Wood-Based Structural-Use Panels and Formaldehyde Emissions

This document addresses some commonly asked questions about the adhesives (resins) used to manufacture wood-based structural-use panels. The information is presented through a simplified explanation of how the resins "work" – considering some of the potential health-related aspects at the same time – and a brief description of the two most commonly used resin types.

Concerns Regarding Potential Formaldehyde Release

There are two main potential sources of formaldehyde emissions from wood composites: unreacted free formaldehyde and formaldehyde resulting from breakdown of the resin. The release of unreacted formaldehyde is greatly limited by controlling the ratio of formaldehyde to the other reactants (e.g., urea, melamine, or phenol) in the resin and by several other factors, when it is manufactured. A potentially greater source of formaldehyde emissions comes from the chemical breakdown of cured resin through the addition of water (called *hydrolysis*). Formaldehyde emissions resulting from hydrolysis of the cured resin affects products bonded with amino resins, such as urea formaldehyde (UF). UF resins are less chemically stable than phenol formaldehyde (PF) resins in their cured state and can hydrolyze under appropriate conditions of elevated temperature and humidity. The chemical structure of cured PF resin is less attractive towards water (less hydrophilic) than the structure of cured UF resin. Phenolic-based compounds also tend to be more chemically stable. Both of these characteristics make cured PF resin much less susceptible to hydrolysis than UF. This is one of the reasons that PF resins are considered to be waterproof, while UF is not.

What resins are commonly used to make wood-based structural-use panels?

The resins used to make OSB and plywood (wood structural panels) are part of a group of materials called polymers (a word meaning "many units"), which are long chain-like molecules. Polymers can occur naturally (as cellulose and lignin in trees, for example) or as man-made materials (like polyethylene milk jugs). Small building blocks, analogous to the individual links that form a chain, react with each other to form long chain-like molecules; or *polymers*. Some polymers melt when they are heated. They are called *thermoplastics*, a term we commonly shorten to "plastic". We encounter plastics in daily life as bottles and bags, some of the fibers used in clothing, as well as the carpets we walk on. Another type of polymer is known as a *thermoset*. While some of the precursors to thermosetting polymers can melt and flow upon heating, they eventually cure to a rigid form that is unaltered by subsequent heating. We commonly encounter these materials as the plates that cover electrical outlets and switches, many of the handles and knobs on stoves, and as adhesives (like epoxy).

Physical links between the individual units that make up a polymer are formed by a chemical reaction between two molecules. These reactions are usually chemically stable under conditions of normal use for the object, meaning that the bonds don't "come apart" on their own. This particular characteristic is one of the things that allows man-made polymers, and some natural polymers, to be such unique, durable materials. While polymerization reactions can occur at room temperature, the resins used to make wood structural panels require the application of heat (energy) in order to make the reactions occur quickly.

The resins used to make OSB and plywood are supplied to wood products manufacturers as short polymer chains, which are not capable of functioning as an adhesive without further polymerization. They may be applied to wood as water-based solutions, non-aqueous solutions, or as a powder. The liquids are sprayed onto the wood, whereas the powders are physically blended with the wood. Since the resins are chemically reactive before they are heated, they are applied to the wood in a controlled environment in the factory. Workers are protected by adequate ventilation and emissions are controlled by air monitoring equipment.

The term *curing* is used to describe the conversion of the short polymer chains into a large three-dimensional polymer. Adjacent molecules in a liquid resin droplet, or powder particle, quickly react with each other to form a three-dimensional, cross-linked network. Cured resin particles bond with wood wherever they contact it, effectively sticking adjacent flakes together throughout the board. These droplets of adhesives are often visible as tiny red/brown spots on the surface of panels. In plywood, where the adhesive is applied uniformly to the veneers, a continuous red/brown glue line is visible. Once curing is complete, the molecules that make up the adhesive are no longer reactive under normal use conditions. One of the main benefits of thermosetting adhesives is the relative chemical stability of the glue bonds, as opposed to those formed by solvent loss adhesives [such as the common white glues, based on poly vinyl acetate (PVA)]. PVA glues are typically used for products that are not exposed to moisture.

Two types of resins dominate wood-based structural-use panel production; they are phenol-formaldehyde (PF) and polymeric Methylene Diphenyl Diisocyanate (pMDI).

1. Phenol Formaldehyde (PF)

Phenol formaldehyde is the dominant resin used in both plywood and OSB production. Cured PF is considered “waterproof” and this resin is considered to be the benchmark for comparing the water resistance of other adhesives for wood products. Although the cured PF resin is unaffected by exposure to water, panels bonded with this resin are predominately intended for only occasional, short-term exposure to moisture. Cured adhesive is typically reddish brown in color and is visible as either a continuous glueline (in plywood) or as small reddish brown spots (in OSB). These resin gluelines or spots penetrate the wood surface a few cells deep to form bonds with the wood, holding the wood panel together.

Resin manufacturers produce PF adhesives by reacting phenol and formaldehyde (in combination with proprietary additives and extenders) in a high pH (alkaline) water solution. Reactions are not carried to completion, because the resulting thermosetting polymer would be cured and, therefore, no longer useful as an adhesive. Instead, the reaction is stopped at a low degree of conversion. The resulting short chain PF molecules can penetrate into the wood cell walls or hollow spaces inside wood cells. Curing the resin converts the soluble, short chain molecules into an insoluble, three-dimensional network and primarily forms mechanical bonds between the wood and resin. Tests have shown that formaldehyde emissions from phenolic bonded plywood and OSB are not significant enough to be regulated.

2. Polymeric Methylene Diphenyl Diisocyanate (pMDI)

PMDI has become a common resin used in OSB production. Like PF, it produces waterproof bonds suitable for use in Exposure 1 classified panels. In fact, the nature of its adhesion to wood makes its performance better than PF when exposed to moisture. Unlike PF, pMDI does not primarily form mechanical bonds with the wood substrate; instead, it is capable of forming covalent chemical bonds with wood. These chemical bonds are stronger and more stable than mechanical linkages.

The surface of wood is rich in chemical functional groups called hydroxyl groups (–OH). PMDI resins are terminated in isocyanate groups (–N=C=O), which can react with the hydroxyl groups on wood, forming urethane linkages. A combination of factors, such as the non-polar, aromatic component of pMDI resins and the existence of the urethane linkages as part of a cross-linked network, help to make cured pMDI resins resistant to hydrolysis.