the subsequent Main sample.

The test pieces were manufactured into three different pattern, following various composition of the so-called *loose* sides, (sides with checks due to the peeling process) of the layer:

- pattern 1: the loose side of all layers were oriented towards the same direction;
- pattern 2: the loose sides were matched simmetrically to the central glue line;
- pattern 3: the loose sides were coupled simmetrically to the glue line, setted against each other.

Cup (deformation across the grain)	**Pattern *a*** ///////	**Pattern *b*** ///⊥///	**Pattern *c*** /⊥///⊥/	**Main sample all patterns (p.1; p.2; p.3)**
ε_{90}	(‰)	(‰)	(‰)	(‰)
n	2	3	3	8
Average	**6,86**	**1,63**	**0,3**	**4,18**
StDev	6,1	0,04	0	2,37
CoV(%)	88,7	2,18	0	56,6

Table /1.3.4/ 29 - *Planarity of various panel patterns, measured on full-size panels under uncontrolled conditions in the sawmill*

Due to the anisotropy of LVL panels, the cup strongly affected all the manufacturing patterns eccept the patterns *b* and *c*. Note therefore that these two patterns (pattern *b* and *c*) should not be considered as LVL, because of the grain orientation respectively of the central layer (pattern *b*) and two outer layers (pattern *c*, 2° and 10° layers); the grain of these layers was perpendicular to the grain orientation of the other layers.

3.1.4.2.2.1 Homogeneous environvental conditions [team involved: 06] (writing: 06) [mn]

The deformation of the panels is expressed as a difference between the positions - referred to a reference plane - of a point located at the center of the test piece surface measured at 20 °C - 65 % RH and at 20 °C - 80 % RH environmemtal conditions.

This method give the amplitude of the total deformation ($\varepsilon_{0,90}$) reported for two different manufacturing techniques in the Tables /3.1.4/ 29 and /3.1.4/ 30 as ‰.

Total deformation	**I *a*** ///////	**C *a*** ///////	**T *a*** ///////	**Whole set *a*** ///////	**I *b*** ///⊥///	**I *c*** /⊥///⊥/	**Whole set**
$\varepsilon_{0,90}$	(‰)	(‰)	(‰)	(‰)	(‰)	(‰)	(‰)
n	3	3	3	9	3	3	15
Average	1,62	0,9	1,56	**1,36**	**2,27**	**0,78**	**1,43**
StDev	1,56	0,78	1,1	1,09	2,86	0,569	1,46
CoV(%)	96,4	87	69,4	79,8	126,1	72,7	102

Table /3.1.4/ 29 - *Total deformation ($\varepsilon_{0,90}$) of 27 mm panels, divided into three patterns following different kind of composition of the grain direction of the layers*

The patterns *a* and *b* resulted less stable compare to pattern *c*. Therefore, as specified above, only pattern *a* could be considered LVL

Total deformation of panels	**Pattern 1**	**Pattern 2**	**Pattern 3**	**Whole set**
$\varepsilon_{0,90}$	(‰)	(‰)	(‰)	(‰)
n	4	4	4	12
Average	**2,34**	**1,08**	**1,03**	**1,48**
StDev	1,45	1,19	0,96	1,27
CoV(%)	61,9	110,1	93,4	55,4

Table /3.1.4/ 30 - *Total deformation ($\varepsilon_{0,90}$) of 27 mm panels, divided into three patterns following different kind of composition of the loose side of the layers*

Pattern 1 panels, with non-equilibrated orienatation of loose sides, shows a large deformation ratio, two times larger than the deformation of the other more equilibrated composition patterns. The total average deformation of panels made through both the manufacturing techniques - expressed as ratio on the basis of 1000 mm length - is 1,5/1000. All the groups have a wide range of variation.

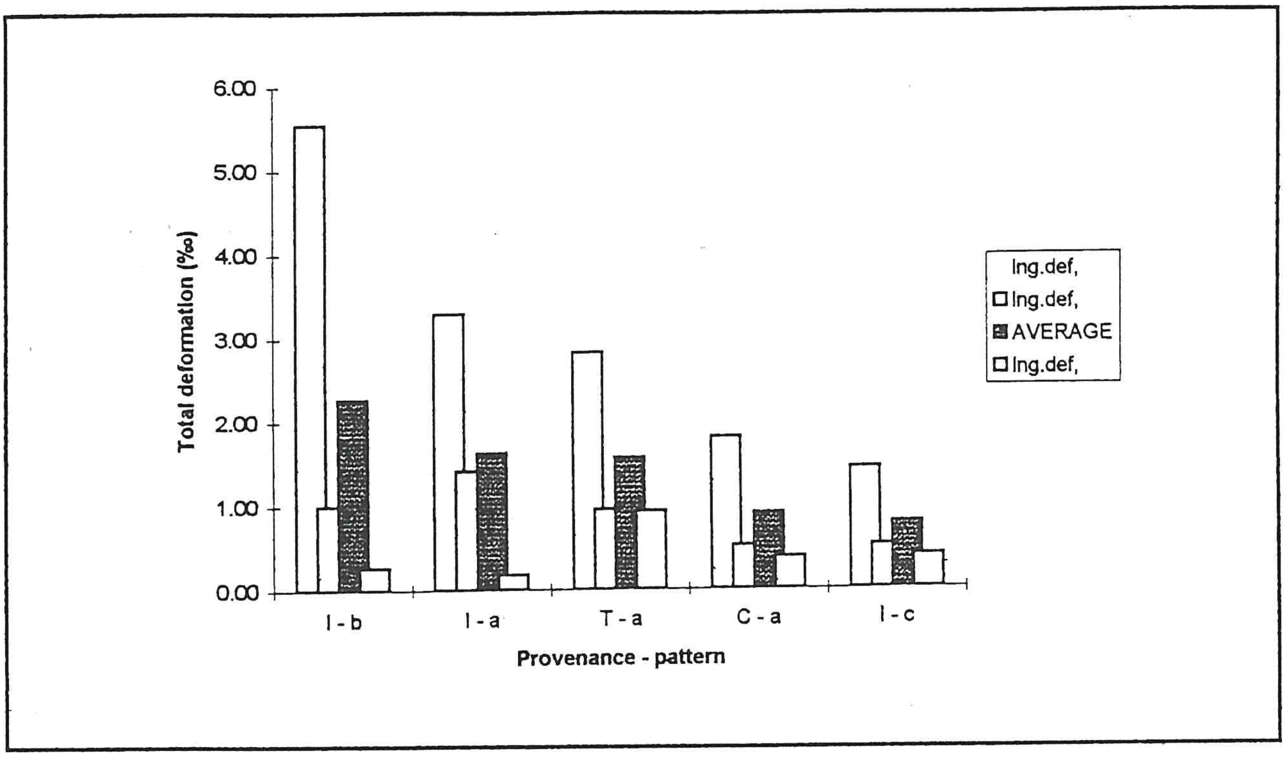


Figure /3.1.4/ 2 - *Total deformation ($\varepsilon_{0,90}$) of 27 mm panels, divided into three patterns following different kind of composition of the grain direction of the layers*

