Influence of wood extractibles on the gluing quality of oak LVL

PROCEEDINGS COORDINATOR **Loredana Anne Marie BADESCU**

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INFLUENCE OF WOOD EXTRACTIBLES ON THE GLUING QUALITY IN OAK LVL

Mariana SVORADOVÁ, Laurent BLÉRON, Rémy MARCHAL, Giacomo GOLI, Fabrice COTTIN

Abstract: *Medioeuropean Oaks present a high variability for their rate of ellagitannins in heartwood and, from then, for their natural durability. More-over, there is a significative difference between sessile oak (Quercus sessiliflora S.m.) and pedonculate oak (Quercus pedunculata Ehrh.) concerning this characteristic.*

To appreciate eventual effects of these wood extractives on the adhesion of some structural glues, different LVL samples have been manufactured using

- *4 different glues (Melamine Urea-Formaldehyde, Phenol Resorcinol-Formaldehyde, Polyurethane, a PRF mixed with natural tannins),*
- *veneers from 4 sectors (sapwood, "young heartwood", "medium heartwood", "old heartwood")*
- *3 veneer thickness (1, 2, 3 mm)*
- *2 preliminary bolts preparation (no boiling / boiling at 60°C)*
- *2 oak species (sessile and pedonculate oak)*

The glue bonds quality has been evaluated by mechanical bending test on about 14 samples for each kind of LVL. These preliminary tests show some significant effects of wood species, veneer thickness and glue but no clear effect of boiling and of radial position.

1. INTRODUCTION

In the framework of the research program "Durachêne" relative to the characterization of the two main French oak species natural durability *(Quercus pedunculata Ehrh* and *Quercus sessiliflora S.m.)*, it has been demonstrated that [3]

- these species show important differences for the amount and the nature of ellagitannins responsible of the wood durability, pedonculate oaks presenting the higher natural durability;
- the rate of ellagitannin continually decreases from the pith to the bark ;
- the variability of the oak wood durability is quite high inside the species.

Our laboratory is particularly involved in the technical development of oak LVL in view to valorize large quantities of second quality woods from coppice ([1], [2], [4], [5] and [6]). It becomes now important to check

- if wood extractives like ellagitannins interacts with different usual structural glues;
- how does the process (peeling by itself including the boiling stage; assembling with glues) change the "natural" durability of LVL designed for structure, furniture or joinery.

This paper mainly concerns the first aspect, the second one being in progress, requiring long term test of biological contamination.

2. MATERIAL AND METHODS

Two trees (one pedonculate oak and one sessile oak) have been selected in the same area of the State Forest of Cluny, France (Table 1)

Table 1.
Description of the two logs

	Length of the log	Age	Bigger diameter	Smaller diameter	Volume
Peconculate oak	10 m	150 years	57 cm	47 cm	1.8 m^3
Sessile oak	9 m	120 years	50 cm	35 cm	1.2 m^3

Each tree has been crosscut into 600 mm long bolts alternated with 100 mm thick disks used for chemical characterisation performed in Ecole Supérieure du Bois (ESB), Nantes. The bolts have been peeled to prepare LVL boards following 192 different modalities, i.e.

- 2 species : pedonculate oak / sessile oak ;
- 2 thermal treatments : boiling at 60°C during 16 hours / no treatment (green wood peeled at the current temperature of 20°C);
- 3 peeling thickness : 1, 2 and 3 mm;
- 4 radial position in the wood : old heartwood (A), intermediate heartwood (B), young heartwood (C) and sapwood (U);
- 4 types of glue: one Melamine Urea-Formaldehyde (MUF), one Phenol Resorcinol-Formaldehyde (PRF), one polyurethane (PU) and one PRF mixed with natural tannins (Honeymoon Glue or HG).

Because of some lacks of matter (more particularly of veneers produced into the sapwood, small quantities of Honeymoon Glue which is an experimental one, veneers from unheated bolts sometime difficult to collect because of their low quality, ...) only 82 modalities have been obtained.

2.1 Preparation of the samples

2.1.1 Peeling process and drying

The comparisons of LVL

- assembled with veneers coming from boiled or unboiled bolts
- made with veneers of different thickness

were partly suggested by the results of Sabine Boury [2] showing influences of these two parameters on the resistance of oak wood to fungi. These influences could be due to some wood extractives watering down during boiling and to the different rates of water eliminated during peeling according to the cutting depth.

After marking the four radial zones on the round woods, half of the bolts have been heated into a boiler and then peeled at the same conditions than for the unboiled bolts on the industrial CNC peeling lathe of ENSAM. Each bolt has been completely peeled into one stage of cutting (1, 2 or 3 mm) and the veneer have been manually clipped into 500 mm x 500 mm sheets free of knots, before being dried at 10%.

