

The Right Way of Using Modified Wood Products for Windows

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ABSTRACT

Does wood modification finds its application also in the construction of modern windows? Is there, on the European and/or world wide market, a real demand or a necessity for using modified wood products for windows? If modified wood products should be introduced in the construction of windows, how can mistakes be avoided, regarding the compatibility with other materials, machining, processing and design? In order to be able to assess these issues, the Part 4 of the VFF guideline HO.06, called: “Modified wood products for windows”, includes a complex matrix of test procedures and requirements for the mechanical and physical properties of the material, the compatibility with other materials used for windows, the performance of component parts and of the final product – the window. This concept will be presented, enriched with lots of examples from practical applications and from the waste experience of both the Georg-August-University of Goettingen, regarding the mechanical and physical properties and of the ift Rosenheim regarding the applicability of modified wood products for window construction. This paper follows step-by-step the practical aspects and will point out the most critical issues to be respected, while using modified wood products for the design and production of modern windows.

INTRODUCTION

During the last decades the German window market has acknowledged substantial changes. In 2003, the average market share of wood windows was approximately 20% , consisting of 2.8 million wood windows, while in 2008 it was reduced to approximately 1% (Heinze 2008). Currently, the window market in Germany is dominated by plastic (PVC) and metal (aluminium) frame materials. This is due to the technological advantages during manufacturing and the relatively low maintenance requirements during service life. The requirements on wood species used in the window industry are very high. Dimensional stability, biological durability and resistance against weathering are demanded properties. European wood species fulfil such requirements only to a limited extent. As a consequence, most wood windows are currently built from special tropical timbers, such as Dark Red Meranti, which exhibits better material properties. However, a lot of tropical timber is not provided by sustainable managed forests and is therefore rejected by customers. Additionally the price of tropical hardwood species is increasing, while the availability will decrease (Koch 2006). Based on this background, German window producer together with research institutes are searching for alternatives and have investigated over the last years, the possibilities of using modified wood for window frames. (Puttmann, Krause *et al.* 2009). Since modified wood products are more and more established on the European market, the window industry is highly interested to use such products as well (Krause 2007). The Association of manufacturer

of windows and façades (VFF), which certifies high quality window manufacture with the use of the German quality label: “RAL-Gütezeichen”, developed several technical guidelines to guaranty a high quality of the wooden windows. A new guideline (HO.06-4) has been developed to evaluate the properties of modified wood, which are important for production, installation, service life and waste management of windows. Additionally to the requirements, the guideline will list accepted modified wood products in separate annexes. Producer of modified wood, producer of laminated scantlings made out of modified wood or merchants of these products are invited to apply for a certification.

The aim of this organisation is to support the introduction of modified wood on the German window market and to provide standardised and qualified basic data for window manufacturer, in order to avoid mistakes and to reduce the risk while using modified wood for windows. The committee, which made the guideline and evaluate the applications, consists of industrial partners and members of research institutes. Within the committee the whole process chain of window manufacturing is represented. For an application to the guideline HO.06-4 it is required to define a specific modified wood product. A general permission for a modification system such as thermal treatment will not be given. The applicant has to define the system in terms of wood species, treatment levels, quality control, *etc.* The guideline is developed for modification processes, which change the properties within the whole cross section of the material. Surface treatments are not accepted. Nowadays the committee has various applications from several producers, some more are in preparation. The required tests will be listed and explained in the following description.

BASIC PROPERTIES

The chapter basic properties informs about general wood properties. The primary wood species is defined via scientific and trade name. Optional the producer can give information about origin and certification level. Information about the sawn wood quality level according EN 942 and EN 14220 are necessary and the form and dimension of the delivered product, such as massive or laminated scantling or lamella.

DISCRIPTION OF PROCESS

This chapter includes the basic information about the modification process. It is necessary to describe and define the modification process. A short description about the general treatment and the main parameters written in which easy to understand facts, maybe with references to more detail literature. As an example, the description for thermal treated wood should include process conditions: heating medium, temperature and pressure level. Target weight percent gain (WPG) after a chemical treatment is an important value.