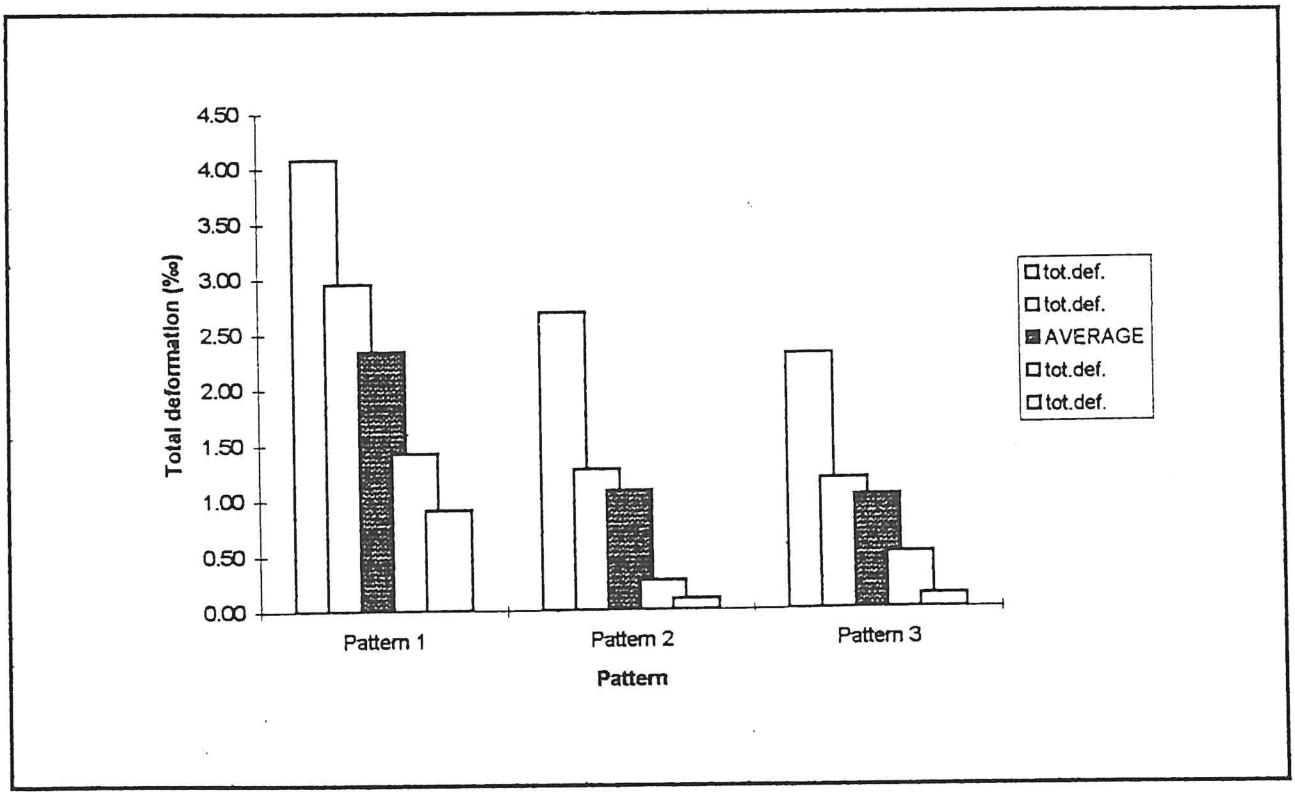


Figure /3.1.4/ 3 - *Total deformation ($\varepsilon_{0,90}$) of 27 mm panels, divided into three patterns following different kind of composition of the loose side of the layers*

3.1.4.2.2.2.Non homogeneous conditions [team involved: 02] (writing: 02)

The results are summarized in Figs./3.1.4/ 2 and /3.1.4/ 3 and Tables 3.1.4.1.2.2/1 and 2.
As expected, deflections along the longitudinal direction are much lower than those in the transversal direction (the former being about 2 to 3% of the latter). All panels reached the maximum deflection after an exposure of about 20 weeks (see Fig./3.1.4/ 2). Although maximum deflections could be considered to be reached, moisture gradients were still increasing at that time (see Fig./3.1.4/ 3).
Based on a span length of 1 m, maximum transversal deflections are about 110 mm, more than 10% of the reference span (see Table 3.1.4.1.2.2/1).

With regard to the different compositions, only small differences can be observed between them. The transversal deflections slightly increase from Comp.1 to Comp.3, following the same trend showed by the correspondent dimensional changes and shrinkages (see Table 3.1.4.1.2.2/2). The moisture gradients in Comp.2 and 3 are always higher than those of Comp.1.

From the dynamic point of view, it can be observed that half of the maximum deflection was reached after about only two weeks.

Comparing the results with the same obtained for SWP (Task E.2), LVL deflections are lower (70% of the value expected from a panel of equal thickness)

The following conclusion can be stated:

- LVL panels can be considered as a higly anisotropic material
- LVL panels has a shape stability higher than that of chestnut Solid Wood Panels
- The composition has not much influence on the shape stability.

Specific bibliographical references:

VACEK, V.; MAHUT, J.; KRAKOVSKY, A. (1989) "Methods and possibilities for measuring and evaluating the flatness of panel materials". Bratislava, Czechoslovakia Zbornik Vedeckych Prac - Drevarskej Faculty Vysokej Skoly Lesnickej a Drevarskej vo Zvolene, 1987/88, 207-219.

3.1.4.2.3 Wear of tools [team involved: 06] (writing: 06) [mn]
The wear of the tool was measured by the backwarding of the cutting edge; the average values indicate that the preliminary sample panels were abrasive both on non-hardened and hardened steel. On the main sample the different glue composition (different fillers) resulted less abrasive. The profile of the slope reproducing the cutting edge shows that the wear was mainly due to the abrasivness of glue lines.
The non-hardened knives with machining the first sample panels showed the strongst wear; in Figure F/46 the profile of the slope reproducing the cutting edge.

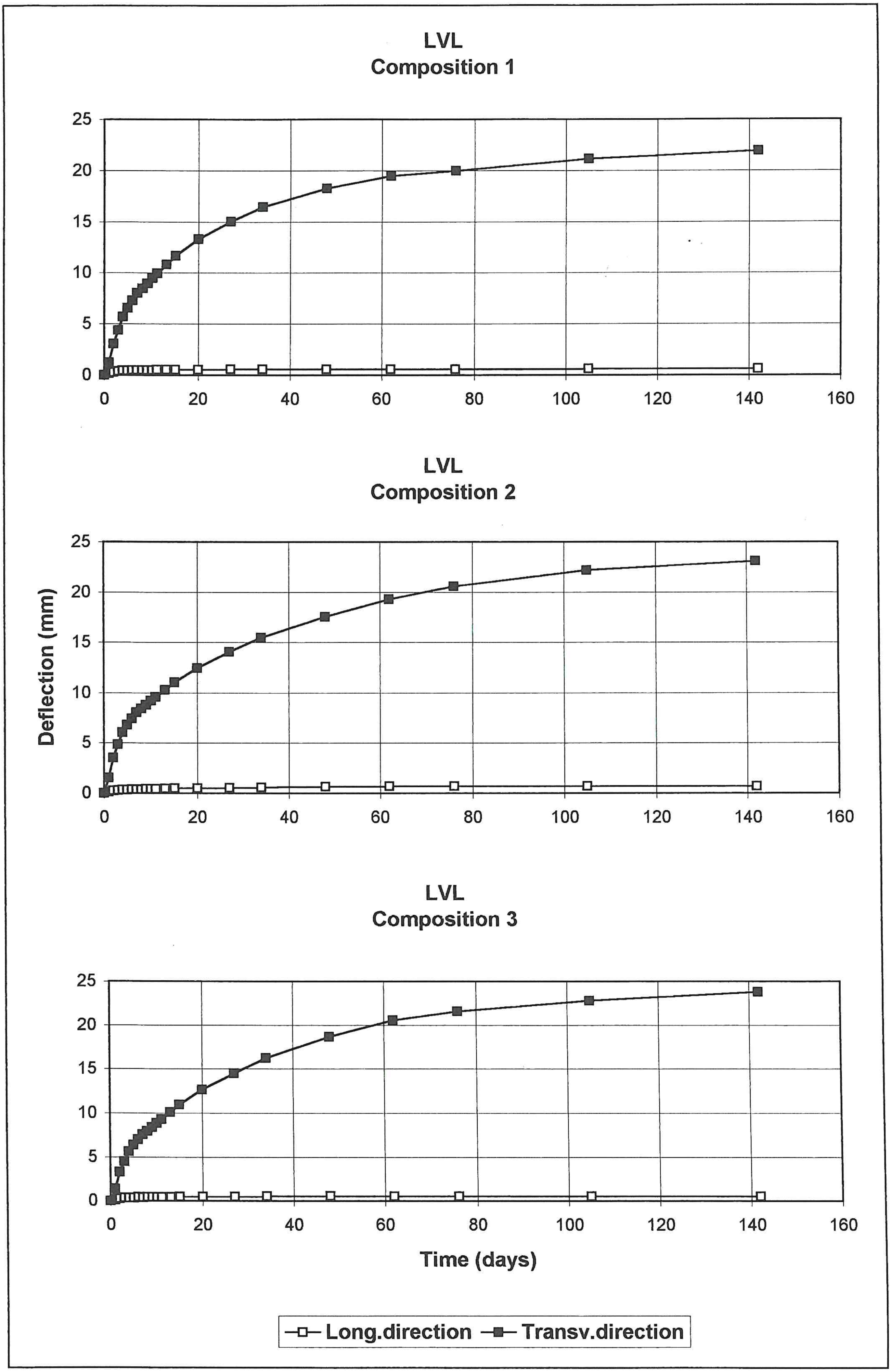

LVL
Composition 1
LVL
Composition 2
LVL
Composition 3
Deflection (mm)
Time (days)
Long.direction
Transv.direction