2.1.2 Gluing and pressing

We have selected 3 structural glues among those available on the market (MUF, PRF, PU) and added an experimental one developed by Pr Pizzi and based on natural tannins. The gluing parameters are presented in table 2.

The target being the production of 20 mm thick LVL boards, we have assembled 20 veneers of 1 mm or 10 veneers of 2 mm or 7 veneers of 3 mm.

The MUF was the Cascomin MUF 1238 mixed with the hardener 2540 (respectively 100 parts and 25 parts of the weight) proposed by Akzo Nobel for gluing plywood resistant to humidity.

The PRF was the Enocol XRL490 mixed with the hardener XDL 490 (respectively 100 parts and 25 parts) proposed by Bostik Findley mainly for structural-grade glulam.

The PU was the Semparoc I 12 NV (mono component) provided by Collano and usually used for finger jointing in glulam fabrication.

The Honeymoon Glue (separate application) has been developed by Pr Antonio Pizzi ([7] and [8]) : one veneer surface was spread with a commercial PRF glue with its hardener when the other veneer surface was spread with the same quantity of a solution of tannin from mimosa before to be put into contact, then press. It is a fast set adhesive system.

The 500 mm x 500 mm boards obtained were then stocked during few weeks for conditioning before machining and testing.

Table 2.
Characteristics of gluing and pressing

Glue	Glue spread simple face (g/m²)	Spreading method	Pressure (MPa)	Temperature (°C)	Pressing time (h)
MUF	250	roller spreader	0.8	20	10
PRF	300	manually (spatula)	0.8		16
PU	200		0.8		4
HMG	300		0.7		16-24

2.2 The experiments

2.2.1 Mechanical tests

Each board has be length-cut in their longitudinal direction in order to obtain – after removing samples with gluing defects – a minimum of 10 samples per modality. After cross cutting and planning, the dimensions of the samples were 20 mm x 20 mm x 300 mm.

To test the mechanical behaviour of these LVL and the strength of the glue bonds, we have made 3 points flat bending tests at 20 mm/mn with a 220 mm span. We have computed the rupture stress (σr) and the module of elasticity (MOE).

The density has been measured on two 20 mm x 20 mm x 300 mm samples per modality to calculate the specific mechanical characteristics for better comparisons.

2.2.2 Other tests

For each modality, samples have been contaminated by fungi in order to test the influence of the process and wood parameters on the LVL resistance to rot. These tests are today in progress and the results will be available in a few month.

Table 3
Number of experiments per modality

	Number of trials											
Oak species	Peconculate oak 534						Sessile oak 622					
Heating treatment	Boiling 354			No treatment 180			Boiling 332			No treatment 290		
Peeling thickness	1 mm	2 mm	3 mm	1 mm	2 mm	3 mm	1 mm	2 mm	3 mm	1 mm	2 mm	3 mm
	98	118	138	0	0	180	86	84	162	90	67	133

Radial position	A	B	C	U	A	B	C	U	A	B	C	U	A	B	C	U
	111	94	122	27	45	59	64	12	25	98	127	82	31	85	133	41
Glues	MUF	PRF	PU	HMG	MUF	PRF	PU	HMG	MUF	PRF	PU	HMG	MUF	PRF	PU	HMG
	138	146	64	6	57	51	66	6	127	95	104	6	158	91	35	6

3. RESULTS AND DISCUSSION

In total, 1156 mechanical tests have been performed i.e. an average of 14 tests/modality.

3.1 Wood species effect

For each glue, the sessile oak LVL present the best mechanical properties and the higher fractile to 5% (figure 1) while the LVL densities are quite similar (respectively 0.75 and 0.73 for sessile and pedonculate oak). The results are roughly the same considering the specific mechanical values weighted by the density.

These tendencies are the same for all the radial positions and a little bit more prominent for boiled wood than for wood without any treatment.

The rupture stress reaches quite high mean value (94 MPa for pedonculate oak and 103 MPa for sessile oak).

3.2 Boiling treatment effect

No very significant boiling effect appears on the mechanical properties, more particularly on pedonculate oak. The lose of extractible during the boiling treatment doesn't seem to really interact on the glue bond strength. Nevertheless, fixing the different parameters one after the other, we observe that the mechanical properties are usually higher on LVL coming from heated sessile oak bolts (figure 2) : it could be due to the better veneer quality, presenting less lathe checks, and so higher mechanical characteristics, because of the heating treatment before peeling.

In the case of sessile oak the increase of mechanical properties in include in a range of 10-19%.

These observations are almost always true for all the veneer thickness, all the radial positions and all the glues - except the PRF (figures 6 &7).

