NCMA TEK

National Concrete Masonry Association
an information series from the national authority on concrete masonry technology

CONDENSATION CONTROL IN CONCRETE MASONRY WALLS

TEK 6-17A
Energy & IAQ (2000)

Keywords: air leakage, condensation, energy conservation, infiltration, insulation, moisture, thermal bridging

INTRODUCTION

Building envelope moisture sources include rain, snow, ground water, and condensation of water vapor in the air. Concrete masonry walls are less affected by the problems associated with moisture infiltration than other building materials (i.e. corrosion and rotting). However, prolonged moisture accumulation can lead to mold and mildew growth, paint blistering, and reduced effectiveness of some types of thermal insulation. Excessive condensation also can lead to efflorescence or the temporary formation of frost within a masonry wall. Fortunately, these problems can largely be avoided with proper wall design and construction.

Design strategies for condensation control are well documented. The potential for condensation within a wall, and the likely location of condensation, varies with wall construction and building type as well as seasonal climate changes. For this reason, it is not possible to completely avoid all moisture problems at all times. However, careful design and construction helps reduce the risk and make the building more tolerant to moisture when it occurs. Condensation control strategies include: limiting air leakage, using adequate amounts of thermal insulation, minimizing cold spots, and minimizing water vapor diffusion.

CONDENSATION

Air is made up of various gases, one of which is water vapor. Water vapor can move through a wall in two ways: air flow through a wall carries water vapor with it; and water vapor diffuses from areas of high water vapor pressure to areas of lower pressure. If the temperature within the wall drops below the dew point (or saturation) temperature of the air, the water vapor condenses into liquid form.

The amount of water vapor in air is typically measured by relative humidity, which is the ratio of the amount of water vapor in air at a given temperature (partial water vapor pressure) to the ultimate amount it can hold in vapor form at that temperature (the saturation water vapor pressure). For example, 50% relative humidity means the air contains half the moisture that it is capable of holding at that temperature. Warmer air can hold more water in vapor form than can cold air, therefore the saturation vapor pressure increases with increasing air temperature. When warm moist air comes into contact with a cold surface, the air cools and can no longer hold all of its water vapor – the excess moisture condenses out of the air and deposits on the cold surface.

Local cold spots in a wall can cause small areas of condensation. Cold spots are usually caused either by thermal bridging or by air leakage. Both can be avoided with careful installation of insulation and airflow retarders.

Condensation control focuses on preventing airflow through the wall, on interrupting water vapor diffusion, and on maintaining temperatures above the dew point for surfaces exposed to moisture. Condensation can occur in either summer or winter, depending on climate and moisture conditions. Design strategies for moisture control under heating conditions often differ from those for cooling conditions, even though the basic principles of moisture transfer are the same. The choice of strategies depends on whether the climate requires predominantly heating, predominantly cooling, or a mixture.

CONDENSATION CONTROL

In cold climates, moisture tends to be driven from the warm moist interior to the cold dry exterior. These conditions favor strategies that hold the moisture within the insulated envelope. In hot and humid climates, warm moist exterior air is driven towards the cooler drier interior. In this case, the wall should be designed to keep the moisture on the exterior of the wall. Most climates have some combination of the above conditions. In addition, moisture control in certain building types, such as hotels, motels, and cold storage facilities, will often benefit from using the recommendation for warm humid climates, regardless of the building location.

Definitions of climate zones are somewhat arbitrary. *The*

Moisture Control Handbook (ref. 2) defines both heating climate and warm humid (cooling) climate for use in determining condensation control options. Heating climate is defined as one with 4000 or more heating degree days, base 65°F (18°C) (HDD65, colder climates have higher HDD65 values). Generally, this includes the northern half of the Unites States, Alaska, and all of Canada. Warm humid climates occur where one or both of the following conditions are present: (1) a 67°F (19°C) or higher wet-bulb temperature for 3000 or more hours during the warmest consecutive six months of the year; (2) a 73°F (23°C) or higher wet-bulb temperature for 1500 or more hours during the warmest six consecutive months of the year. The southeastern coastal regions of the United States are generally considered warm humid climates. Mixed climates are those which do not fall into either category above, such as the hot dry climate prevalent in the southwest United States. In these mixed climate areas, the local climate and experience should be evaluated to determine the best condensation control strategies for a particular location and building type. Complete weather data are available from local weather services.