Fig. 13.1.4/2

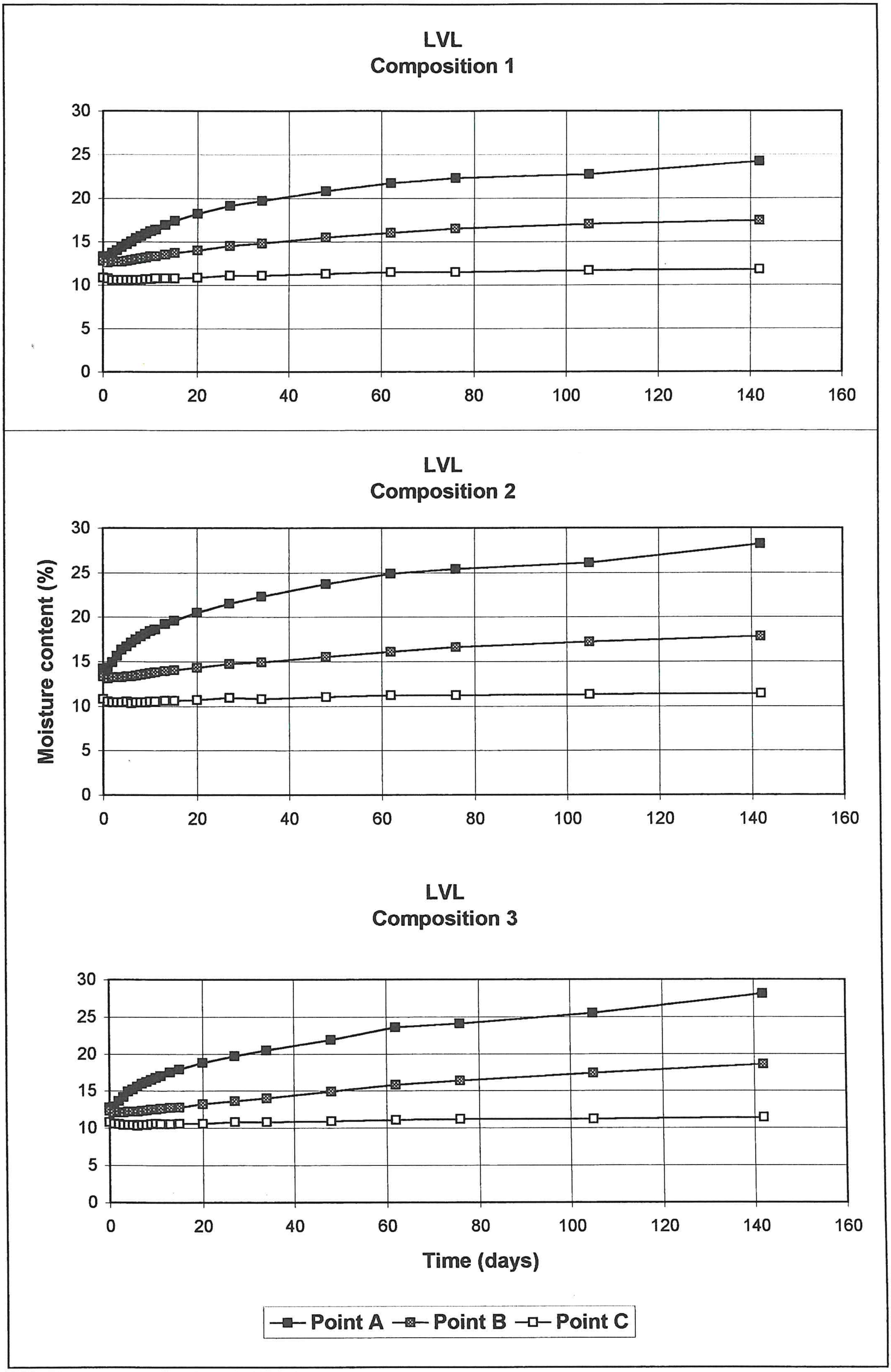

LVL
Composition 1
LVL
Composition 2
LVL
Composition 3
Moisture content (%)
Time (days)
0
5
10
15
20
25
30
0
20
40
60
80
100
120
140
160
Point A
Point B
Point C

Fig. 13.1.4/3

LVL	500 x 500 mm test pieces								
Composition	Weight after conditioning in s.a. [2] (g)	Weight after exposure for 20 weeks (g)	Change in weight (%)	Maximum depth of deflection after exposure for 20 weeks (mm)				Maximum radius of curvature (m)	
				Observed values		Derived values for 1 m length			
				Longitudinal direction	Transversal direction	Longitudinal direction	Transversal direction	Longitudinal direction	Transversal direction
1	4044	4381	8.3 [1]	0.62	21.9	3.0	107	41	1.17
2	4193	4632	10,5 [1]	0.70	23.1	3.5	112	36	1.11
3	3964	4293	8,3 [1]	0.50	23.8	2.5	116	50	1.07

[1]) These values are higher than those observed for 100 X100 mm test pieces because of water condensation on the lower side of the test pieces
[2]) s.a.: standard atmosphere (20°C temperature/65% relative humidity)

Table 3.1.4.1.2.2/1

LVL	100 x 100 mm test pieces								
Composition	Changes after exposure for 20 weeks (%)				Moisture content 2) (%)		Total shrinkage (from exposed to dry conditions) (%)		
	Weight	Dimensions			After conditioning in s.a. 1)	After 20 weeks exposure	Dimensions		
		Longitudinal direction	Transversal direction	Thickness			Longitudinal direction	Transversal direction	Thickness
1	7.7	0.0	1.7	2.6	11.6	20.2	0.1	4.9	3.5
2	7.3	-0.1	1.8	2.5	11.8	20.0	0.0	5.3	3.9
3	9.3	-0.1	2.4	2.7	10.2	20.4	0.0	5.9	3.4

1) s.a.: standard atmosphere (20°C temperature/65% relative humidity)

2) gravimetric method

Table 3.1.4.2.2.2/2

Tool	Steel	Sample	Machined panel length			
			0	500	1000	1300
			(μ)	(μ)	(μ)	(μ)
NT2	non-hardened	Main	0	77	**126**	135
NT3	non-hardened	Main	0	85	**103**	115
NT4	non-hardened	Preliminary	0	108	**142**	-
T2	hardened	Main	0	9,90	**14,1**	18,14
T3	hardened	Main	0	9,94	**14,13**	18,44
T4	hardened	Preliminary	0	48,4	**67,1**	-

Table /3.1.4/ 31 - *Wear of hardened and non-hardened kinves, according to the two different glue composition*

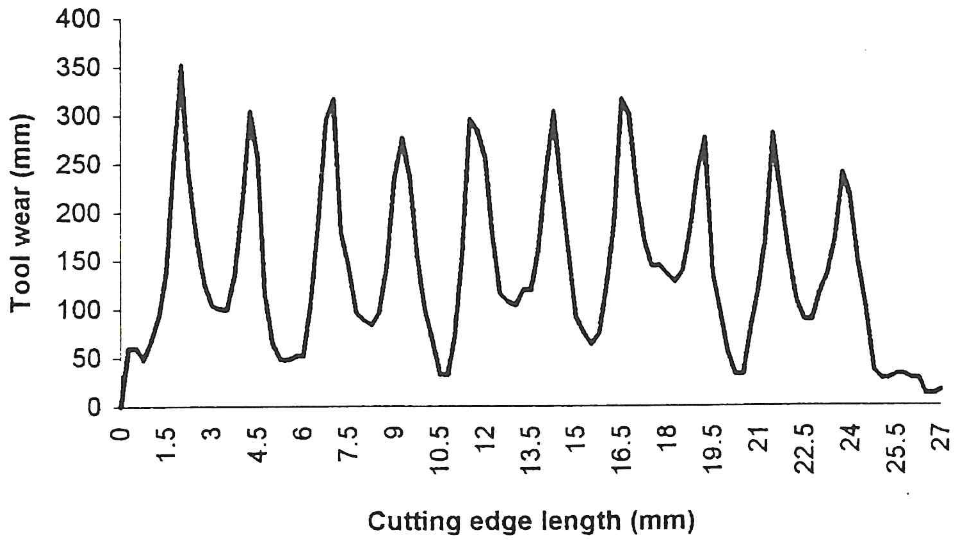


Figure F/46 - *Wear of non-hardened kinves*

3.1.4.3 Natural durability of chestnut LVL compared with solid wood - Results and discussion

Table 3.1.4.3/1 - Mass loss (as percentage) of Chestnut LVL and Chestnut solid wood with fungi test

	Coniophora puteana			*Coriolus versicolor*			*Pleurotus ostreatus*		
LVL provenance	**10 bar**	**18 bar**	**mean**	**10 bar**	**18 bar**	**mean**	**10 bar**	**18 bar**	**mean**
Cevenne	4.04	4.35	4.19	2.45	3.92	3.18	4.68	2.84	3.76
Isere	8.16	3.37	5.76	5.05	3.43	4.24	3.46	1.76	2.61
Torrazzo	3.19	6.12	4.65	2.37	3.28	2.82	4.02	4.90	4.46
total mean			**4.87**			**3.41**			**3.61**
reference species (*Fagus sylvatica*)			30.00			30.65			22.15
Chestnut Solid wood			2.46			3.07			1.37

Table 3.1.4.3/2 - Mass loss (as percentage) of Chestnut LVL after ageing and Chestnut solid wood with fungi test.