3.3 Veneer thickness effect

All the experiments show a clear veneer thickness effect: the "1 mm LVL" presents much better performances than the "2 and 3 mm" LVL group (figure 3). But inside this second group we can note a special increasing tendency from 2 to 3 mm The classification 1 mm > 3 mm > 2 mm is respected inside the two wood species, for all the glues, the radial positions, the heating treatment ($\sigma_{r\ 1mm} = 1.23\ \sigma_{r\ 3\ mm}$ and $\sigma_{r\ 3\ mm} = 1.11\ \sigma_{r\ 2\ mm}$ for pedonculate oak; $\sigma_{r\ 1mm} = 1.21\ \sigma_{r\ 3\ mm}$ and $\sigma_{r\ 3\ mm} = 1.02\ \sigma_{r\ 2\ mm}$ for sessile oak) with an exception for the sessile oak MOE almost insensible to any thickness effect.

The first tendency is quite normal: the veneer quality generally decreases when the thickness increases with the lathe checks gravity. But with such reasoning, the lower value would be obtained with "3 mm LVL". Maybe the 2 mm LVL relative weakness can be explain by a difference of penetration of the glue in the lathe checks, the bigger one in 3 mm thick veneer favouring it, improving a little bit the LVL mechanical resistance.

3.4 Radial position effect

Considering the averages (figure 4), we can observed that the mechanical properties decrease from the pith (A position) to the young heartwood (C position), except for sessile oak MOE. The small increase of the values from the C position to sapwood (U position) can be due to its higher porosity allowing a better penetration of the glues into the veneer. We must be very careful because of the small number of results available on "U-LVL".

The relative weakness of "C-LVL" has to be confirmed on a larger sampling but could be due to chemical and energetic interactions between glues and wood: Sabine Boury explained in her bibliography ([1]) that the transition zone between sapwood and heartwood is the seat of very important physiological activities in wood, the transition to heartwood being a very active phenomena controlling the sapwood proportion into the tree.

But considering the different effects step by step (figures 6 &7), the position classification is not constant according to the type of glue and the veneer thickness.

3.5 Glue effect

In many cases, the polyurethane glue has given the higher mechanical resistances and the rupture very often occurred into the wood (figures 5 and 6). Considering separately the different effects, it appears that the other glues are much more sensible to the radial position and the veneer thickness than the PU glue, the strength of which masks eventual too weak chemical interactions between glue and wood extractives. The PRF glue appears to be the less effective one but the classification MUF/PRF would probably change on wood presenting a higher MC.

The predominance of PU glue no more appears when just considering the MOE (figures 5 and 7).

The HMG, for a part using natural tannins, looks promising showing high fractile values, but the number of samples glued with HMG was quite low.

4. CONCLUSION

The target of this new research program is to design of a new generation of LVL technically efficient but also presenting high environmental characteristics, i.e. a high resistant to biological degradations without any artificial treatment – except the glue.

The preliminary tests presented in this paper don't show any important effect of the peeling process (boiling and stage of cutting) on the mechanical behaviour of the LVL (except the probable lathe check effect). These observations are now to be completed by an analysis

- of the LVL mechanical behaviour based on a bigger sampling ;
- of the nature and quantity of extractives components measured on green wood before and after boiling, and also on veneers just before gluing and pressing ;

Figure 1 : evolution of oak LVL MOE, rupture stress mean values and fractile to 5% (all the data)

