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Air Barriers in Biomedical Buildings with HVAC-Induced Differential Pressures

Introduction

In April 2020, DTR published a Technical News Bulletin, "Building Envelope Air Barriers," which gave a brief introduction to the subject of air barrier systems comprised of continuous membranes, sheets, tapes, and fluid-applied coatings. This article builds upon that introduction to explore Air and Water Barrier (AWB) application in biomedical buildings, particularly those designed and operated to maintain significant differential pressures relative to atmosphere.

AWBs are intended to control the infiltration and exfiltration of air through the exterior envelope of a building. Infiltrating outdoor air can entrain odors, mold, moisture, heat/cold, and more into the indoor environment. The results of this can be disastrous for buildings with indoor environments that support immunocompromised patients, cultured biological specimens, the production of pharmaceuticals, or other sensitive biomedical research and treatment activities.

AWBs work in concert with vapor barriers and insulation systems to ensure that condensation within the wall or roof cross section will not occur during normal temperature and humidity ranges, based on climate. Good design further ensures that, should condensation occur, provisions exist to drain and dry the condensation plane without causing damage or promoting microbiological growth. Air infiltration/exfiltration can also raise the energy required to maintain temperature setpoint considerably and add to the humidification/dehumidification load. Over the same section of building envelope, air leakage can transport orders of magnitude more moisture than vapor pressure-driven diffusion over the same period.

Understanding Modes of Failure

In certain applications, the HVAC system is designed to establish and maintain pressure differentials to mitigate and control the flow of airborne contaminants between rooms and/or between the interior of the building and the outdoor environment. These pressure relationships can be delicate, often relying on the building automation and controls system to adjust air valve and damper positions to overcome external factors, such as wind pressure, stack effect, and fan pressures created by other systems operating in the building, in order to maintain this differential. While a certain degree of infiltration/exfiltration can be compensated for, high leakage rates can make it difficult to maintain the facility in a state of control.

Defects in the continuity of the air barrier may include, but are not limited to:

- **Diffuse Flow:** Where the Materials Of Construction (MOC) are ineffective at controlling airflow through the wall or roof assembly. This may be due to field permeability (air moving through the material itself) or unsealed joints between modular building components (between sheets of sheathing, for example).
- **Orifice Flow:** Where the MOC are relatively impermeable, but the connection between sub-assemblies, such as a door in a rough opening, is inadequately sealed to prevent straight-through air movement.
- **Channel Flow:** Similar to orifice flow, except in lieu of straight-through air movement, the route is more circuitous, resulting in a greater likelihood of the infiltrating/exfiltrating air reaching dewpoint and condensing on surfaces within the assembly.

To mitigate these types of failures, continuity of the air barrier is essential, especially at the transition between vertical and horizontal assemblies and penetrations. The air barrier may be placed anywhere in the assembly and successfully mitigate air movement; the vapor barrier, however, must be placed in a specific plane of the assembly, as dictated by climate, to prevent condensation within the assembly. Failure to seal airflow at the AWB may reduce the effective insulating value of fibrous insulation due to convection of air within the assembly, which also increases the likelihood of condensation and condensation-related damage.

Combining the requirements set forth in ASHRAE 90.1, ICC IECC, and good building practice, an AWB system should be:

(1) Continuous throughout all exterior envelope exposures.

(2) Detailed to minimize penetrations and thermal bridging points.

(3) Able to accommodate the maximum structural movement and pressure differentials (the AWB should not assume the continuity of the VB is sufficient to resist differential pressures developed by the HVAC system).

Air barrier materials should be selected with a permeance not to exceed 0.004 CFM/SF at 0.3" wg (1.57 PSF) [0.02 L/s.m² at 75 Pa] when tested according to ASTM E 2357. Engineering analysis is necessary to account for the impact on higher HVAC-induced differential pressures on the MOC, detailing, and placement of the AWB and VB within the assembly. The detailing of greatest concern is at fenestrations and transitions between roof-wall, wall-floor, and above/below grade, as these present the highest likelihood for gaps and movement-related failures over the life of the structure.

Conclusion

Air barriers are an essential subsystem of the exterior envelope of a building, particularly one subject to HVAC-induced loads. Failure of this subsystem can negatively impact indoor air quality and occupant health and safety. Infiltration, poor control of temperature/relative humidity, and the introduction of particles can be deleterious to the science and medicine conducted in affected spaces and may radically increase the energy required to maintain control of the building within specified limits. Failure is also associated with increased maintenance and decreased useful life of the building due to rot, corrosion, staining, and other damage. Building codes require the inclusion of air barrier systems but are often misunderstood and misapplied by designers and builders alike. The codes are relatively silent on the influence of HVAC-induced differential pressures across exterior envelope assemblies, which highlights the need for engineering analysis to characterize the potential risks associated with air and moisture leakage through these assemblies.