July 8, 2008

Mr. Chris Spaeth,
Energy Panel Structures,
102 East Industrial Park,
Graettinger, IA 51342

Re: Bowing of Structural Insulated Panels

Dear Mr. Spaeth:

Structural Insulated Panels (SIP's) that have interior and exterior facings made from hygroscopic materials such as plywood or oriented strand board (OSB) can bow as a result of moisture content differences between the facings on each side of a panel.

Figure 1 illustrates the phenomena. The panel is straight and true and in plane when the moisture content of both the interior and exterior facing are the same. If the moisture content of the exterior facing increases and the moisture content of the interior facing decreases the panel will bow outwards.

The taller the panel the greater the bow. The thinner the panel the greater the bow. So, tall thin panels are more prone to bowing than short thick panels.

The relative thickness of the facing is not significant to the ultimate movement. In other words, the effect of 7/16 inch vs. 15/32 inch vs. _ inch vs. 19/32 inch has little impact on the magnitude of the bow. However, the thicker the facing the longer the time span for the movement. Thicker facings take longer to reach dynamic moisture equilibrium. In other words they change moisture content more slowly and therefore bowing takes longer – several months as compared to several weeks.

The moisture content of the wood in the OSB or plywood comprising the facing is directly related to the relative humidity the facing is exposed to. A sorption curve for wood is shown in Figure 2. Notice that the curve is not dependant on temperature. Having said that, relative humidity is dependant on temperature. So the temperature dependence is indirect in so far that the temperature can impact relative humidity. This can been seen from looking at a psychrometric chart (Figure 3).

In general, from the psychrometric chart, as air is cooled, its' relative humidity goes up even though the amount of moisture in the air does not change (absolute humidity is constant, but relative humidity goes up as air is cooled).

During the winter, exterior air typically has a high relative humidity (even though it is "dry" in the absolute sense) whereas the interior air has a low relative humidity. Exterior relative humidity's of 70 percent are common in cold climates during the winter and are coupled with interior relative humidity's of 25 percent or lower. This can translate into a moisture content difference of 10 percent between facings (15 percent in the exterior facing and 5 percent in the interior facing).

The anisotropic nature of the OSB relative to plywood is not a significant factor in bowing. OSB does get "thicker" than plywood when moisture content changes occur, but the relative differences in length and width due to moisture content changes are not significant as the fibers in both OSB and plywood remain in the plane of the panels. In other words there is not much difference in the bowing of panels faced with OSB versus plywood.

Even though there are differences among fiber orientations with respect to movement (Figure 4) and even though dimensional changes are minor longitudinally, the length of the panels (8 ft or more) is sufficient to have observable movement. That is why even in conventional frame construction 3/8 inch gaps are recommended between sheets of OSB and plywood when these products are used as sheathings.

The conditions of manufacture can have an impact on bowing as well as the speed of construction and the time of year of panel installation.

For example, OSB and plywood shipped directly from a mill typically has a low moisture content – close to zero – as both are manufactured in a heat intensive process. If this OSB or plywood is immediately used (not stored outside for any appreciable length of time) to manufacture SIP the facings start out with a low moisture content. If they are shipped and installed very quickly after manufacture and the building is closed in very quickly during the winter, the interior facing will remain at a low moisture content whereas the exterior facing will rise to a high moisture content and maximum bowing occurs.

Whereas, if the panels are stored outside for sometime before they are shipped or installed the moisture content of both facings will rise roughly at the same rate. If they are then installed at the mid point of their ultimate range of seasonal variation in moisture content minimum bowing occurs.

This is analogous to wood flooring. Old timers have learned to "condition" the wood flooring to the mid point of its expected moisture range prior to installation – typically 7 to 8 percent moisture content.

With SIP's, if both facings are at a 10 percent moisture content when they are installed, and the interior eventually drops to 5 percent and the exterior goes to 15 percent, the relative difference is only 5 percent from the start point. Whereas if they both start out at 1 or 2 percent and the interior goes to 5 percent and the exterior goes to 15 percent the relative difference is 12 or 13 percent.

Combining all of the factors, the most bowing occurs in tall thin panels manufactured with dry OSB and installed quickly into a structure that is closed in quickly during the winter. The least bowing occurs in short thick panels installed in the spring or the fall on a long production schedule where moisture contents of facings equilibrate to the mid range of the expected moisture content service range prior to close in.