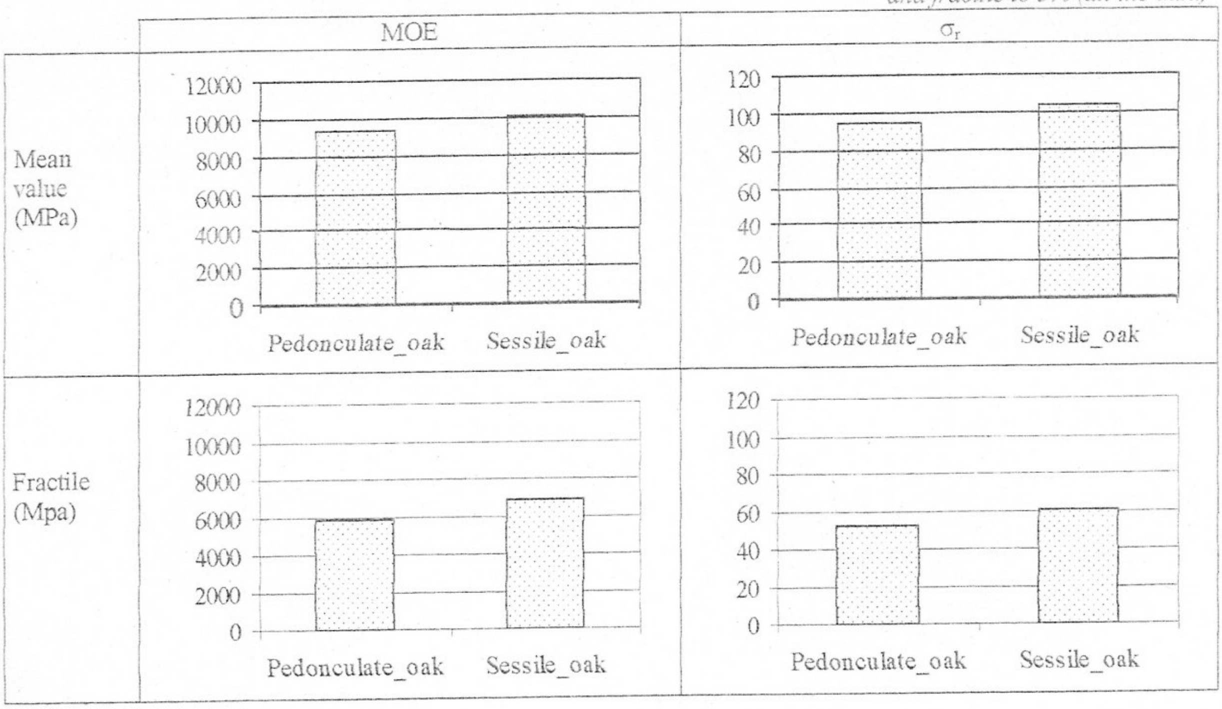


Figure 2: Hygrothermal treatment effect on oak LVL MOE, rupture stress mean values and fractile to 5%. (all the data)

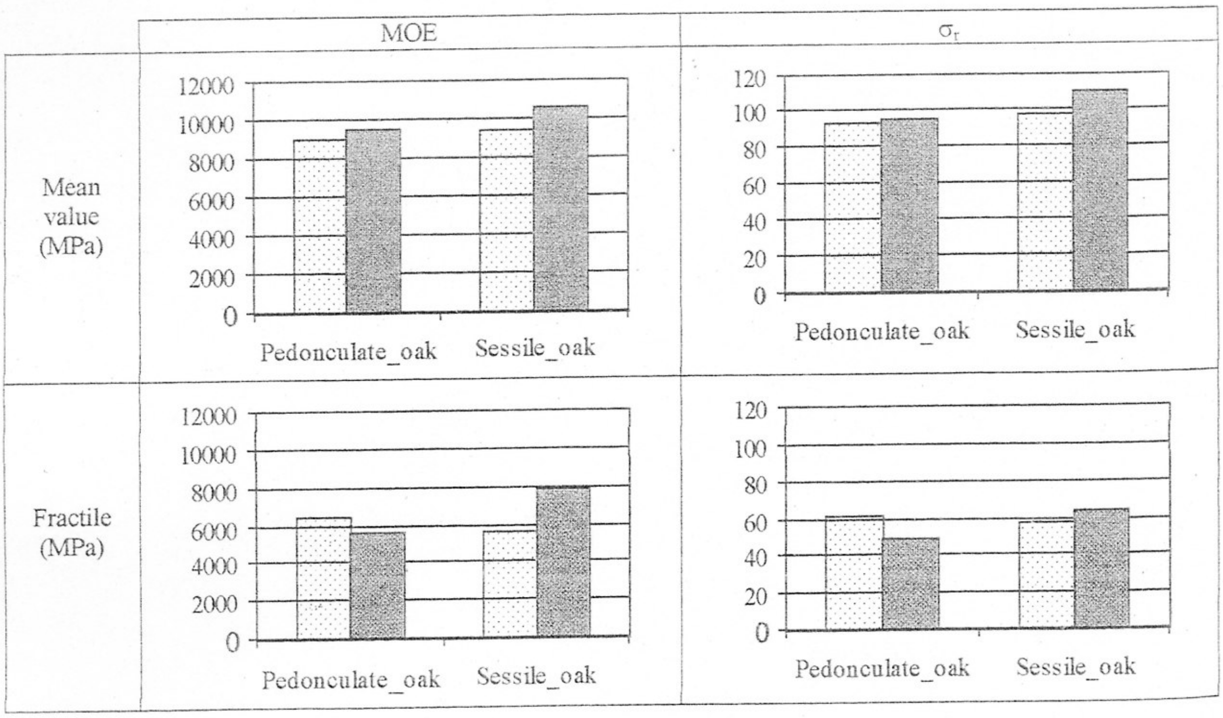


Figure 3 : Veneer thickness effect on oak LVL MOE, rupture stress mean values and fractile to 5% (all the data)

