

NEW TECHNOLOGIES AND ALTERNATIVE USES FOR POPLAR WOOD

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Summary

After a brief introduction on the importance of poplar for both the environment and the wood-industry system, the current common uses of poplar wood are discussed, with particular reference to the production of plywood, which is by far the most important and remunerative destination for the best raw material resulting from intensive poplar cultivation.

Plywood can be considered a “mature” product both in terms of development (efficiency levels, yields and productivity) and of market (at the moment plywood is also suffering from the competition of new kinds of panels). From a technical point of view, possible innovations are strictly related to the ability to find new uses and new products, possibly with value added figures. In this frame, the building sector seems to offer new possibilities, also thanks to the renewed interest for wood and wood-based products.

Another possible destination for poplar wood could be the production of glue-laminated timber. A quite complete research was done in Italy on this subject, which included the possibility of mixing poplar with other species (in particular eucalypt and larch). Details are given on the results obtained.

In the building sector, beyond the possibility of using purposely-produced plywood, Poplar wood could also be a very good raw-material for the production of “engineered panels” (LVL, OSB).

In conclusion, poplar wood is surely suitable also for use in other sectors. The reliability of products (with improved properties, if necessary) and their ecological characteristics, together with the preparation of updated technical information, are, in any case, among the main factors that can guarantee an increase of the use of poplar wood in non-traditional applications.

Resumen

Nuevas tecnologías y alternativas de uso para la madera de chopo

Después de una breve introducción sobre la importancia del álamo tanto para el medio ambiente como para la industrial de la madera, se analizarán los usos más comunes de la madera de chopo, en particular la producción de chapas, que es el mas importante y rentable destino para la materia prima de mejor calidad, resultado del cultivo intensivo del chopo.

La madera contrachapada puede ser considerado un producto "maduro" tanto en términos de desarrollo (niveles de eficacia, producciones como productividad) y de mercado (en este momento el chapeado, también sufre de la competencia de las nuevas clases de paneles). Desde un punto de vista técnico, las posibles innovaciones están relacionadas estrictamente con la capacidad de encontrar nuevos usos y productos, con un mayor valor añadido. En este marco, el sector de la construcción parece ofrecer nuevas posibilidades, gracias al interés renovado por la madera y productos derivados de la madera.

Otro destino posible para la madera de chopo podría ser la producción de madera laminada encolada. En Italia se realizó una investigación bastante completa sobre este tema, que incluyó la posibilidad del chopo mezclado con otra especie (en particular eucalipto y alerce). Se adjuntan detalles de los resultados obtenidos.

En el sector de la construcción, más allá de la posibilidad de usar el contrachapado producido para este fin, la madera de chopo también podría ser una materia prima muy buena para la producción "de paneles tecnológicos" (LVL, OSB).

Para concluir, la madera de chopo es seguramente conveniente también para el uso en otros sectores. La fiabilidad de productos (con propiedades mejoradas, si fuera necesario) y sus características ecológicas, juntos con la preparación de información técnica actualizada, son, en cualquier caso, algunos de los principales factores que pueden garantizar un aumento del empleo de madera de chopo en usos no tradicionales.

Poplar: ecoNOMY

The intensive cultivation of poplar owes (figure 1) part of its success to the great

versatility of its wood and to its most appreciated properties, such as lightness, clear colour, homogeneity, ease of working (peeling, bonding and finishing).



Figure 1. Typical mature poplar plantation (photo by A. Giorcelli).

It is well known that poplar wood can be put to several different uses, which vary according to the evolution of the market and the development of industrial technologies, with minimum waste. Beyond the “noblest” portion (about 70 %), typically used for the production of plywood panels, the remaining parts are generally used for the production of

particleboard, packaging (i.e. pallets and fruit boxes), pulp or biomass for energy (a very interesting and ecological alternative to traditional oil-based fuels) (Castro and Zanuttini, 1991). The main products are represented in figure 2, where they are grouped on the basis of the different stem portions (i.e. to log diameters) they can be obtained from.