	Coniophora puteana			*Coriolus versicolor*			*Pleurotus ostreatus*		
LVL provenance	**10 bar**	**18 bar**	**mean**	**10 bar**	**18 bar**	**mean**	**10 bar**	**18 bar**	**mean**
Cevenne	3.38	4.37	3.87	2.95	3.82	3.38	3.36	3.57	3.46
Isere	6.22	4.11	5.16	4.59	3.74	4.16	4.41	3.59	4.00
Torrazzo	3.98	5.43	4.70	2.92	3.49	3.20	3.78	4.60	4.19
total mean			**2.46**			**3.58**			**3.88**

reference species (*Fagus sylvatica*)	30.00			30.65			22.15
Chestnut Solid wood	2.46			3.07			1.37

Table 3.1.4.3/3 - Natural durability index of chestnut LVL and solid wood

	NDI*	Durability class	Description
LVL	0.162	**2**	Durable
LVL (after ageing)	0.153	**2**	Durable
Solid wood	0.084	**1**	Very durable

(*) Natural Durability Index with *Coniophora puteana*: Ratio of Average Corrected Mass Loss of Test Specimens to Average Mass Loss of Reference Specimens (30,00%).

The natural durability of LVL chestnut has been quantified as a whole, without taking into account neither the provenance of the wood material nor the parameters of the glueing pressure; in fact, the results were obtained with only a limited number of samples (6 for each group) and cannot be used for significant conclusion.
The natural durability against Basidiomycetes has been quantified measuring the weigth losses obtained with *Coniophora cerebella* (brown rot fungus); in fact, the weight losses caused by *Coniophora cerebella* are lightly heigher in comparison with the two remaing test fungi.
According to our test, LVL has a natural durability to fungi classified as "durable"; the same classification has been obtained for LVL even after same accelerated ageing cycles.
Chestnut solid wood has been classified as "very durable" in connection with the same fungus.

3.1.5 Appearance grading [Teams involved: 07,13] (team writing: 07)

As already mentioned in paragraph 3.1.1.4.5, the 56 mm panels were produced by adopting two different types of composition. The first type consisted of face veneers made from 1st quality class veneers and internal layers from jointed veneers, that in theory were free of holes and loose knots, whereas in the second type the internal layers were produced with entire 2nd class quality veneers containing a certain number of tolerable defects.

The panels produced from the first type of composition should have been the best quality as they were produced from jointed veneers free of loose knots, while the second type of composition should have produced a lower quality panel.

During the production of window parts, the shaping of mouldings from blocks made of chestnut heartwood or LVL to form the rails and rebates of the window will bring to light the defects that are present inside the blocks. It is therefore important to consider the visual quality, immensely important in this type of product, of the internal layers of the two types of panel. To

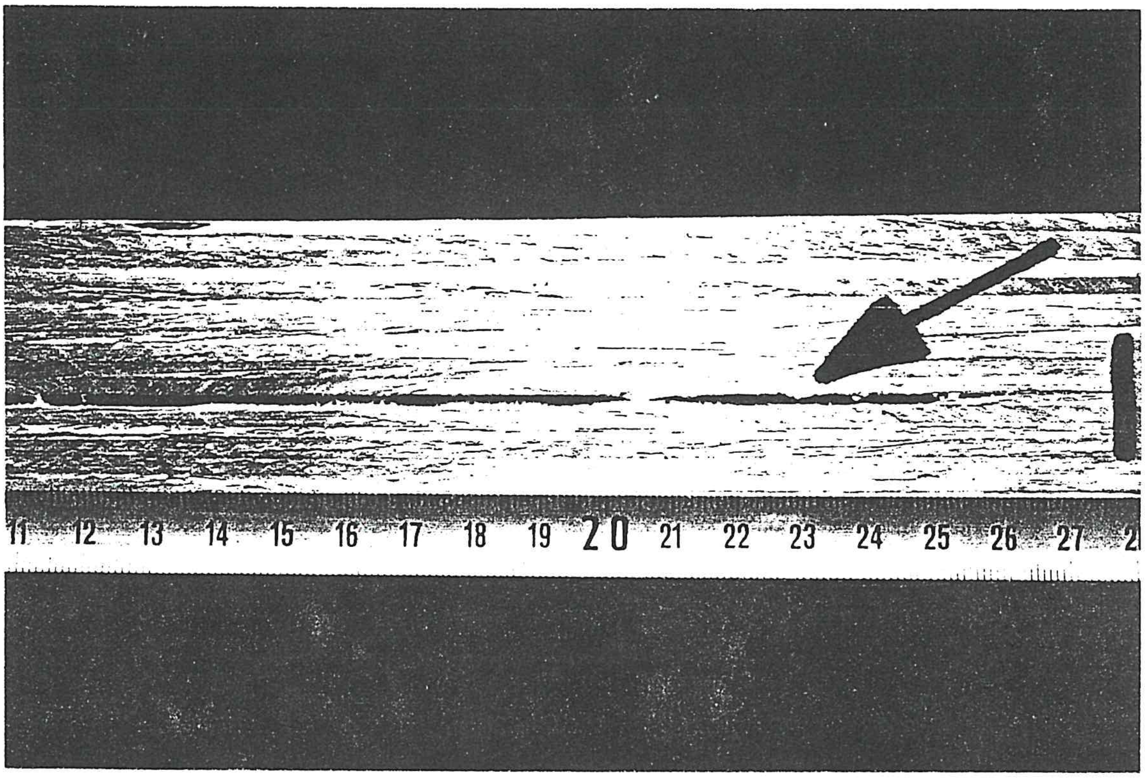


Figure F/47a - Jointing defect

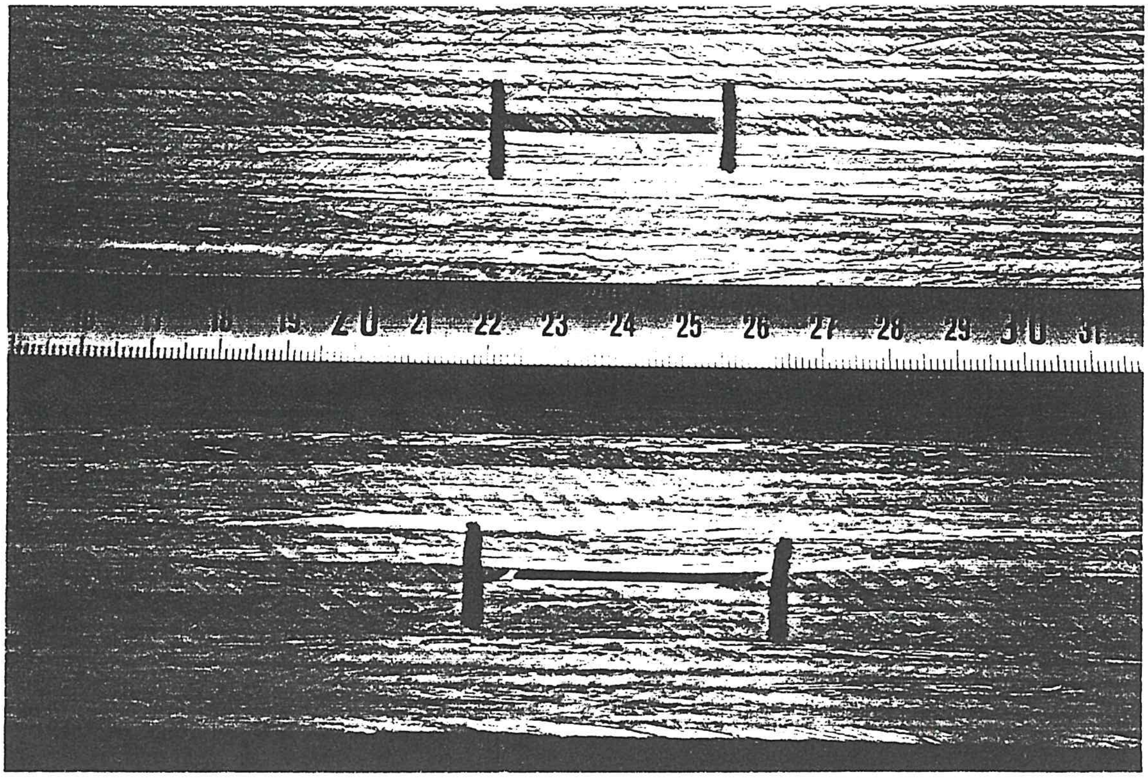


Figure F/47b - Above: loose knot; below: hole formed by the falling away of a loose knot.

do this, one panel of each of the two types of composition was cut into strips 2 cm wide and the defects on one of the two faces of each strip were observed (see Fig. F/47).

From the observations made a difference emerged between the two types of panel that was completely opposite to the one expected. In fact the inside of the panel constructed from jointed veneers showed a considerable quantity of solutions of continuity predominantly along the length of the sheet and attributable to defective jointing of the strips. It also showed a quantity of holes and loose knots that was not very much lower than that of the panel made from 2nd class quality veneers. Table 13 shows the frequency and average extension of the various types of defect found on the faces of the strips.

Table 13 - Frequency (no. of strips on which defect is evident over the total number of strips) and extension of the principal defects encountered inside the panels produced.