Can bowing be eliminated? In short, no. Can it be reduced? Yes. Is it worth it to do so? Probably not. Conditioning panel facings prior to manufacture or conditioning panel facings prior to installation is not likely practical.

I recommend installing SIP's so that they can move as moisture content changes in panel facings occur. This is traditionally done with wood trusses to deal with truss rise. Floating corners are standard to address the movement issue of wood trusses due to moisture content changes between the top and bottom chords (Figure 5, Figure 6 and Figure 7).

With respect to SIP and floating corners a recommended approach is given in Figure 8.

Please feel free to contact me at (978) 589-5100 with any questions.

Sincerely,

Joseph Lstiburek, Ph.D., P.Eng.
Building Science Corporation

Figure 1: Bowing of SIPs with hygroscopic facings

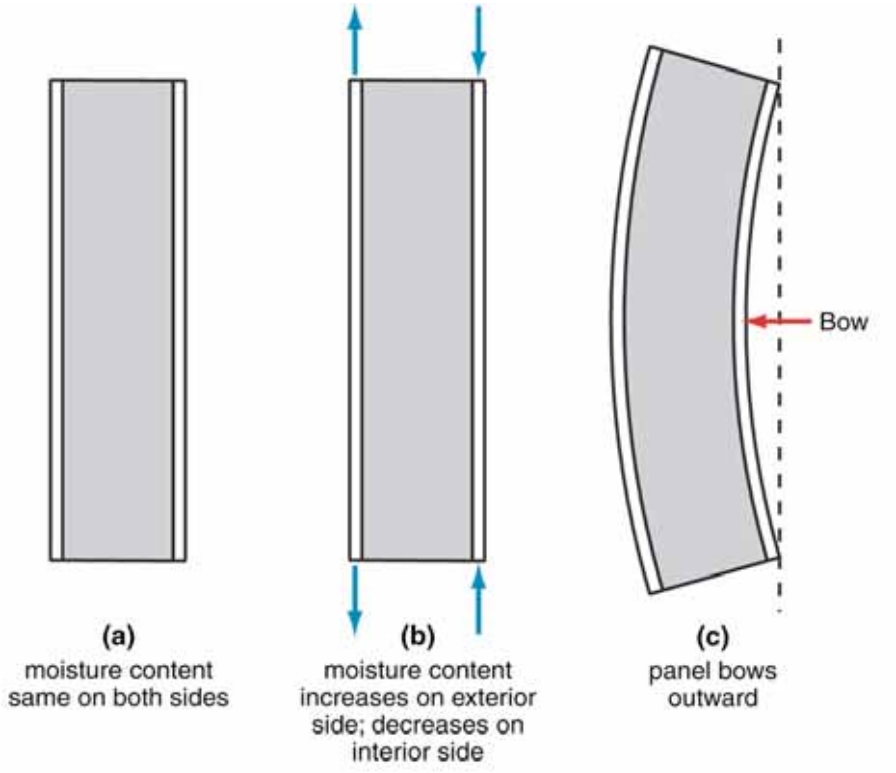

Figure 2: Moisture content vs. Relative humidity

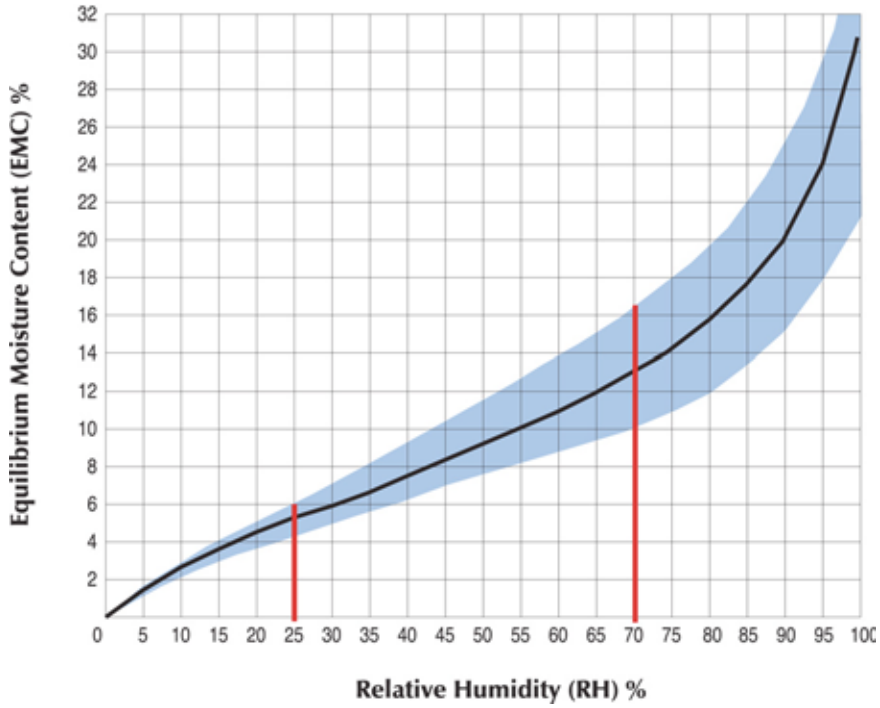

Figure 3: Psychrometric chart

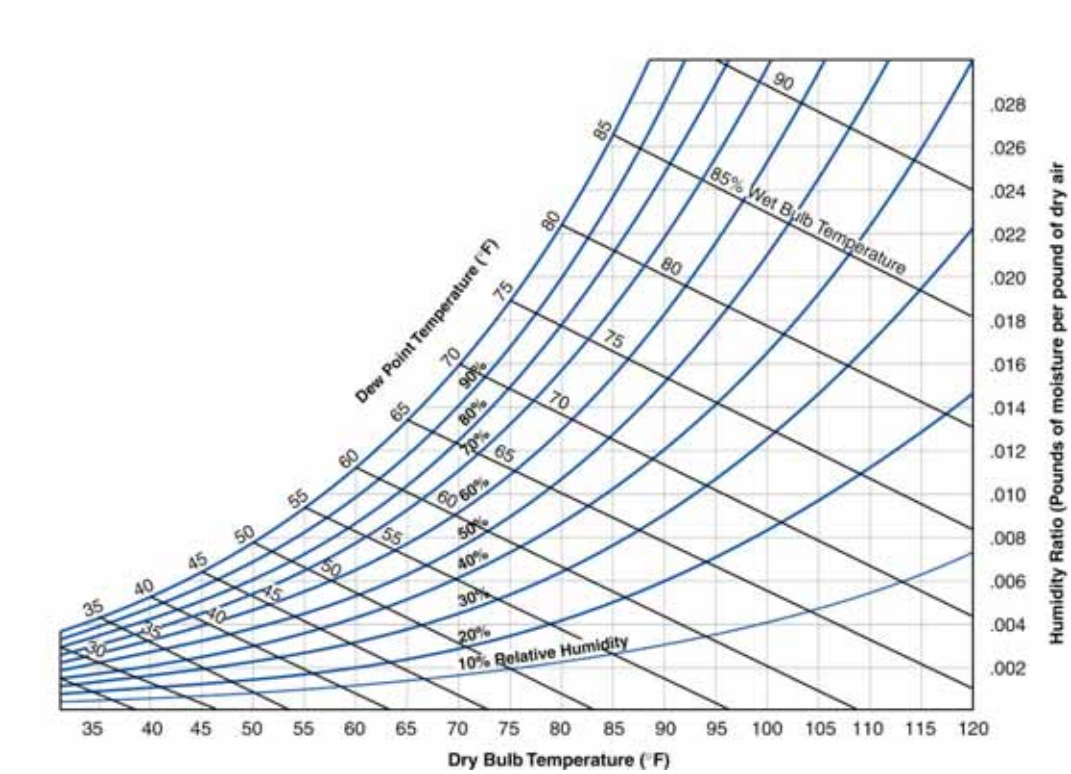

Figure 4: Shrinkage vs. Moisture content