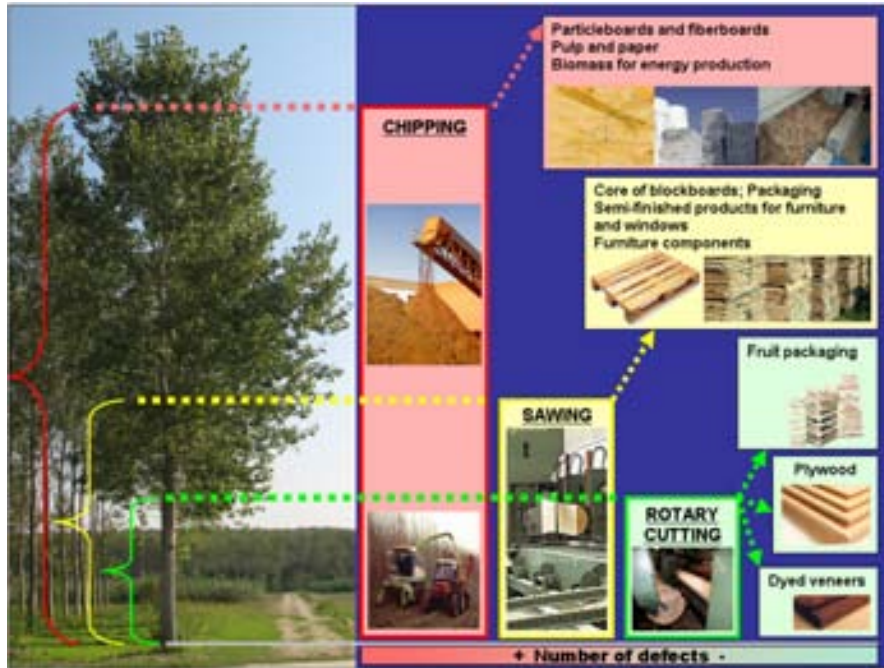


Figure 2. Scheme of the possible uses for the different tree portions.

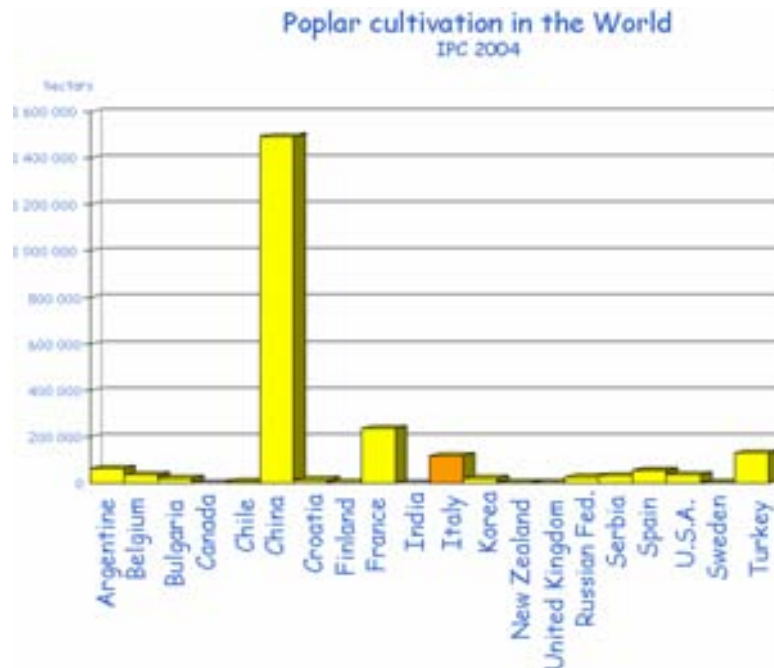


Figure 3. Poplar cultivation in the world.

The great diffusion of poplar in specialized cultivation is obviously also due to its very fast growth and to its capacity to adapt to different climate and soil conditions (as long as enough water is available). The graph in figure 3, based on data of the

International Poplar Commission (FAO, 2004), shows poplar cultivated areas in the world.

The situation in Italy provides a clear example of the importance that poplar can have for the wood industry: the area

cultivated with poplar represents only 1,3 % of the total forest area but yields nearly 45 % of the domestic round wood for industrial use (Bisoffi and Coaloa, 2000).