Type of veneer inside the panel	**Jointing defects**		**Holes formed by the falling away of loose knots**		**Loose knots**	
	frequency (%)	extension (cm)	frequency (%)	diameter (cm)	frequency (%)	diameter (cm)
Composition 1: jointed sheets	52	17.8	40	1.4	79	1.6
Composition 2: entire 2nd class quality sheets	28	14.5	24	1.4	83	1.9

It becomes clear by looking at the third and fourth columns that the trimming of 3rd and 4th class quality veneers into flawless strips produced jointed veneers of a quality that is comparable to the 2nd class quality veneers and not to those of the 1st class as was hoped. With this operation then the processed material can be improved, but only to a limited degree.

On the other hand, the large quantity of jointing defects shows that jointing by sewing with nylon thread is not suitable for producing this type of panel because it allows too much clearance for the strips. When the parcel is formed or when it is pressed, the strips can diverge and cause solutions of continuity inside the panel, that are then filled with glue.

The use of modern glue-based joiners can probably efficiently solve this problem, so that the veneer produced can be fully exploited. Moreover, butt-jointing, also of entire veneers, could be of great interest in view of the use of chestnut LVL also for structural supports (e.g. roof beams).

3.1.6 Costs [Teams involved:13] (team writing: 13)

Work times for the production of LVL were calculated by measuring the number of (manpower) hours worked and the work of the machinery used in each phase of the production cycle. On the basis of this data, the production rates were determined for the panels, for both the thicknesses required and the production costs were estimated.

To calculate the manpower costs, the average value of 25,..000 LIT/hour was assumed, inclusive of taxes and social security (the average cost of a worker of 3rd grade with a 'timber worker' contract).

The tables below show the production costs incurred for panels of both thicknesses. They are about 52,500 LIT/m^2 for 27 mm panels and 108,500 LIT/m^2 for 56 mm panels. To these figures the overheads must be added and the profit of the processing industry. Regardless of the qualitative features of the product, the unit cost per square metre of chestnut LVL with a thickness of 27 mm is lower than that of other similar semi-finished products such as

microlaminated beech panels with 25 cm thickness (i.e. panels composed of bonded veneers with parallel grains), that costs around 57,000 LIT/m^2.
For the 56 mm thickness, the chestnut LVL shows a small difference of cost with respect to the beech panels of the same thickness that require about 131,000 LIT/m^2 to produce. The composition 1 costs about 100,000 LIT/m^3 more than the composition 2; both the type of composition are necessary to use completely the veneers obtained from rotary cutting.
In the light of the findings, even if the processing yields, that are currently decidedly low, can be improved in the future, the chestnut LVL panels must be placed in the medium-high price range.

Table 14 - Machine processing and manpower work times and costs for veneer cutting and the production of chestnut LVL panels with a thickness of 27 mm, values refer to m³ of the finished panel.

	Operation	Personnel engaged (n° workers)	Hours worked (hours/ m^3)	Cost of manpower (LIT/m^3) (1)	Machine or equipment used	Machine hours (no. hours)	Machine cost (LIT/h)	Machine cost (LIT/m^3)	Total cost of operation (LIT/m^3)
1	Sorting and equalising of stems	2	3.5	175,000	1 power saw	1.7	6000	10,200	185,200
1	Steam Treatment(2)	1	2	50,000				65,000	115,000
2	Bark peeling						10,000 (3)	35,000	35,000
3	Veneer cutting	4	1.5	150,000	veneer cutter	1.4	75,000	105,000	255,000
4	Drying	2	0.7	35,000	dryer	0.6	80,000	48,000	83,000
5	Veneer selection	2	1	50,000					50,000
6	Straightening of strips	3	1	75,000	straightener	1	10,000	10,000	85,000
7	Jointing of strips	1	1.5	37,500	jointer	1.5	15,000	22,500	60,000
8	Gluing, composition and pressing	4	2.25	225,000	spreading machine and hand press	2.25	33,000	217,000 (4) 76,000	518,000
9	Squaring and smoothing				squaring machine and lapping machine			70,000^3	70,000
								total processing cost 1,456,200	

Cost of raw material per m^3	**Cost of raw material for m3 of panel**
150,000	**570,000 (3)**

Overall cost for m^3 of panel LVL 2,026,200	
Cost for m^2 of LVL panel	54,700

Table 15 - Machine processing and manpower work times and costs for rotary cutting and the production of chestnut LVL panels with a thickness of 56 mm, values refer to m³ of the finished panel.

	Operation	Personnel engaged (n° workers)	Hours worked (hrs/ m³)	Cost of manpower (LIT/m³) (1)	Machine or equipment used	Machine hours (n° hrs)	Machine cost (LIT/h)	Machine cost (LIT/m³)	Total cost of operation (LIT/m³)
1	Sorting and equalising of stems	2	3.5	175,000	1 power saw	1.8	6000	10,800	185,800
2	Steam treatment (2)	1	2	50,000				65,000	115,000
3	Bark peeling					10,000[3]		36000	36,000
3	Rotary cutting	4	1.5	150,000	rotary cutter	1.5	75,000	112,500	262,500
4	Drying	2	0.7	35,000	dryer	0.7	80,000	56,000	91,000
5	Veneer selection	2	1	50,000					50,000
6	Straightening of strips	3	1	75,000	straightener	1	10,000	10,000	85,000
7	Jointing of strips	1	1.5	37,500	jointer	1.5	15,000	22,500	60,000
8	Gluing, composition and pressing	4	2	200,000	spreading machine and press	2	33,000	226,300 (4) 66,000	496,300
9	Squaring and smoothing				squaring machine and lapping machine			50,000	50,000 (3)
									total processing cost 1,431,600

Cost of raw material per m^3	**Cost of raw material for m3 of panel**
150,000	**570,000 (3)**

Overall cost for m^3 of panel LVL: 2,001,600	
Cost for m^2 of LVL panel	112,100

(1) Average cost per hour equal to 25,000 LIT/hour.
(2) Lump-sum.
(3) Unit cost (per cubic metre).
(4) Cost of glue mixture based on melamine, urea, fenol-formaldeide.
(5) Estimated on the basis of the processing yield for which about 3.8 m^3 of chestnut stems are needed to obtain 1 m^3 of LVL (panel yield 26.5 %).

3.2 Subtask F2 - Thick Sliced Veneer for prefinished composite parquet strips

[Teams involved: 07,09] (team writing: 07,09)

3.2.1 Yield [Teams involved: 07,09] (team writing: 07)

3.2.1.1 Production of thick sliced veneer

As has already been mentioned, cross-cutting was carried out only for the logs of Italian origin. The losses due to this operation was calculated as the percentage ratio between the material discarded and the total volume of the original logs. Since, in the case of logs for rotary-cutting, frequencies are not distributed following a normal curve, for these the values corresponding to the three quartiles are given, in addition to the mean value, which is 24% (Table 16).

These losses includes under-sized logs (initially bolts of a diameter of up to 15 cm were expected to be used) and portions with defects of shape or defects in the wood.

Table 16 - Cross-cutting losses of Italian lot

Origin	**No.Of stems**	**Vol. (m3)**	**Mean length of stems (m)**	**Waste in cross-cutting (% of initial volume)**				**Mean diameter of bolts Obtained From stems (cm)**
				25° percentile	50° percentile	75° percentile		
PIEDMONT 2	55	6.721	4.5	5	22	46		19

The final **yield** in parquet sheets, calculated on 65 bolts of Italian origin and 34 of French origin, were 11% and 8% of the volume of the bolts, respectively. To this volumetric yield there corresponded a surface yield of 33 m3 per cubic metre and 25 m^2 per cubic metre of round timber, respectively, which amounted to approximately one third of the yield from oak timber.

The main processing waste occurred in the phases of squaring, slicing and trimming.

Waste due to squaring was higher for the French lot (34 % of the total volume of the bolts), which consisted of wooden stock of a larger diameter, whilst it was 23% for the Italian lot, which generally consisted of smaller logs and for which particular care was taken to minimize waste due to squaring offcuts. No link, instead, emerged between waste due to squaring and tapering, ellipticity of the cross section, or length of the bolt. Rationalization of this processing phase should, however, not only tend to minimize waste, but also guarantee a subsequent optimal use of the square block obtained; for example, care should be taken to see that a possible diametral growth stress check is parallel to two faces of the square block, so as to obtain unsplit sliced pieces.

For the chestnut of Italian origin, the **waste in raw material due to the board left over from slicing (residue board)** was 19% of the volume of the initial square block (mean thickness of the board, 28 mm); for the chestnut of French origin, it was 21% (mean thickness of the board, 36 mm). The thickness of the board, on the other hand, was not determined so much by the technical limits of the machine, as by the presence and extent of growth stress checks which would inevitably have prevented the use of sheets obtained from the innermost portion of the square block. Considering the frequent presence of checks that develop starting from the pith, it would seem advisable to leave a board at least 40 mm thick, regardless of the diameter of the bolts, since the sliced pieces obtained from the innermost portion, even though apparently sound, split easily in the subsequent processing steps.

To contain the untoward effect of growth stress checks, it is very important to adopt suitable steam treatment, which, in the case in point, was only in part possible (see Section 3.2.2.1).