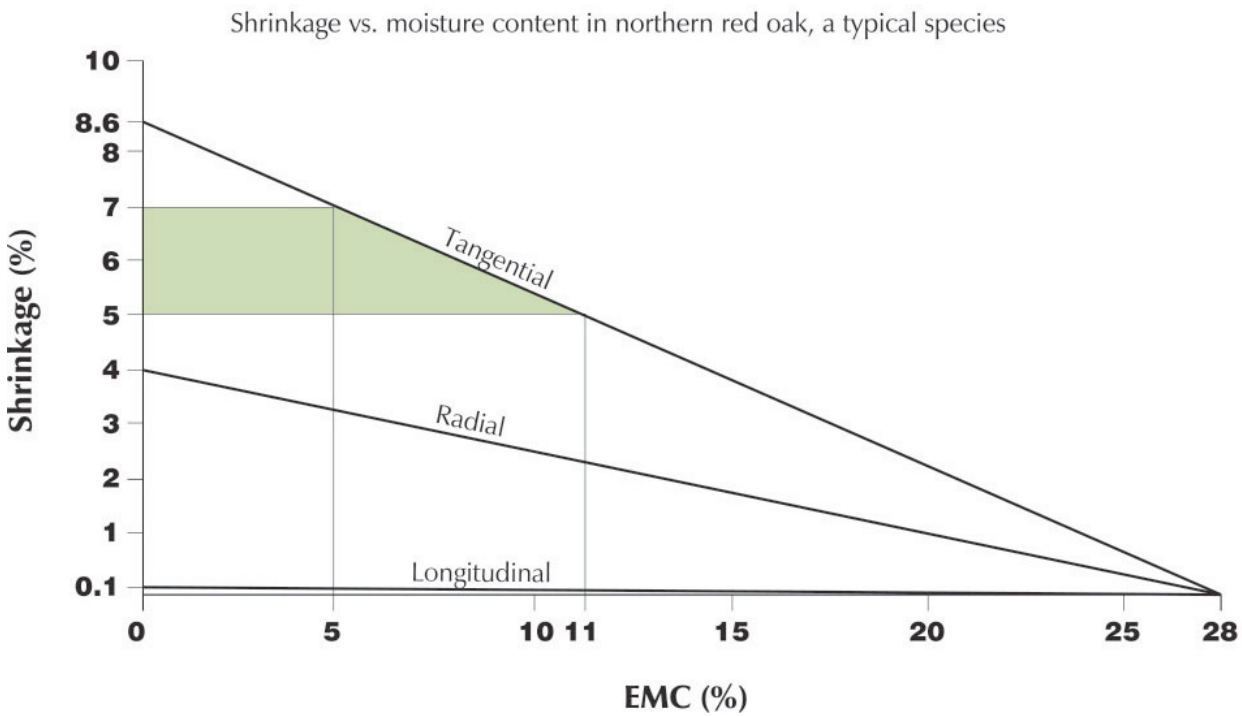

Figure 5: Bottom chord bowing

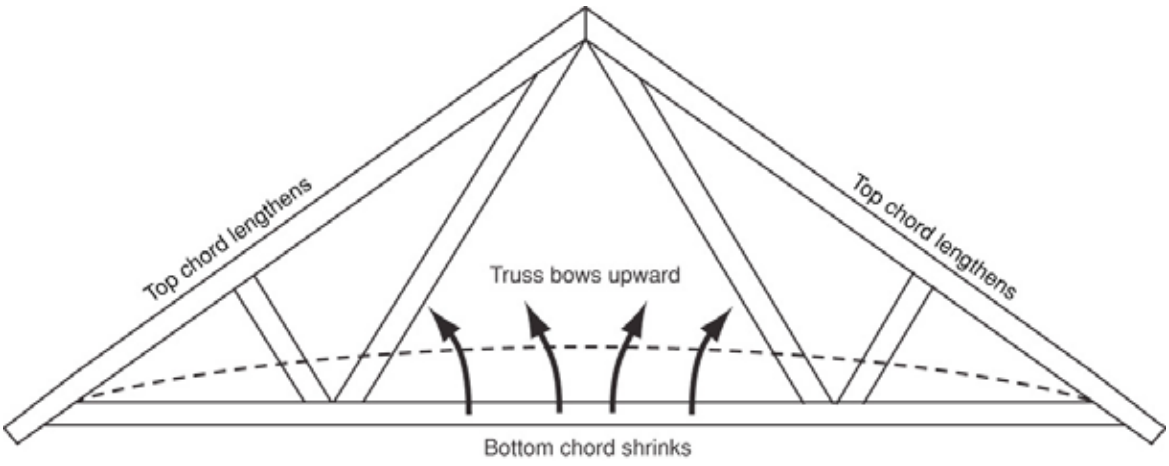

Figure 6: Floating drywall corners

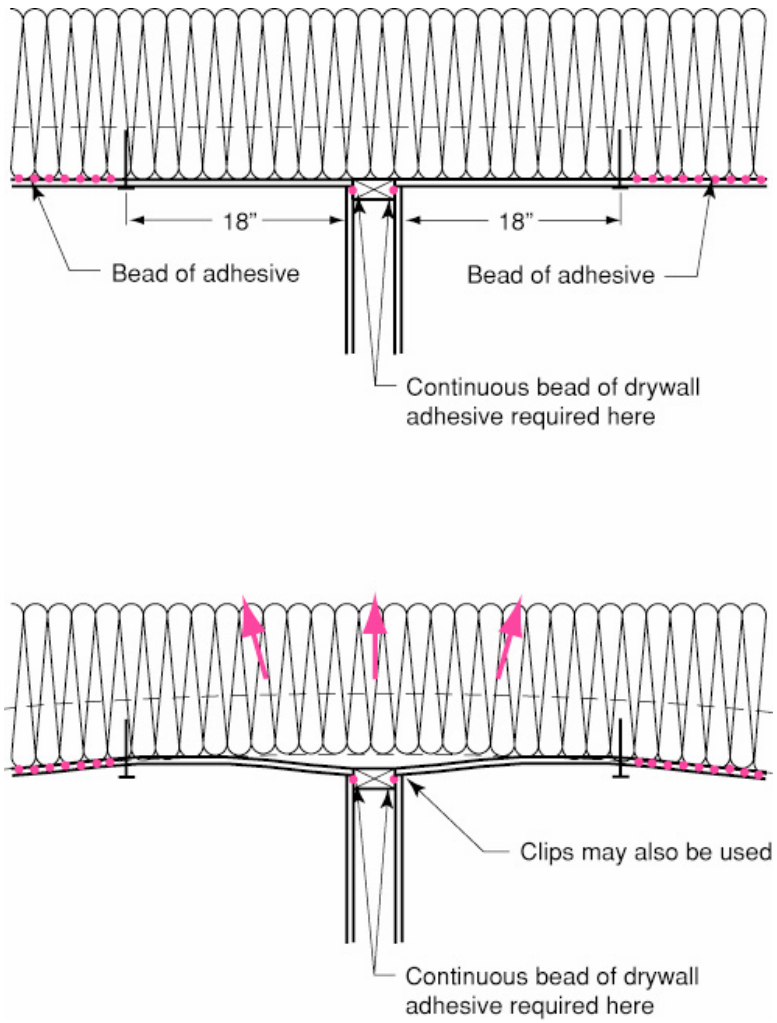

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Figure 7: Floating drywall corners

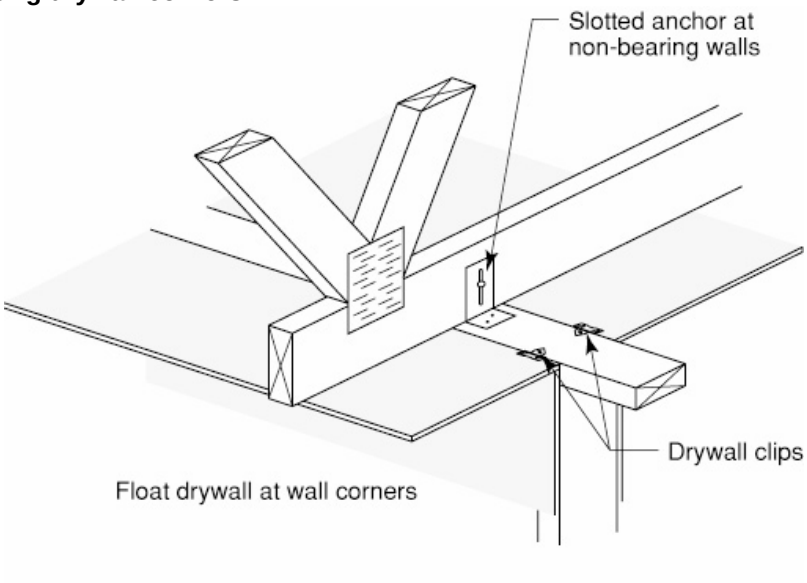

Figure 8: Floating corners