Poplar: ecoLOGY

As a result of the increasing concern of the general public for the environment, the problems of eco-compatibility and sustainability are now affecting all productive sectors, including the industry of wood and wood-based panels. Consequently, also poplar cultivation is at the moment “under observation”, mostly because of its diffusion along river banks, which are considered to be “environmentally sensitive” areas. Poplar growing is sometimes regarded as the antithesis of the natural forest (flattened landscape, little biodiversity, green pollution being its main drawbacks), often forgetting that poplar is grown “out of the forest” to produce wood in agricultural areas, with much less ecological impact than agricultural crops and with a greater safeguard of biodiversity. Moreover, in agricultural areas poplar cultivation can function as a “biological corridor”, with a determining role in phytoremediation and carbon fixation.

It's important to remember that poplar plantations, if correctly managed minimizing the environmental impact, can be certified according to an international scheme (FSC or PEFC), permitting to obtain raw material that can be used by industries in the frame of a “chain of custody”, to meet the consumers' request for certified products.

Another important benefit is the great capacity of poplar to absorb CO₂ and to stock Carbon. One hectare planted with poplar can absorb up to 25 tons of CO₂. It has been calculated that this theoretically corresponds to an economical value of about 1000 U.S. Dollars per year.

A last ecological aspect, related to a possible expansion of the use of poplar-derived products in other sectors, including building, is the substitution of materials whose production requires a higher energy expenditure (Berti et al, 2002).

The importance of plywood

Among the several possible uses to which poplar wood is put, plywood (figure 4) is one of the most important ones; being by far the most remunerative, it is also the main target for poplar growers. Poplar plywood is nearly always destined to the furniture sector (including also motor-home applications), where its low density is very appreciated and practically impossible to achieve with other products. However, plywood is already a “mature” product, one for which further developments and applications are hard to imagine, due also to an increased use of new and often cheaper wood-based panels (e.g. OSB) and to the rather limited number of “technical applications” with requirements so strict as to be hardly met by other panel types.



Figure 4. Poplar plywood panels

It must be pointed out that if the **range of possible technical applications** is small it is not because of some “bad” characteristics of poplar wood (low natural durability and quite poor mechanical properties) but mostly because the use of wood (and wood based panels) for structural purposes in many Countries where poplar is

traditionally cultivated in specialized plantations (Italy is among them) is traditionally small.

“Engineered” wood products

In many other Countries - Canada, United States, France, Germany and some North-European countries among others - the use of wood for structural purposes is much more frequent; solid wood (typically beams) is often substituted with the so called “engineered” wood products, designed to meet application-specific performance requirements.

The main reasons of the success of these products are the following:

- optimization of physical-mechanical behaviour and reduction of wood natural variability, obtained by a selection of the raw material and a controlled re-

composition, so as to obtain more isotropic and homogeneous products;

- improvement of the product durability, obtained by chemical or physical means (i.e. treatments or choice of appropriate adhesives).

Thanks to these characteristics, designed to meet specific use requirements, these products have been able to gain important sectors of the market. In this way a product which was a “commodity” (semi-finished product for general purposes) has been changed into a “specialty” (i.e. a service-product aimed at a well defined specific use).

It’s interesting to notice that these products are not made of very strong and durable wood, but of materials often quite similar to cultivated poplar (Aspen, for example), as shown in the following table:

Product	Product density (kg/m ³)	Natural durability of the wood used (EN 350/2)	Main applications
Birch and “Combi” Finnish plywood	600-700	very low	all sectors
North-American OSB and plywood made of <i>Aspen (Populus tremuloides, P. grandidentata)</i> , fir and other softwoods	400-500	low/very low	building, transports, packaging
<i>Intrallam</i> [®] - LSL made of <i>Aspen</i>	600	very low	building
<i>Parallam</i> [®] - PSL made of <i>Yellow Poplar (Liriodendron tulipifera)</i>	600	very low	building

Poplar wood is much appreciated for its visual aspect and for the high-quality finishing achievable. Due to precise breeding choices and to the intensive cultivation techniques often adopted, it has a low density and, accordingly, poor mechanical properties (as compared with Aspen and Yellow Poplar); on the other hand thanks to the high performance-to-weight ratio its structural efficiency is very high. However it’s important to notice that, should the market require poplar wood with improved strength properties, poplar

growers could choose to plant different clones that, though growing faster than the widely known clone ‘I-214’, have a denser and stronger wood (20 – 30 % more than ‘I-214’). These clones are not currently cultivated only because their wood is less appreciated by the traditional plywood industries.