High **wastage from trimming** was moreover recorded owing to the abundant presence of loose knots (very frequently of small dimensions), of occasional ring shakes, and growth stress checks in the core of the bolt. Once more on account of defects present in the wood, in the **final selection,** 11% of the total number of sheets produced from the Italian bolts and 23% of those produced from the French bolts were discarded.

The processing waste for the entire production cycle and the yield in sheets of the bolts of Italian and French origin are given in Fig. F/48.

From a comparison between the two histograms, it may be noted that the difference in yield between the two lots is due mainly to the squaring waste. Furthermore, even if the yield in sheets with respect to the volume of the square blocks, instead of the yield with respect to the volume of the bolts, is considered, the two lots do not show a significantly different mean yield (Fig. F/49).

It should moreover be considered that the waste in volume given in the graph of Fig. F/48 also includes the raw material discarded owing to the leaving of a suitable allowance in length, width and thickness, and the waste due to dimensional shrinkage of the semifinished products. In this connection, the waste due to allowance amounted to approximately 40% of the volume of the finished parquet sheets. This means that if, for example, the final yield in parquet sheets is 10% of the volume of the bolt, the waste due to allowance amounts to 4%. The total volumetric shrinkage of wood from the green state to 15% of final mean moisture content, instead, did not exceed 6-7% of the initial volume.

3.2.1.2 Comparison between sawing and slicing

In the case of vertical frame multiblade sawing, the final yield in sheets amounted to 16% of the volume of the bolts, i.e., 49 m^2 per cubic metre of round wood. In this connection, it should be remembered that the quality of the sawn bolts, which were moreover carefully chosen, is not comparable with the poorer quality of the bolts that underwent slicing.

On the whole, however, the surface appearance of the sawn veneers was better than that of the sliced veneers, owing to the fact that the saw blade does not cause microsplits or grain tearing as does the action of the knife of the slicer. Moreover, given the same thickness, the sawn pieces showed greater solidity to the touch than the sliced pieces, which had a greater tendency to split.

If a comparison is to be made between yield obtained from slicing and yield obtained from sawing, assuming that the waste due to squaring, allowance, and defects of the wood are the same for both processing systems, it will be sufficient to consider the waste due to the residue board and to the sawdust, as shown in Table 17. In these conditions, whilst sawing entails a constant processing waste, in the case of slicing the waste due to the residue board, given the same thickness of the latter, decreases as the size of the square block increases, thus becoming more and more advantageous.

Table 17 - Comparison between theoretical waste due to slicing and that due to sawing, expressed as percentage of volume of square block

Type of processing	**Slicing**		**Sawing**	
Size of bolts	Square blocks obtained from bolts of 20 cm	Square blocks obtained from bolts of 25 cm	Square blocks obtained from bolts of 20 cm	Square blocks obtained from bolts of 25 cm
Waste due to board left over from slicing (thickness 40 mm) or to sawdust	28%	23%	32%	32%

3.2.1.3 Production of prefinished composite parquet strips

From the sorting of sheets into first and second choice there did not appear to emerge significant differences between the two lots of chestnut wood (see Table 18).

In the production of prefinished parquet strips, the processes of separation of the strips, cutting of the support, and varnishing did not involve, of themselves, any loss of useful surface. Likewise, waste due to processing snags during the same phases were negligible (approx. 1% of the pieces processed).

On the other hand, more substantial waste of raw material was recorded during the profiling of the edges to make the tongue and groove profiles. This process, by itself, involved a variation in the surface of the strips, which was reduced from 60 (or 80) x 10 cm to 59 (or 79) x 9 cm and which led to a loss, on the other hand inevitable, of 12% of the processable surface. Moreover, during profiling, the opening of a number of splits at the ends of some of the sheets was observed. For this reason, one part of the defective pieces was sectioned transversely and reduced in length, and undersized pieces, 45 cm long, were obtained from the 60-cm long pieces, and undersized pieces, 63 cm long, from the 80-cm long pieces. Another part, instead, was completely discarded, so that there was a further loss of 8% of the potential product surface.

Table 18 - Subdivision of sheets produced, according to size, type of processing, and quality.

Origin	**Italian**		**French**		**Italian + French**	**Italian + French**	**Italian**
Type of processing	**slicing**						**sawing**
Length	60 cm	80 cm	60 cm	80 cm	60 cm	80 cm	60 cm
Initial numb.	976	553	505	314	1481	867	168
Surface (m^2)	58.56	44.24	30.30	25.12	88.86	69.36	10.08
% first choice	54%	70%	76%	58%	62%	66%	48%
% second choice	46%	30%	24%	42%	38%	34%	52%
Overall qualitative distribution	61% first choice 39 % second choice		68% first choice 32% second choice		64% first choice 36% second choice		48% first choice 52% second choice

The final production of prefinished parquet strips was thus 123.52 m3, or 79% of the initial surface of the sheets sent for production. The final yield in prefinished pieces made with sheets obtained from lengthwise slicing of chestnut bolts coming from coppices was 19 m3 per cubic metre of round wood of French origin and 26 m3 per cubic metre of round wood of Italian origin. The yield of the sheets obtained using a vertical frame multiblade saw was higher, owing to the better quality of the original bolts. However, a more reliable comparison would require an investigation carried out using a larger sample.

3.2.2 Relationships between quality of wood and processing yield [Teams involved: 07,09] (team writing: 07)

The aim of the qualitative analysis of the wood was, on the one hand, to characterize the processed timber from the two sources in order to assess a possible different behaviour and, on the other, to identify the defects that adversely affect production of sheets via lengthwise slicing and to provide indications for a classification of the roundwood chosen for this type of transformation.

3.2.2.1 Characterization of the two lots of chestnut wood

On the basis of the surveys made, it is possible to provide a description of the defects found in the two lots, and also to make a statistical evaluation of the significance of the differences found.

As far as presence of knots is concerned, it was noted that sound knots having a diameter of up to 2 cm can be tolerated, as these in general do not split under the action of the slicing knife, whereas loose knots, even small-sized ones, in any case prevent production of sheets that may be used for prefinished composite parquet. Consequently, if sound knots of a diameter of less than 2 cm are disregarded, the parameter which shows the closest correlation to yield, and hence also the one that is most useful to describe the two lots, proved to be the sum of the lengths free from knots only of the faces of the square block that had knotless portions of at least 65-cm length, divided by the length of the piece.

The two lots proved different, showing statistical significance, from the standpoint of diametral checks and knots, but not from the standpoint of ring shake, which in every case was of limited extent, also because both lots had been selected so as to be as free as possible from this defect. Furthermore, new ring shake did not appear in either lot after steam-treatment. The Italian lot presented knot-free portions of greater length, but more developed growth stress checks. In this connection, a different behaviour was noted in the two lots of timber: whereas the bolts of French origin recorded a limited increase in the size of the checks on the tops, which even after steam-treatment were not on average longer than one half the diameter of the bolt, the behaviour of the Italian bolts was very different, insofar as in 90% of the latter these checks more than doubled their length, frequently spreading from one side to the other of the top of the piece. This difference could be due, on the one hand, to a higher level of growth stresses and, on the other, to the fact that the logs of the Italian lot were worked a short time after felling, whereas, the fact that the French ones remained on the yard for a few months may have allowed a gradual release of these stresses.

Table 19 gives the frequencies and average values of the defects examined and the corresponding Student's t-test for the significance of the difference. The two samples are to be considered with a sufficient degree of confidence as belonging to two different populations only when the level of significance of this test is lower than 0.05.

Table 19 - Characterization of the two chestnut lots according to defects

DEFECT	PARAMETER	PIEDMONT 2 (104 bolts) mean (standard dev.)	CEVENNES 2 (33 bolts) mean (standard dev.)	Level of significance of difference of mean (Student's t-test for independent samples)
RING SHAKE	frequency %	25%	15%	
	extent*	3.9 (2.8)	4.0 (0.7)	0.90 - not significant
DIAMETRAL CHECKS	frequency %	99%	100%	
	extent before steam treatment**	0.49 (0.35)	0.38 (0.19)	0.027 - significant
	extent after steam treatment	1.18 (1.04)	0.42 (0.21)	0.000 - highly significant
KNOTS	portion free from knots*** (cm)	285 (82)	174 (73)	0.000 - highly significant

* = expressed as described in Section 2.2.2.12

** = calculated as ratio between length of check and diameter of bolt

*** = expressed as length of the knot-free portion of the 4 faces of the square block divided by the length of the piece

3.2.2.2 Relation between quality of wood and processing yield

As has been already mentioned in Section 3.2.1.1, the yield in sheets with respect to the square blocks of the two lots did not reveal statistically significant differences (Fig. F/49). This may be explained by the fact neither of the two lots was superior as regards all the defects considered, but, for example, a smaller number of knots was accompanied by a higher presence of splits, and vice versa. It is difficult to assess the influence of the individual defects, in that during processing measures were taken to reduce the corresponding adverse effects, such as, for instance, that of orienting the diametral checks parallel to the slicing plane. In addition, the yield of a process that entails a number of manufacturing operations as the one in question is linked to a large number of factors, either singly or combined, in which defects play an important, but not determining, role. Other factors to be taken into due consideration are, for example, defects such as tearing of the grain and splitting, which occur, more readily, but not exclusively, at the knots. Also the state of maintenance of the blades has a major importance. Deformations due to cutting may then be associated or otherwise with those resulting from release of growth stresses and subsequently with those due to drying, and at times involve discarding of the worked piece. A very important factor is the professional expertise of the operators carrying out trimming, if discarding of defective portions is to be reduced to the minimum.