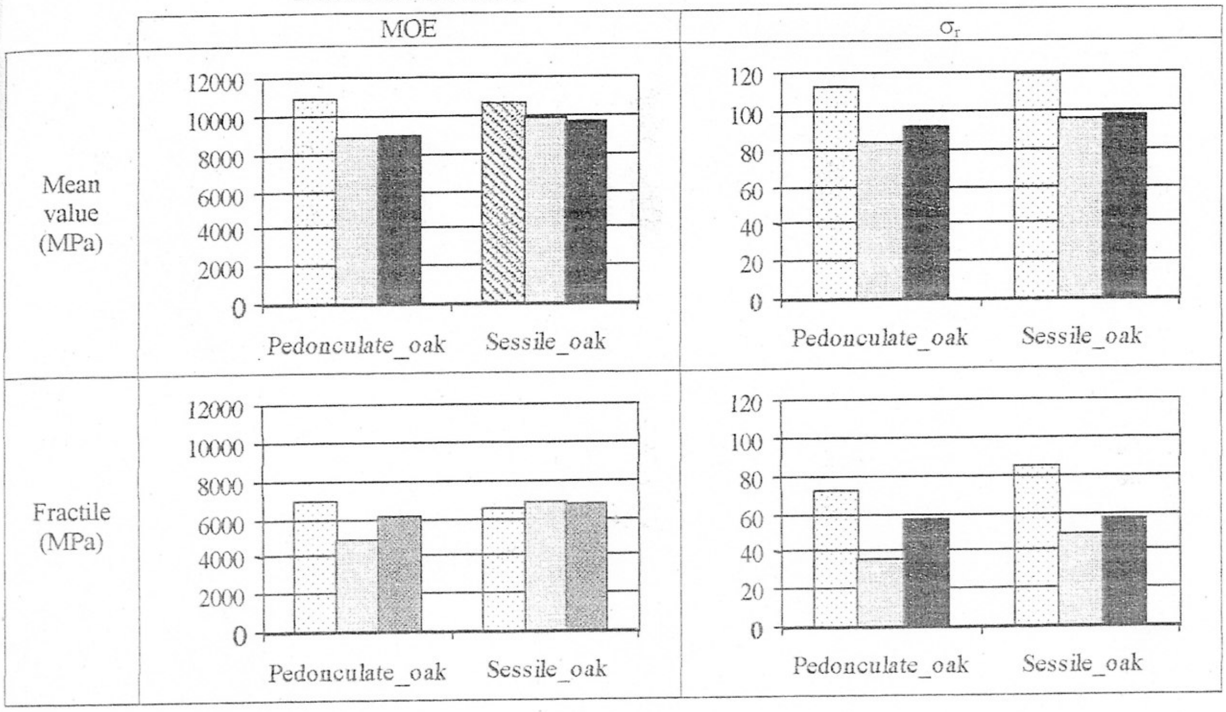


Figure 4 : Radial position effect on oak LVL MOE, rupture stress mean values and fractile to 5% (all the data)