Historical examples of structural uses of poplar wood

Several historical examples of poplar wood being used in building contexts in Italy

(although other woody species were available) prove that there is no technical

reason for not using poplar wood for structural purposes:

Example:	Source:
Roof structure of “Sala delle feste” – Valentino Castle - Torino, XVIII century.	Bertolini C., 1989a
Roof centering of “Verdi” theatre - Pisa, XIX century.	Carmassi M., 1994
Bridge centering of Paderno d’Adda viaduct - Como, XIX century.	Bertolini C., 1989b
Airplanes manufacturing, until about 1930 (fuselage parts, wing longerons, etc.), in very famous brands (as Caproni, Savoia-Marchetti, etc.).	Giordano G., 1983
Boards for scaffoldings and moulds.	Giordano G., 1964

In these cases poplar wood was chosen on account of its lightness and very good dimensional stability; any problems related to its poor durability and mechanical behaviour were given due consideration and solved at design stage: these structures are still there to prove their resistance.

Poplar glued laminated timber

Among the reasons that hindered the use of poplar wood in building, we should take into account that there are no such thing as a pure poplar forests; poplar trees are sporadically spread, heterogeneous and rarely big enough to reach the size required for the production of structural beams. Nowadays, thanks to the gluelam (glued laminated timber) technology, the size of the raw material is not a limitation anymore: starting from a traditional industrial transformation such as sawing, it is now possible to obtain products (beams) of virtually infinite size.

One of the authors (Castro), together with colleagues from other research structures, has carried out several studies on the possibility of using poplar wood for the production of gluelam. Here follow in short the main results obtained.

The first studies were carried out on poplar wood from typical specialized plantations (Pedrotti *et al*, 1997; Castro and Paganini, 1997.); all the phases of the process were investigated both in the laboratory and at industrial level. The results, and in particular the high bonding reliability,

proved poplar wood to be perfectly suitable for this use, although the quite poor bending performance did not allow classification of the beams in the frame of “Eurocode 5” (the European standard providing requirements for all timber structures). In spite of the low bending values, the shear behaviour of poplar wood resulted to be very interesting, suggesting that this wood could be advantageously used in small span beams or in the central portion of mixed gluelam.

We then started to investigate the possibility of realizing gluelam with high structural efficiency (ratio between mechanical performance and wood density) by combining poplar wood with stronger species, used symmetrically in outer laminations (figure 5).



Figure 5. Series of mixed poplar-eucalyptus beams after the bending test (photo by G. Castro).

The first species we tried to mix poplar with was *Eucalyptus grandis* (Castro and

Paganini, 2003), characterised by very high mechanical performance and shrinking values similar to those of poplar wood. The results showed that, using eucalyptus for a single couple of laminations (i.e. 2/7 of the section), bonded with five central poplar laminations, it is possible to obtain an increase of 78 % in bending strength (MOR) and of 50 % in modulus of elasticity (MOE) with respect to all-poplar beams, while the shear modulus remains nearly the same. Bonding showed complete reliability also at the interface between the two species. With this behaviour, the beams can be easily classified according to the classes provided by prEN 1194 for mixed beams.

Figure 6 shows the mechanical performance of the beams (from left to right the graph represents the data relative to the progressive increase of eucalyptus laminations, starting from all-poplar beams and ending with all-eucalyptus ones).