QUALITY CONTROL

Quality assurance is a key issue for window producers, in order to accept modified wood as a new material and at higher prices compared to untreated wood. During the last years the quality of imported tropical hardwoods is decreasing and several times wood species have misleading declaration and therefore unsuitable wood has been used for windows (Koch 2006). Consequences of this are difficult relations within the process chain in terms of liability.

The quality strategy of producer of modified wood should include internal and external quality control. Certification about an external quality control must be presented such as according ISO 9000. The manufacturers have to assure the delivery of a constant quality of their products.

MATERIAL PROPERTIES

The material properties of the modified wood must be evaluated and reported according European regulations from scientific research or testing institutes.

Biological durability

Since there is no special regulation, how the resistance of modified wood against basidiomycetes is investigated and classified, a classification comparable to natural wood species are accepted. The classification can be done according to EN 350 and EN 113 or CEN/TS 15083-1. Durability class 3 or higher should be reached. It is preferred to carry out the tests including “*Gloeophyllum trabeum*”, which is an important fungus in window constructions. Durability in soil contact must not be tested.

Resistance against blue stain

Blue stain and moulds live on and in the wood and cause damage via discoloration. Additionally, they can increase the speed water uptake of the wood. Wood modification processes are normally biocide free and therefore the growth of blue stain is possible. Resistance can be investigated according EN 152-1 and maybe declared as resistant. Otherwise an anti blue stain agent should be used in the coating.

Density

All wood modification processes influence the density of the wood. While TMT exhibits a reduced density (Hill 2006), all other modifications increase it compared to untreated wood. Density can be measured according DIN 52182 or EN 408

Swelling and shrinking

One of the main objectives of wood modification is to reduce the swelling and shrinking of wood and enable home-grown wood species, which have a low dimensional stability, the use in the window industry such as European beech. Dimensional stability can be measured according DIN 52184. All anatomical directions must be evaluated.

Capillary water uptake

Uptake of liquid water via construction joints is one of the major damages in wooden window constructions. Therefore the capillary water uptake in the three anatomical directions must be measured. For wood, there is no special standard available, but the EN ISO 15148 can be easily adapted for this purpose.

Equilibrium moisture content

In modified wood normally the equilibrium moisture content (emc) is change compared to untreated wood. The moisture content at 20°C and 65% relative humidity must be stated (EN13183-1). The producers of modified wood are ask to give information about estimation of moisture content via electrical resistance method or electrical capacitance method.

Fire behavior

The behavior in case of could be different between untreated and modified wood. Therefore a classification in necessary according class E (EN 13501-1/A1) or B2 (DIN 4102).

Heat conductivity

In North and Middle Europe, the insulation efficiency of windows has a high impact on efficiency of the whole building. Because of some modified wood reduces the heat conductivity compared to untreated wood, the value shows an additional benefit of modified wood. Heat conductivity can be measured according EN 12667.

Mechanical Properties:

Most of the modification processes influences the mechanical properties of the treated wood. Various modifications are able to increase properties, such as modulus of elasticity with melamine treatment or hardness with DMDHEU. Other modifications reduce strength properties such as bending strength in heat treated timber. A very sensitive parameter is the impact bending which is reduced by various treatments. The relation between density and surface feel compared to mechanical properties are not necessarily equal to untreated wood. This makes it necessary to give detailed information to the window producer about the mechanical properties of the new material. The following table shows a summary about the requested mechanical properties and the associated standards.

Mechanical Property	Standards
Bending strength	EN 408 or DIN 52186
Modulus of elasticity	EN 408 or DIN 52186
Compression strength	
a) parallel to grain	EN 408 or DIN 52185
b) perpendicular to grain	EN 408 or DIN 52192
Impact bending	DIN 52189
Screw withdrawal resistance	EN 320 (adapted to window production)
Surface hardness (Brinell or Janka)	EN 1534 or ASTM D 143

APPLICABILITY FOR WINDOW MANUFACTURING

Through modification processes, fast growing wood species of low durability classes, can improve their durability up to those of tropical wood species, they can improve their dimensional stability and thus become a potential resource for wood windows. These, are good reasons to use modified wood products for windows, but they are not necessary sufficient to guarantee a successful usage. Windows are complex products, which have to fulfil multiple functional and quality requirements. They are made out of many different materials, which interact and which are compatible to each other (Moarcas 2008).