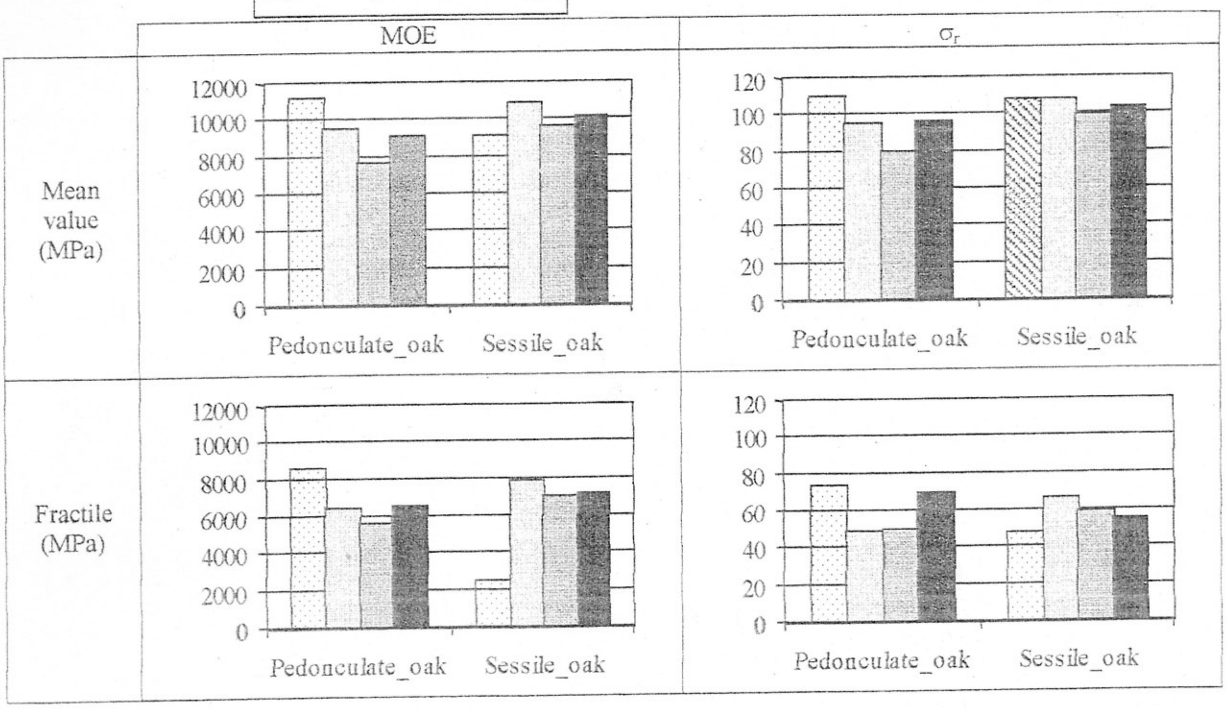


Figure 5 : Glue effect on oak LVL MOE, rupture stress mean values and fractile to 5% (all the data)

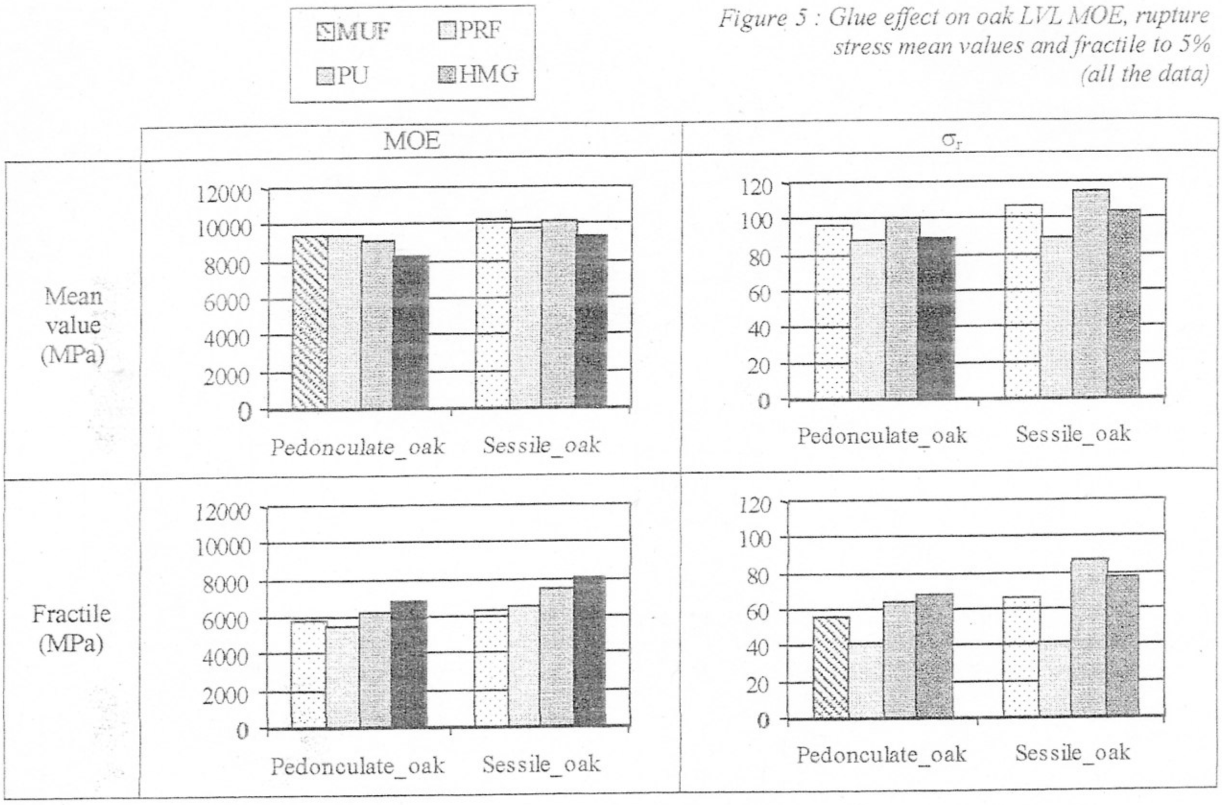


Figure 6 : Glue, position, thickness, boiling and wood species effects of oak LVL rupture stress (all the data)

