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# FACTORS INFLUENCING THE QUALITY OF WOOD ADHESION–PART 1: CHEMICAL INTERFERENCE

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## 1.0 INTRODUCTION

Technology in adhesive bonding of wood has been continually developed, and it is one of the key factors in aiding the efficient utilization of scarce timber resources. Adhesives have inevitably being widely used in wood-based industries due to many of their advantages such as the ability to distribute loads over the entire bonded area of the wood component, thereby increasing the strength and stiffness of the wood products. It is also needed for joining of different types of woody materials together. In addition, it is more practical to utilise adhesive in joining smaller timber offcuts into desired component sizes.

In the wood-based industry, adhesives are widely used for manufacturing of building materials, such as fibreboards, particleboards, doors, windows and frames, glued-laminated wood products, plywood etc. On the other hand, adhesives are also used in the assembly of non-structural materials such as furniture, and construction of residential and commercial buildings. Besides that, adhesives also are used for refurbishment and repairing of wood structures. Figure 1 shows an example of glued-laminated product being used in a building.

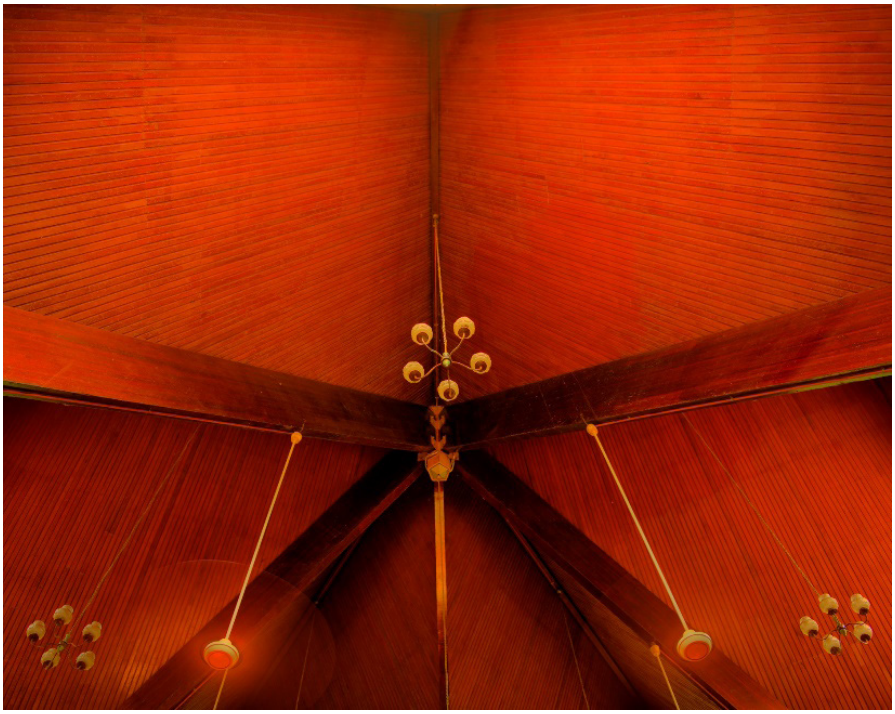

**Figure 1** Slanted glued-laminated beams used as load bearing roof components in FRIM's mosque while exposing their beauty

Generally, there are four main factors which will influence the quality of wood adhesion, namely: (i) chemical properties of the wood surfaces, (ii) physical properties of wood particularly moisture content, density, porosity, swelling-shrinking and surface properties, (iii) type of adhesives, and (iv) the bonding process such as control of moisture content of adhesion substrate, glue spread, assembly and pressing time, post-curing conditioning and choice of jointing.

The efficiency of adhesive bonding is influenced by the chemical and physical condition of the substrates in satisfying the bonding performance. In terms of the physical condition of the substrate, the wood-surface should be flat, smooth and free from excessive surface irregularity produced by machineries or other. The surface should also be free from dirt, oils or debris (Charles & Christopher 2010).

As for the chemistry aspect, the effectiveness of adhesion bonding can be influenced by the presence of natural wood extractives, as well as the type of chemical preservative used. The natural wood extractives and chemical preservatives would normally alter the surface chemistry of wood, thereby causing poor adhesion. This alteration can reduce the bonding integrity of wood which is far more complicated to be detected and explained than the effect of physical properties of the wood surfaces.

This paper explains the fundamental mechanism of wood adhesion and addresses the influence of natural wood extractives and chemical preservatives on the quality of the wood adhesion.

## 2.0 MECHANISM OF WOOD ADHESION

Basically, adhesives help in the transferring and distributing of loads between wood components, thus increasing the quality of wood adhesion products (Ammann & Niemz 2015). The effectiveness of adhesives to transfer the loads and hold together two or more wood surfaces would depend on the mechanical and chemical mechanism of the adhesives.

### 2.1 Mechanical mechanism

Mechanical mechanism is regarding how and where the adhesive layers holds between the wood substrates. This mechanism works because wood is porous in nature. The effectiveness of the interlocking takes place when adhesive penetrates deep enough into the porous structure of the wood enabling bonding between the wood substrates. Theoretically, the increase in the penetration or spread of adhesives into/onto the porous structure of wood will increase the contact depth or contact area of the adhesives in/on the wood, respectively. This will increase the performance of mechanical interlocking resulting in the increase of the bonding strength.

### 2.2 Chemical mechanism

In general, the effect of adhesion can be attributed to two factors, van der Waals force and hydrogen bonding (Pizzi & Mittal 2003).

The polar surface of the wood attracts the polar adhesives, such as urea-formaldehyde, polyurethane and other vinyl adhesives by using the van der Waals forces.