The fact that modified wood products have some improved properties, doesn't qualify them automatically as a replacement of "normal wood". It is important to test the compatibility of modified wood products with the other materials and to assess their performance and contribution to the functional and qualitative value of the windows. In order to be able to assess these issues, the Part 4 of the VFF guideline HO.06, called: "Modified wood products for windows", includes also a matrix of test procedures, assessment criteria and requirements regarding the compatibility with other materials,

such as adhesives (for the lamination and corner joints), coatings, insulating glass edges, sealants, hinges and fixings (corrosion), etc. Furthermore, the performance of the window components, such as laminated scantlings and corner joints is tested. Finally, the window as a final product is tested for its simulated long time performance and functional properties, such as for mechanical durability, air and water tightness, resistance to wind load and to impact load and long term resistance to natural weathering.

APPLICABILITY FOR WINDOWS

As mentioned before the applicability of modified wood products for window construction is determined according to HO.06 -4 within three test modules:

- module 1: compatibility with coatings, adhesives, sealants and sealing profiles, insulating glass edges, hinges and fixings
- module 2: assessment of the performance of component parts: laminated scantlings, corner joints
- module 3: assessment of the functional performance (mechanical durability, permeability to air, water and wind) and of the simulated aging test, such as mechanical durability and natural weathering

It is recommended to test modified wood products in direct comparison with untreated wood, so as to be able to assess the influence of modification on the performance (Moarcas 2009).

Module 1 compatibility tests

The compatibility of modified wood products with other materials is a very important issue. Through modification, the water and/or moisture absorption is usually reduced. Obviously, this has a positive influence on the dimensional stability of modified wood products. However, this characteristic can influence in a negative way the application of water based products, such as adhesives and coatings. Most of the compatibility tests are simulating 'worse case' conditions of temperature and moisture, in order to find out if certain reactions occur.

Coating: most of the window coating systems used in Germany are water based. The water part of these systems is usually absorbed by untreated wood and the solid parts build the surface layer. However, for modified wood products, with a low absorption capability, it has to be checked if the adhesion of the coating on the substrate is realized and if the substances used for modification do not emerge from inside of the products to the surface, i.e. under temperature and moisture. These critical issues are usually tested by artificial weathering tests according to EN 927-6, in order to get a relatively quick answer (see Figure 1). However, there is no correlation between artificial and natural weathering test (EN 927-3, see Figure 2/left), therefore the later has also to be done. Other tests are the referring to the water absorption (EN 927-5), wet and dry adhesion, blocking, compatibility with mortar and metals (see Figure 2/middle and right), etc.

Sealants and sealant profiles: the substances used for modification can react, under certain circumstances, with the basic substances of sealants, sealant profiles or insulated glass bond (Figure 3). Therefore the tests according to DIN 52452-4 and respective HO.03 are conducted on different products, used currently for window construction, such as silicon, elastomer, PVC, polyethylen, polypropylen, butyl, etc. Again under the influence of temperature and humidity, the compatibility of coated and uncoated modified wood products is checked.