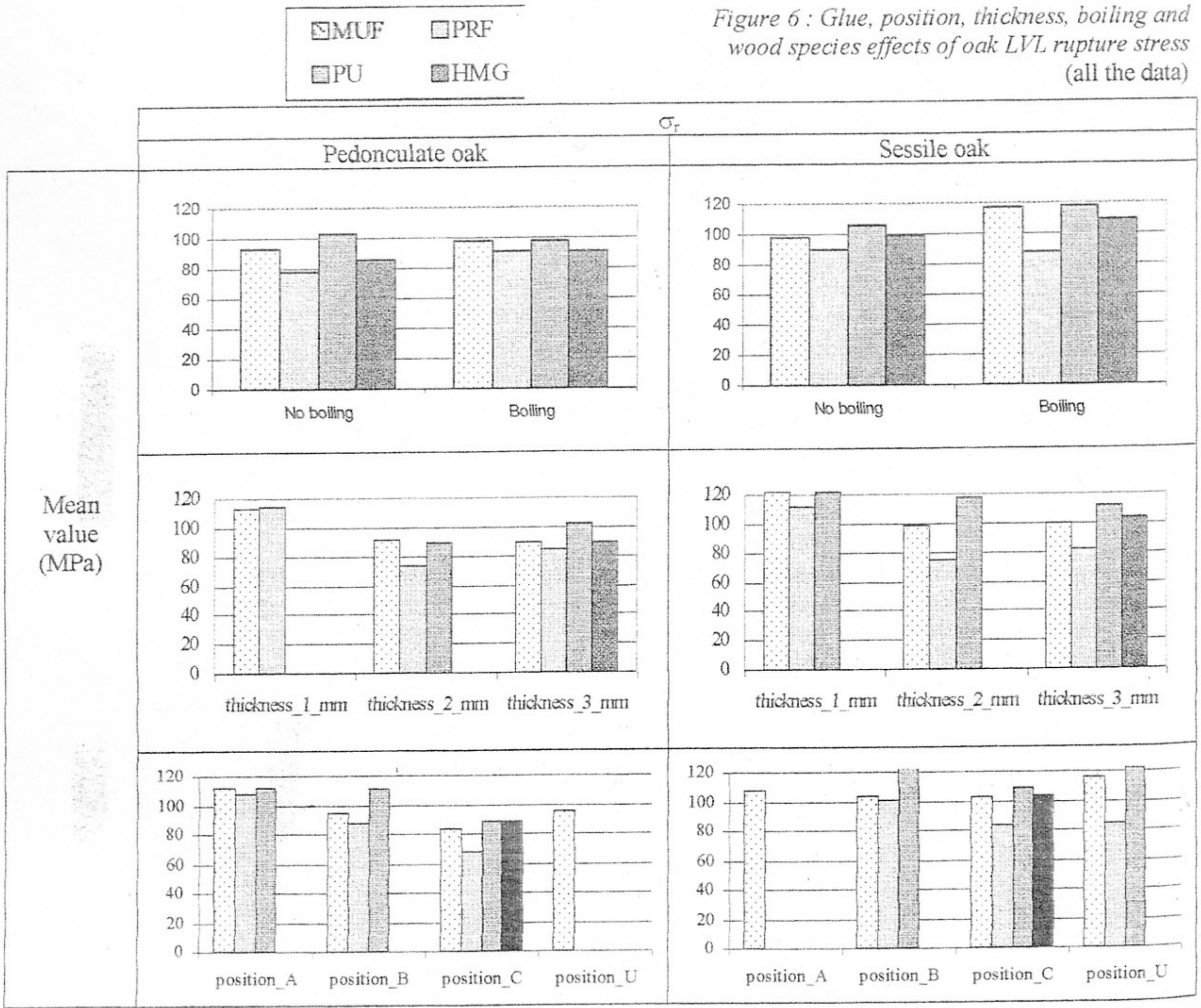
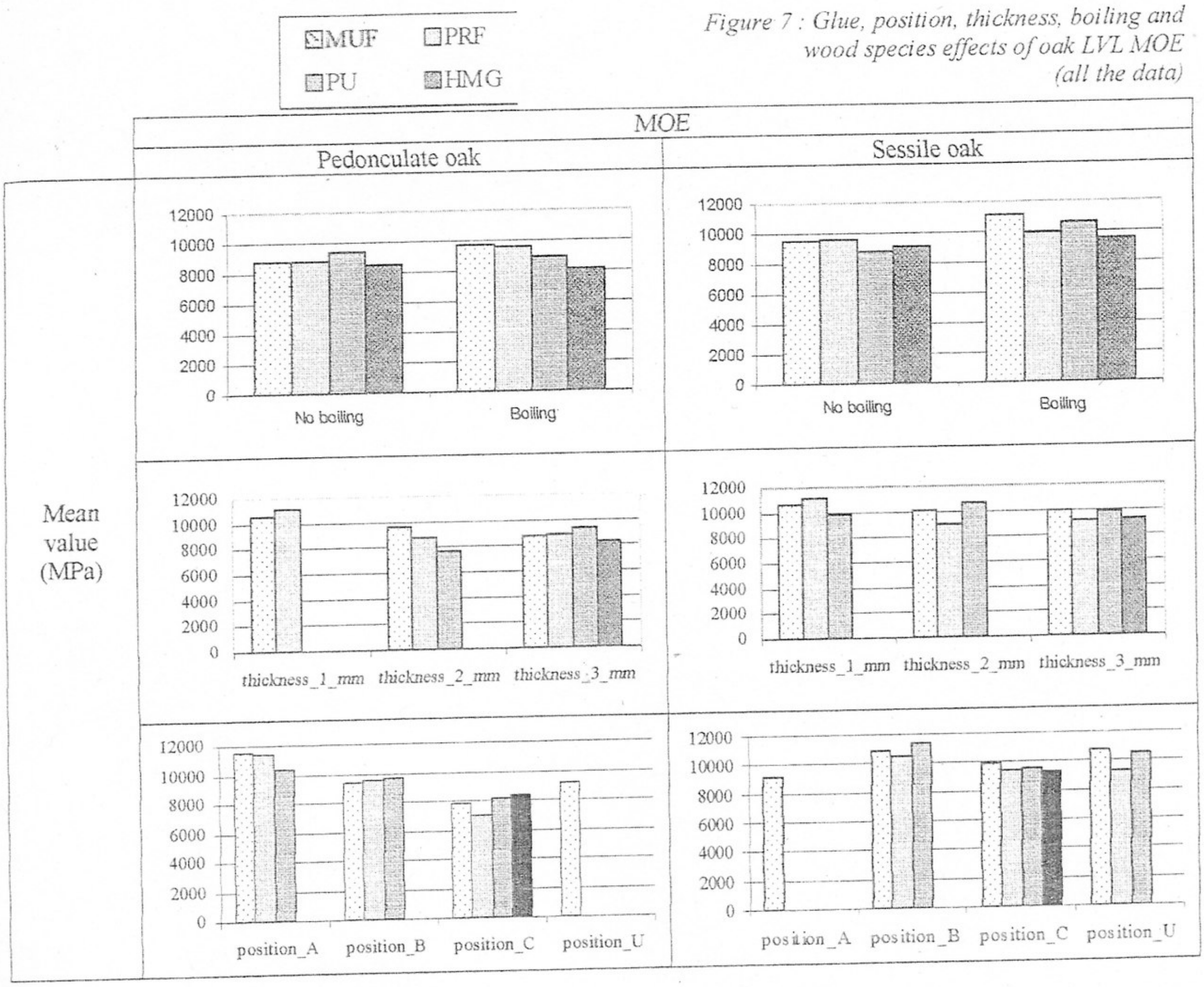