For all these reasons, whilst in the course of processing the defects that limit production were clearly identified, from the computer processing carried out to seek the relation between yield and defects in the wood, only modest results emerged.

The presence of ring shake caused, by itself, a decrease in yield corresponding to 3% of the volume of the square blocks, irrespective of the extent of the phenomenon; however, ring shake did not prove statistically significant. It should be recalled that the ring shake found was, on average, of limited extent.

The knots, expressed as "length of the useful portions (i.e., greater than 65 cm) of the faces of each individual square block" have a statistically significant, albeit not marked, effect on the production of sheets from each bolt. Considering the total bolts on which the entire slicing process was carried out, this parameter determined to the extent of 17% the overall variability of yield in sheets. If the analysis is restricted to more uniform sub-samples, such as that consisting of the French bolts alone, better correlations may be found between presence of knots and yield, but in no case such that might explain more than 25% of the variability of the yield.

The presence of checks certainly limits yield, above all if, in the course of squaring of the bolt and slicing, care is not taken to maintain the cutting plane parallel to the splitting plane. From a numerical point of view, however, there do not appear to be correlations between the extent of the checks after steam treatment and yield in sheets. Finally, checks were the main reason for the rejection of a certain number of sheets in which splitting appeared on the heads during processes that subjected the piece to mechanical stress (e.g., sanding or tongue-and-groove profiling).

3.2.3 Proposal for roundwood grading [Teams involved: 07,09] (team writing: 07)

Were lengthwise slicing to be used in future on an industrial scale for the production of sheets for prefinished composite parquet flooring, for the purposes of a possible classification of the roundwood to be used, the following pointers should be borne in mind:

1. The minimum diameter at the tip must be 18 cm.
2. The minimum length must be at least twice the length of the sheets that are to be obtained. In addition an allowance of at least 5 cm should be considered for each length.
3. No ring shake is allowed, whatever its extent or origin.
4. It is advisable to select lots of timber with a low level of growth stress and to adopt all possible measures to limit the development of diametral checks. Moreover, checks on the tops of green bolts should not exceed one third of the diameter.
5. No loose knots are allowed of any type or size. Bolts with adherent knots smaller than 2 cm in diameter are allowed; however, it must be remembered that these will necessarily lead to 2nd-choice veneers. Likewise to be rejected are bolts with covered knots or ones presenting signs of epicormic shoots on the bark. Finally, it is more important to assess the length of the useful portions of each bolt rather than to quantify the number and dimensions of the knots present.

On the basis of the above indications, it is believed that the most suitable material for manufacturing TSV for prefinished parquet strips is roundwood from young stems (or from apical portions of aged stems) having the following characteristics:

- they have grown in dense populations on fertile stands where there is good natural pruning and the majority of the branches still present are living;
- their dimensions are modest and the distances between the knots are large.

3.2.4 Work times, productivity and estimation of production costs [Teams involved: 07] (team writing: 07)

3.2.4.1 Production costs of chestnut sheets

The work times for manufacturing sheets using the slicing process were recorded at the first level (Berti et al., 1989), i.e., measuring the time taken and the overall quantity worked for each phase of the production cycle. On the basis of these times, the productivity was calculated and the processing costs estimated. As regards the latter, it is possible only to formulate rough estimates, since a number of important parameters, such as service life of the equipment and the number of hours per year of machine use, company fixed costs, and the rate of interest to be applied on invested capital were not known. As regards labour costs, an average value of 25,000 lira/h inclusive of taxes and social security contributions was assumed.

From Table 5 it emerges that the recorded unit cost of transformation and of raw material for production of chestnut sheets does not differ significantly whether slicing or sawing is adopted, and ranges from 20,000 lira/m^2 to 22,000 lira/m^2. To this figure must be added the overheads and the profits of the firm carrying out the transformation, which altogether may be estimated at 10,000 lira/m^3 (4), thus the total cost arrives at 30,000-32,000 lira/m^3. These values are higher than the market price of sheets traditionally used in the sector, such as oak sheets, which costs 20,000 - 22,000 lira/m^3.

(If the price of a cubic metre of oak timber for manufacturing wood flooring is taken to be 400,000 lira, and it is assumed that, with a transformation cost of 500,000 lira/m^3, 90 square metres of sheets are obtained from each cubic metre of roundwood, the total cost of this product may be estimated at 10,000 lira/m^3. This cost, compared with the market price of 20,000 lira/m^3, leaves the firm carrying out sawing a reasonable margin for general overheads and company profit, which may therefore be estimated at 10,000 lira/m^3)

On the basis of these calculations, the transformation of chestnut wood from coppice stands, for the time being, would not appear to be economically advantageous, since the processing yield expected is no higher than 30 m^3 per cubic metre of roundwood. Instead, assuming a constant price of raw material and constant transformation costs, corresponding, respectively, to approximately 150,000 lira and 500,000 lira per square metre of worked timber, there might be a certain advantage in working chestnut wood with yields of at least 45-50 m^3 per cubic metre of roundwood; this would correspond to a transformation cost and a cost of raw material of approximately 14,000 lira per square metre of veneer sheets, which would then amount to 24,000 lira, if overheads and company profit margin are included. From what has so far been said, it emerges that prefinished chestnut parquet strips, irrespective of their qualitative features, could not be proposed on the market as an Italian product having a lower cost than the types of wood traditionally used (oak and above all tropical timber, such as iroko and doussiè). Chestnut for parquet flooring could have a commercial success if it were promoted as a product of the transformation of timber coming from the cultivation and exploitation of forests in the Mediterranean area, and if public appreciation were aroused for such a product.

3.2.4.2 Production costs of prefinished parquet strips

The production cost of prefinished parquet strips consists of the following three main items:

1. cost of the chestnut heartwood sheets
2. cost of the wood-based subfloor support, which may be either a plywood or an OSB panel
3. processing cost (gluing, cutting, finishing, and profiling)..

Item 1 has already been amply discussed in the foregoing section. Items 2 and 3 are independent of the kind of wood used for the surface layer of the flooring.

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According to the type of panel used, plywood or OSB, and, in the case of plywood, according to the number of layers and the kind of wood, the cost of the subfloor may range from 9,000 lira/m^2 to 12,000 lira/m^2. In the case in point, a poplar plywood panel and a birch plywood panel, both produced in Italy, were used. These consisted of 5 layers and cost 9,500 lira/m^2 and 10,500 lira/m^2 , respectively.

The costs of manufacture of the prefinished parquet may be estimated at approximately 40,000 lira/m^2.

To calculate the overall cost of the product, it is necessary to take into account that during manufacture, there is a loss of useful surface of 12%, and hence the costs of the sheets and the subfloor support must be increased by approximately 14%, since from 100 m^3 of veneer sheets and subfloor, only 88 m^3 of prefinished parquet strips are produced.

Consequently, we have:

Cost of chestnut veneer sheets: 30,000 lira/m^2 + 14%	= 34,200 lira/m^2
Cost of subfloor: 10,000 lira/m^2 + 14%	= 11,400 lira/m^2
Processing cost	= 40,000 lira/m^2
Total cost	**= 85,600 lira/m^2**

If we take as reference a prefinished parquet made of oak, with a patterned grain and OSB subfloor support, having a cost of approximately 70,000 lira/m^2, prefinished chestnut parquet strips, against expectations, would fall in the medium-to-high price range. In this connection, those operating in the sector initially showed considerable interest in this product also because, at least in theory, it seemed to be more economic compared to those made using traditional types of wood.

Table 5 - Work times and partial and total costs of machinery and labour for lengthwise slicing and sawing, per cubic metre of roundwood timber worked or per square metre of sheets produced, assuming a yield of 30 m^3 per cubic metre of roundwood.