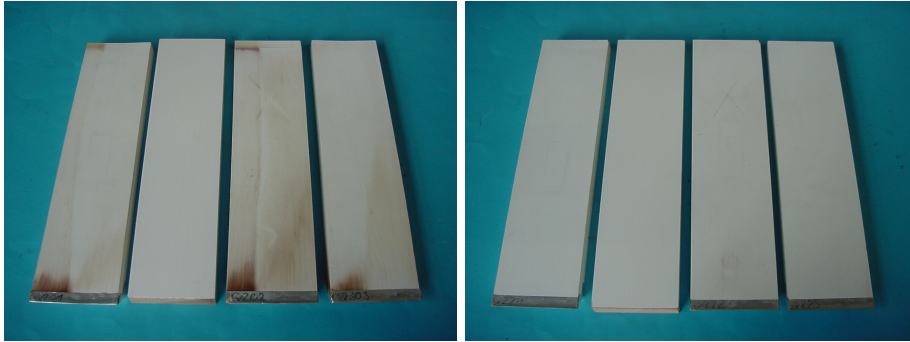


Figure 1: Artificial weathering - left: untreated wood; right: modified wood; the second sample from left is the reference sample



Figure 2: Natural weathering (left); compatibility with mortar (middle) and with metal (right)

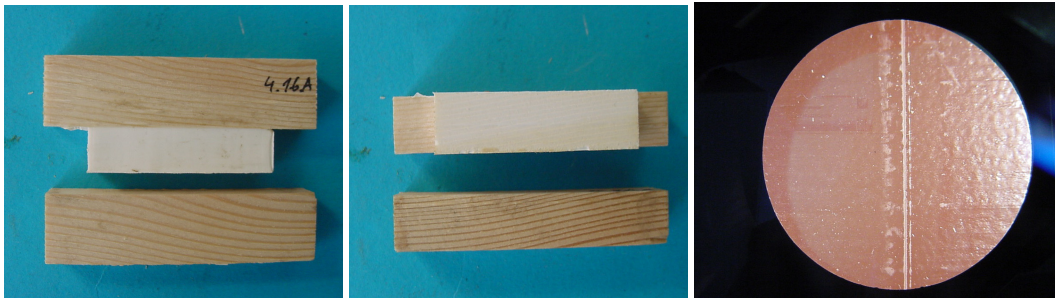


Figure 3: Examples of un-compatibility with: sealants (left, middle); sealant profiles (right)

Hinges and fixings are very important component parts of windows and doors, especially for safety reasons. Therefore, the testing of compatibility with these components is a major issue, while introducing modified wood for joinery. Through different climatic tests combined with mechanical/ withdraw tests, the corrosion degree of hinges and screws and the mechanical resistance is tested. If corrosion occurs, then the screws are in danger to break (Figure 4), which can cause the out-come of windows or doors, which can lead to accidents.

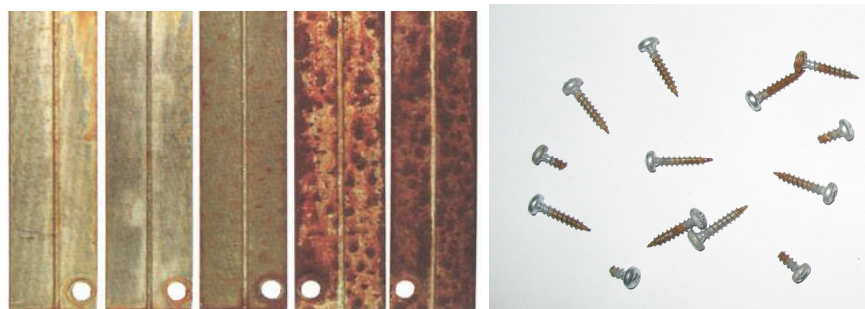


Figure 4: Examples of corrosion on hinge's parts with different coatings (left); on screws (right)

The machining of modified wood products is a very important issue, including technical and safety aspects, for the construction of windows. The technical aspects refer to the different machining operations and settings for the tools. The safety aspects refer to the developing of dust and noise at workplace, the evacuation of shavings, *etc.*

Module 2 performance of component parts: laminated scantlings, corner joints:

After the compatibility with different materials has been tested, the next level is to assess if the performance of most important component parts of windows, laminated scantlings and corner joints, is acceptable and comparable with the performance of untreated wood.