Figure 7 : Glue, position, thickness, boiling and wood species effects of oak LVL MOE (all the data)



- of the resistance of the different LVL types to biological degradations;

before conclude to the real effect of the peeling and assembling processes on the LVL properties and to confirm then explain such phenomena like the "bad" behaviour of LVL composed with 2 mm thick veneers.

All such of complementary tests are now in progress and after these preliminary experiments, the program will go one in the framework of a PhD programme co-supervised by ENSAM, France and Technical University in Zvolen, Slovakia.

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Authors:

Mariana SVORADOVÁ, PhD student (co-tutelle TUZ / ENSAM)
Faculty of Wood Science and Technology, Technical University in Zvolen, 960 53 Zvolen, Slovak Republic - msvoradova@pobox.sk - www.tuzvo.sk

Laurent BLÉRON, Associate Professor - Fabrice COTTIN, Technician - Rémy MARCHAL, Professor,
Material and Process Laboratory, Ecole Nationale Supérieure d'Arts et Métiers (LABOMAP-ENSAM)
71250 Cluny, France - laurent.bleron@cluny.ensam.fr - remy.marchal@cluny.ensam.fr - www.cluny.ensam.fr/labomap
ph +33 (0)385 595 327 – fax +33 (0)385 595 370

Giacomo GOLI, PhD student (co-tutelle UNIFI / ENSAM)
DISTAF University of Florence - 50141 Florence, Italy - giacomo.goli@unifi.it - www.laurealegno.unifi.it.
ph + 32 (0)385 595 360 – fax +32 (0)385 595 360

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Secretariat ICWSE-2002:

Professor Dr. Eng Loredana Anne-Marie BADESCU

"TRANSILVANIA" University of Brasov
Faculty of Wood Industriy
Str. Colina Universitatii nr.1
2200 Brasov, ROMANIA

Tel/Fax: **40 268 415 315
Mobil **40 722 953 653
E-mail:loredana@unitbv.ro, http://www.unitbv.ro/il/ccspl
Web site www.unitbv.ro/il/ICWSE

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PROCEEDINGS COORDINATOR Professor Dr. Eng. Loredana Anne-Marie BADESCU