	1	2	3	4	5	6	7	8	9
1	Operation	Compos. of work squad (nb of workers)	Labour time (h) per m^3	Labour cost per m^3 (1 h= 25,000 L) (L)	Type of machine used	Mach. hrs.	Machine cost (L/h)	Total cost of machine (col.7 x col. 6) (L)	Total costs of operat. per m^3 (col. 8 + col. 4) (L)
2	Sorting of stock and cross-cutting	1	1	25,000	Chain saw	0.5	6000	3,000	28,000
3	Steam treatment							50,000	50,000
4	Squaring	2	1	25,000	Band saw	0.5	30,000	15,000	40,000
5	Slicing	2	4	100,000	Marunaka slicer	1.5	50,000	75,000	175,000
6	Sawing	1	4	100,000	Vertical frame multi-blade saw	3	50,000	150,000	250,000
7	Drying*							30,000	30,000*
8	Trimming	1	2	50,000	Cutting-off machine	1	5,000	5,000	55,000
9	Sanding	2	1	25,000	Roller sander	0.5	15,000	7,500	32,500
10	Trimming and forming of packs	2	2	50,000	Double radial saw	0.75	10,000	7,500	57,500
11	-Totals for slicing - Cost per m^3 of veneers produced		10,5	275,000 9,160				193,000 6,440	468,000 15,600
12	-Totals for sawing - Cost per m^3 of veneers produced			275,000 9,160				218,000 7,270	493,000 16,430

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13	- Cost of raw material per m^3 - Cost of material per m^3								150,000 5,000
14	**- Total cost per m^3 of sliced sheets** **- Total cost per m^3 of sawn sheets**								**20,600** **21,430**

3.2.5 Notes on qualification of product [Teams involved: 07] (team writing: 07)

Product qualification was not included among the aims of this programme, nor was a survey on acceptability. However, in the course of the tests, a number of indications emerged, which are worthy of mention.

The prefinished parquet strips produced, on which the Participant No. 07 intends to carry out a technological characterization outside the present programme, met with the favour of all the operators of the sector who happened to be asked their opinion on the matter, particularly on account of the good aesthetic features of the product (Fig. F/50).

The poplar subfloor support used as a replacement for the birch one presented a number of drawbacks linked to the fact that this wood is less hard and, at times, under the action of the press, showed irregular and undesired decreases in thickness. As regards the run of the grain of the outer and inner layers of the subfloor panel, it is extremely important that the layer of the panel that forms the projecting rib of the tongue and groove should have the grain running parallel to that of the heartwood veneer sheet. This enables a better mating of the strips and greatly facilitates the laying of the parquet.

It is not yet possible, instead, to assess the effect of a possible evolution of the microsplits due to slicing on the surface quality of the parquet, once this is laid.

4 CONCLUSIONS

natural durability of LVL chestnut compared with chestnut solid wood

It is important to know the natural durability against fungi of LVL, since it could be used in exterior conditions, above ground and not covered, as windows frames, where moisture levels for wood reaches frequently 20%. These conditions can cause a fungus attack.

From an investigation resulted that the fungi attack hazard is rather frequent in windows frames and the attack takes place usually in the bottom of the frames where rain water stay a long time. The fungi attack is chiefly caused by brown rot fungi.

This first set of tests, carried out on LVL chestnut bonded with MUF63T, resulted in classifying LVL as "durable".
These results are rather promising, but a lot of tests, including also cycles of leaching, are still necessary before to consider that this product can be efficiently used in structures in exterior conditions above ground (Hazard class 3 according UNI EN 335/1) without a preservative treatment.

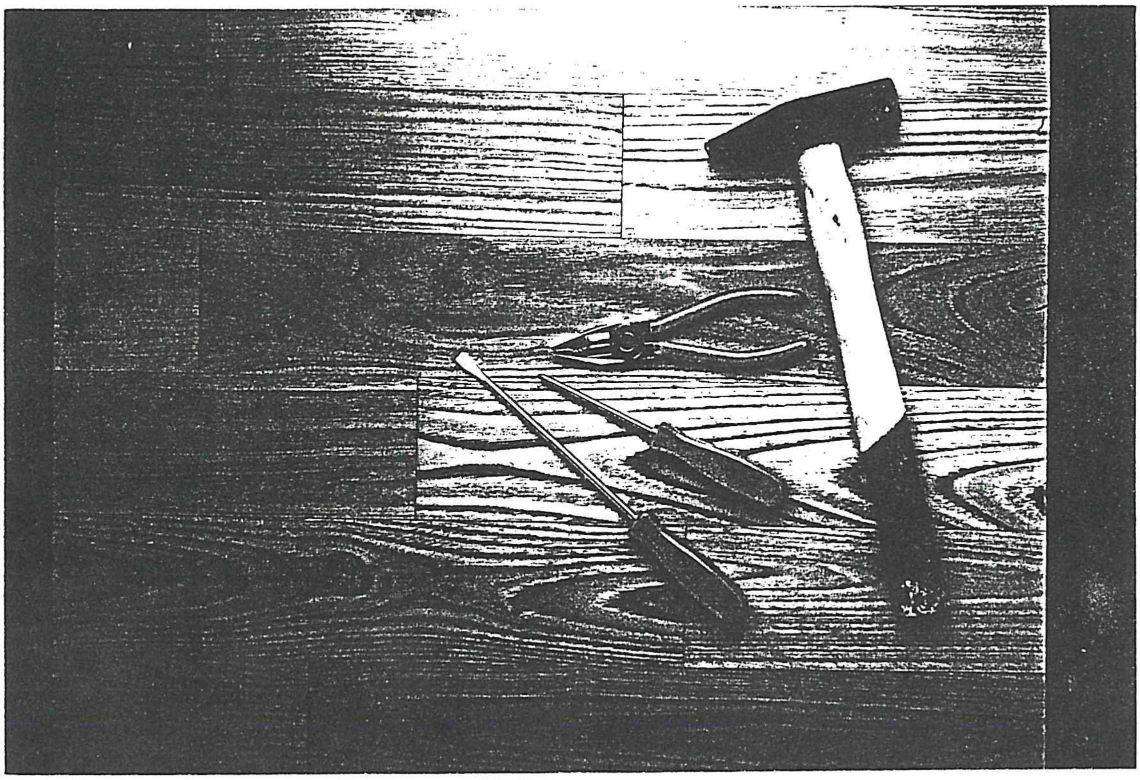

Figure F/50 - Example of finished parquet made with Chestnut TSV

for LVL processing

Peeling of Chestnut logs utilised from coppices is fully feasible from a technical point of view, provided that the steaming of bolts is made according to appropriate cycles.

Starting from unselected bolts, the yield in terms of dry veneers is quite low.

For acceptable results, the jointing of strips should be performed by means of glue jointing; "sewing" with nylon thread has proved to allow too much clearance between strips.

The italian market is not yet fully ready to accept chestnut LVL. This is mainly due to the lack of information about this inoovative product: the dissemination of the results deriving from this research could modify substantially the reaction of potential users.

Chestnut logs with bark presently need a sanitary certification: this means that problems may arise for the import-export of valuable provenances among different Countries.

Costs are estimated slightly higher than 3000 000 Lira/m^3 , i.e. comparable to the costs for Non-Structural Glulam (already used for window frames).

for TSV processing

Lengthwise slicing for the manufacture of TSV, starting from small-sized chestnut roundwood obtained from coppice stands, proved technically possible. The sheets obtained present good aesthetic qualities and can be used as outer heartwood layers in prefinished composite parquet strips. However, bolts having a minimum diameter of 18 cm and a minimum length of 1.30 m should be available.

The processing yield is somewhat low, i.e., approximately 10% of the initial volume of the bolt, corresponding to a production of 30 m^3 of sheet per cubic metre of roundwood. Four fifths of the sliced pieces produced were discarded on account of defects in the wood, above all for knots and growth stress checks.

Sound knots of up to 2 cm in diameter may be accepted, since these do not give rise to discontinuities in the sliced sheet, even though they entail a down-grading of the veneer containing them. Growth stress checks rule out the use of the innermost portions of the stem. The undesired effects of these checks can be prevented if particular care is taken when squaring and slicing the bolts, and their development can be kept under control by adopting a low-temperature steam treatment. Ring shake, even though of limited extent, is deleterious and is to be considered an inadmissible defect.

It is believed that, if particular solutions are adopted during processing and if TSVs can be trimmed to lengths also below 60 cm, it will be possible to increase the yield up to 45-50 m^3 per cubic metre of roundwood. In this way, although sheets made of chestnut obtained from coppice stands may not prove more economic to produce than sheets obtained from the woods traditionally used in the sector (e.g., oak), they could at least be proposed as a product able to occupy a medium-to-high market niche and as one that is attractive on account of its particular ecological spin-offs.

Sawing using a vertical frame multiblade saw appears to be a valid vertical frame to lengthwise slicing, in that, albeit at the expense of some further waste of raw material, it makes steam treatment unnecessary and enables a better surface quality of the sheets to be achieved.

The production of prefinished parquet strips using heartwood chestnut sheets is based on recent, but by now consolidated, techniques. In the tests carried out, no particular production problems arose, but there was, however, a higher number of pieces discarded than is normal in strips manufacturing, mainly on account of splits which appeared in the sheets in the course of edge profiling.

The final product obtained, which was subdivided into two grades according to the pattern of the grain and the presence of knots, presents noteworthy aesthetic features and has met with the favour of the firms that took part in the research. Subsequent research will enable a characterisation of this product both from a technological standpoint and a performance standpoint.

It should be stressed that the using of thinner sheets (around 2 mm thick) will highly enhance the profitability of thick slice veneering, because:

- the ratio m^2 of parquet / m^3 of logs will increase;
- the surface quality of veneer sheets will be improved;
- the problems caused by the residual twisting after flat drying will be completely negligible.