Laminated scantlings made completely or just partially out of modified wood products are used for the construction of windows. Because of the different internal movements of the lamellas made out of modified and/or unmodified wood, the gluing of laminated scantlings is a difficult task. Furthermore, the usually used PVAc glue doesn't work properly in most of the cases, because of the reduced water absorption of modified wood. Especially when two lamellas, made out of modified wood are glued to each other, then the water based adhesive can not be absorbed, so in the end a thin glue layer is created with insufficient adhesion strength (Figure 4).

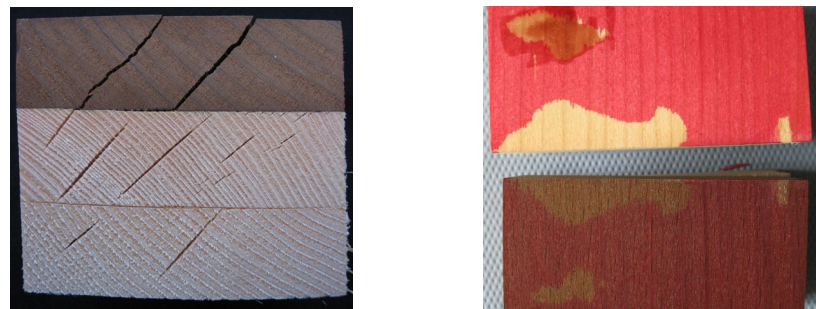


Figure 5: laminated profile with one lamellae of modified wood (left); example of lack of adhesion between modified and untreated wood (right)

Generally, according to the **ift** experience on testing laminated scantlings, according to the **ift** guideline HO.10/1, made out of modified wood products, the EPI and PU adhesives have shown better results than PVAc adhesives.

Corner joints have to provide the necessary mechanical resistance for windows, especially in an opened position, when the glass weight is acting as shear/tension loading. In Germany, most wood windows have glued corner joints. The test method of corner joints was established in the **ift** guideline FE-08-1, which determines requirements for the tension and shear resistance as well as the tightness of corner joints. According to the measured tension and shear resistance of the corner joints in an initial state condition and after an ageing cycle, the tested corner joint system will be classified in different weight categories for windows. These weight categories for corner joints are correlated with the weight categories for hinges.

Module 3 mechanical durability and natural weathering of windows

After the compatibility of the different materials has been tested and the performance of component parts has been assessed, a third level of tests follow, which address the window as a whole product.

Mechanical durability and functional tests are including obligatory and not-obligatory tests for windows for the CE mark, such as mechanical durability acc. to EN 1191, safety tests acc. to EN 14609, air and water permeability acc. to EN 1026 and EN 1027, operating forces acc. to EN 12046-1, resistance to racking EN 14608 and resistance to static torsion EN 14608, resistance to wind load EN 12211, *etc.* These tests ensure that

the window, made out of modified wood, has a comparable product performance to common wood windows.

Natural weathering of windows lasts for two years. The complete windows are mounted vertically. Every six month, the windows are inspected according to the following criteria: weathering of the surface coating, cracking of the modified wood, some hinges are opened to assess if corrosion has occurred, etc.

Other tests which are conducted on the modified wood itself and on the window is the emission test of VOC acc. to EN ISO 16000-6 and EN ISO 16000-9. Furthermore, information regarding the recycling of modified wood products have to be stated by the producer.

CONCLUSIONS

After a modified wood product has successfully absolved the tests mentioned before, a separate annex to the HO.06-4 will be issued with the performance results of the respective modified wood and basic indications for window producers. Additionally, the ift Rosenheim has created a layout for a “system description” for the usage of modified wood products for windows. This is a paper with relevant details referring the compatible materials, the structure of laminated scantlings, weight resistance of corner joints and performance of the final product. This system description is actually a directive guide line for window manufacturer in using in a correct way a certain modified wood product for window constructions. Furthermore, the ift Rosenheim also has developed a “product pass”, which is representative for the quality assurance for modified wood products within the ift certification program. These three documents, the annex to HO.06-4, the ift ‘system description’ and the ‘product pass’ will ensure the right way of using modified wood products for the construction of quality windows for the German and European market.

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