The adhesion between the adhesives which contain hydroxyl group (-OH) such as phenolic resin, urea-formaldehyde etc. with wood surface occur because the cellulose molecule in the wood also contains the -OH groups. The –OH in cellulose of wood and –OH in adhesive will then build hydrogen links known as hydrogen bonding.

Nonetheless, the effectiveness of these chemical mechanisms, either from van der Waals force or hydrogen bonding would depend on the contact area of adhesives with wood. A larger surface will increase the strength of bonding, thus increasing the quality of the end product.

## 3.0 EFFECT OF CHEMICAL INTEFERENCE ON THE QUALITY OF WOOD ADHESION

The effectiveness of both mechanical and chemical mechanisms on the bonding depends on the existence of chemical interferences (natural wood extractives or chemical preservatives) on wood surfaces. The bonding integrity could be reduced if the wood surfaces have chemical interferences.

### 3.1 Natural wood extractives

Natural wood extractives can be defined as a complex mixture of chemical compounds in any wood anatomical structure. These chemical compounds include tannins, pitch, volatile hydrocarbons, flavones, catechins and lignans. The properties of these chemical compounds vary. Some are acidic, alkaline or oily. The amount of chemical compound presents in wood varies from wood species to wood genetic. The annual and seasonal climate, as well as the geographical area where the wood is planted contributes to the variability of chemical content.

Classification of wood as hardwood or softwood also determines the quality and the type of wood extractives. In general, hardwood contains more wood extractives that softwood. The location where a wood is derived from the tree, either from heartwood or sapwood would also show difference in gluability characteristics. Therefore, gluing characteristic between hardwood and softwood or between heartwood and sapwood is different, possibly due to the nature and the amount of extractives present in each criterion.

The presence of natural wood extractives affects the quality of adhesive bonding, very often it is undesirable and bonding effect can be unpredictable (Marra 1992). Natural wood extractives can affect the performance of wood adhesion by:

#### 3.1.1 The inactivation of wood surfaces

Natural wood extractives play a role in the inactivation of wood surfaces. This phenomenon occurs because the extractives can move to the wood surfaces via several ways, such as migrating with the existing water (high moisture content) by diffusion or vaporisation. Once the extractives move up to the wood surface, they can block the pores of wood and inhibit proper penetration of adhesives into the surface of the wood anatomy. Oily extractives and pitch which are hydrophobic in nature would repel waterborne adhesives in forming interlocking reaction with the wood.

#### 3.1.2 The disturbance of the curing processes

The acidity of wood extractives can disturb the curing process of some alkaline-based adhesives. Likewise alkaline wood extractives can also retard the normal polymerization of acid-based adhesives such as urea-formaldehyde. As such, this would compromise the integrity of the adhesive bonding.

### 3.2 Influence of chemical preservatives

To improve the wood durability against wood decaying fungi, termite and insect borer, wood is usually treated using a variety of chemical preservatives including boron compounds, chromated copper arsenate (CCA), creosote, copper azole etc. (Vick & Christiansen 1993, Kilmer & Blankenhorn 1998, Ozcifci 2008). On the other hand, wood protection against fire and weather can be achieved through impregnation or painting with fire retardant and water repellents chemicals. However, these wood treatments will generally influence the bonding strength between the adhesive and wood as these chemical preservatives are considered as contaminants on the wood surface. By increasing the concentration of chemical preservatives, it will proportionately increase the delamination of wood (Tascioglu et al. 2003).

Basically, the chemical preservatives can influence the performance of adhesive in two ways:

### 3.2.1 By reducing the ability of adhesive penetration

The presence of chemical preservatives will block most of the porous structure of the wood. Figure 2 shows wood sample that had been treated with high concentration of boron compounds (6% w/v). The crystallisation of boron compounds on the wood surface had impeded the infiltration of adhesives to the porous structure of the wood, thus reducing the contact depth and resulting in poor bonding.

Besides that, boron compounds, categorized as acid salts, also increase the hygroscopicity of the wood. Boron compounds would release acid at elevated temperatures which can impede the curing of alkaline adhesive such as phenolic resin. However, alkaline adhesives can still make durable bonds between the wood treated with boron compounds, but only after some treatments: (i) washing the wood surfaces to be bonded with certain alkaline aqueous solutions, followed by drying before bonding, or (ii) by using adhesives of appropriate molecular-size distribution. But the successfulness of the bonding after any of these treatments would depend also on the wood species.

**Figure 2** Poor gluing integrity of a glued-laminated red-balau specimen treated with boron at 6% w/v concentration. The black lines (yellow ellipse) were drawn parallel to the glueline indicating the length of delamination after being subjected to vacuum pressure delamination test.

### 3.2.2 By retarding the hydrogen bonding

Modification of wood using acetylation process will reduce the moisture-related dimensional changes of wood and can decrease the hygroscopicity of the wood, which in turn reduces the wettability of the wood surfaces (Custódio et al. 2009). This occurs during the acetylation process, in which the acetic anhydride will react with the hydroxyl groups in the hemicellulose and lignin of wood, subsequently converting the compounds to acetyl groups. As a result, this causes lower affinity for water on the wood surfaces. The water-borne adhesive, which depends on hydrophilic adherence, will be less efficient in penetration. In contrast, room-temperature-curing adhesives such as resorcinolic and acid-catalysed phenolic would develop strong and durable bond to acetylated wood (Davis 1997, Custódio et al. 2009).

## 4.0 CONCLUSION

Understanding the effect of chemical interferences on bonding is very important for the selection of correct wood adhesive of any given species. The wood and adhesive bonding is affected by the mechanical and chemical mechanisms between them. The quality of adhesion depends on the existence of natural wood extractives and the influence of chemical preservative. The method for effectiveness wood bonding varies for all adhesive types and wood species. Thus the factors mentioned shall be taken into consideration.

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