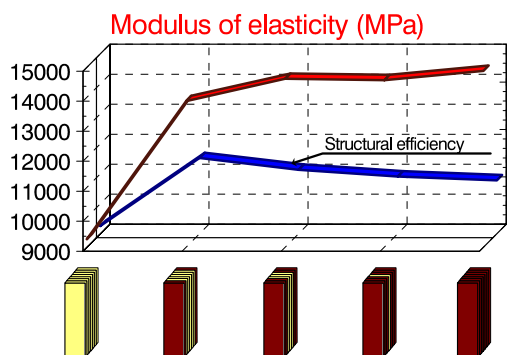


Figure 6. Modulus of elasticity and structural efficiency of all the series of mixed poplar-eucalyptus beams

Considering these very interesting results, we decided to extend the research to two other species: spruce (*Picea abies* Karst.) and larch (*Larix decidua* Mill.) (Paganini and Castro, 2000 and 2001).

Mixing these species with poplar was also interesting to study the effect of their different shrinkage on the glue lines during the severe delamination test required by the

European Standard EN 391. For both poplar-spruce and poplar-larch mixed beams, the best structural efficiency was obtained with the beams having two outer stronger (spruce or larch) laminations on each side (i.e. 4/11 of the section) and seven central poplar laminations. These beams showed an increase of about 65 % in MOE and of 45 % in MOR, compared with all-poplar beams. Substituting spruce or larch with poplar in the seven central laminations could result in saving about 20-25 % of material costs. Bonding (evaluated by a shear test and a severe delamination test) showed once again complete reliability, also at the interface between the two species.

A further advantage provided by mixed beams is their behaviour at failure: the load-deformation graphs resulting from the bending tests show that these elements are less fragile (i.e. more “ductile”) than one-species beams. Considering the importance of such behaviour, particularly in terms of structural safety in seismic areas, we decided to conclude our research project with a specific investigation on the failure behaviour of asymmetric poplar-eucalyptus beams (Paganini *et al.*, 2004).

Specimens of these asymmetrically mixed species showed better bending behaviour, both as to the energy dissipated and the ratio between deformation at rupture and elastic deformation. The energy dissipated at ultimate load, and at a subsequent 5 % reduction of such load, was significantly higher in the mixed beams.

In cyclic bending, the specimens showed perfect elastic behaviour.

The rupture patterns of the specimens with mixed species were very interesting. The compression rupture, across the poplar lamination as a whole, proceeded from the compressed side towards the side under tension, thus moving the neutral axis close

to the glue line (at the interface between poplar and eucalyptus). This caused a macroscopic elongation of the load-deformation graphs.

Final considerations

Results obtained from several researches confirm the possibility of using poplar wood also for structural applications. Thanks to its high structural efficiency, this material, although characterized by quite poor mechanical properties as to absolute values, seems to be particularly suitable for the production of engineered products. Moreover, it has been proved that it can be successfully used for the central portion of mixed-species products (e.g. glued laminated timber), whose external parts could be realized with stronger species.

The key to success in structural applications are accurate design, product reliability and availability of precise technical information: these are the main factors that could grant successful and even increasing use of this wood in the building sector.



Figure 7. O.S.B. panels used as a temporary fence (photo by L. Sebastiani).

Of course we are not hypothesizing the decline of poplar wood in traditional panels

for the furniture industry, we are simply suggesting an expansion of its use for new applications, from those requiring little innovation (such as special purpose poplar plywood) and ending with others that are more complex to produce, as it is the case with LVL or OSB (a product that is currently gaining large portions of the market) (figure 7).

To close with the point of view of poplar growers, here follow a few cultivation models that result in crops with different properties that determine their use:

- plantation spacing: very dense (> 5000 trees/ha);
rotation: 1 to 2 years;
clones: very fast growing;
aim: raw material suitable for the production of particleboards or biomass for energy;
- plantation spacing: dense (about 1000 trees/ha);
rotation: 4 to 5 years;
clones: fast growing and with high density wood;
aim: material suitable for the production of pallets or OSB panels;
- plantation spacing: traditional intensive cultivation (about 300 trees /ha);
rotation: 10 to 12 years, with several operations (e.g. pruning) to maximize wood quality;
clones: low density and very clear wood;
aim: material suitable for the production of plywood for furniture and motor-home industry;
- plantation spacing: traditional intensive cultivation (about 300 trees /ha);
rotation: 10 to 12 years, with minimal operations to minimize costs;
clones: fast growing and with high density wood;
aim: material suitable for the production of packaging, pallets and plywood for specific purposes and building.

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