Restricting Water Vapor Flow

Two barrier-type products are used to reduce moisture flow through a wall: airflow retarders and water vapor retarders. Airflow retarders are designed to reduce airflow, and thereby the associated heat and moisture flows. Airflow retarders must also be adequately supported and be strong enough to resist wind pressure and suction.

Water vapor retarders are designed to restrict water vapor flow by diffusion. In some cases, though not all, the water vapor retarder also acts as an airflow retarder. Water vapor retarders are often mandated in heating climates (ref. 3).

Regardless of climate zone, airtight construction will help eliminate airflow through the envelope, which carries moisture and produces localized cold spots, which are more prone to condensation. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) recommendations (ref. 1) stress the importance of providing airtight construction, because air movement results in more water vapor movement through the building envelope than does water vapor diffusion.

Although 6 to 22% of residential air leakage occurs at doors and windows, 18 to 50% typically takes place through walls, and 3 to 30% through the ceiling. Many of the wall leak points are at electrical outlets, plumbing penetrations, and at the top and bottom of exterior walls. Therefore, when used, airflow and vapor retarders must be carefully installed to be continuous and effective.

For walls with an airtight layer, such as an airflow retarder, condensation on the airtight layer can be avoided by locating it on the warm side of the insulation (to keep it above the dew point), or by ensuring the airtight layer allows water vapor transmission.

Heating Climates

In heating climates, condensation is most likely to occur under winter conditions, when interior air is warm and moist, and exterior air is cold and dry. The higher interior water vapor pressure tends to drive moisture through the building envelope towards the outside. In addition, air exfiltration can be aggravated by improperly balanced forced-air heating systems, which can pressurize interior rooms, driving interior air into the walls. Because the interior humidity is higher than that outside, this air flow can carry significant amounts of moisture, increasing the chances of condensation. The overall condensation control strategy is to keep the moist air inside the insulated portion of the building envelope.

Strategies to accomplish this include: design and construct an air tight wall and roof system; minimize room pressurization; provide an interior vapor retarder; and/or keeping wall elements subjected to moisture above the dew point temperature. Providing an air tight wall and minimizing room pressurization both help reduce or eliminate air exfiltration through the wall.

In a heating climate, buildings should ideally be operated at a neutral pressure to reduce air exfiltration. This is accomplished by properly balancing the HVAC system to control the dominant direction of air flow. From a moisture control standpoint, a negative indoor pressure will help prevent exfiltration. However, because of the potential for backdrafting of combustion appliances and for increased entry of radon gas from the soil, negative indoor air pressures are generally not recommended. Significant positive indoor air pressures should be avoided in heating climates.

A water vapor retarder placed on the interior side of the insulation will also reduce the possibility of condensation within the wall. This significantly reduces water vapor diffusion into or beyond the insulation, keeping the moist air above the dew point temperature where condensation will not occur.

In heating climates, a vapor retarder should not be placed on the exterior of the wall, unless the exterior insulation itself acts as a vapor retarder. For example, an exterior insulation system, such as rigid insulation with stucco over concrete masonry, can act as a vapor retarder. However, since the exterior insulation helps keep all wall components above the dew point, this construction does not pose a significant condensation risk.

In other cases, if a vapor retarder is placed on the exterior of the insulation, water vapor can penetrate the insulation, enter the "cold" part of the wall and condense on the vapor retarder. Trapped behind the vapor retarder, the moisture potentially could cause frost formation in concrete masonry walls or decay in wood or steel stud walls.

Warm Humid (Cooling) Climates

In warm humid (cooling) climates, buildings are typically air-conditioned, resulting in cool dry interior air and warm humid outside air. In this case, the dominant moisture flow is from exterior to interior, so this situation requires different design strategies than those for heating climates.

In addition, research conducted by the American Hotel and Motel Association (ref. 4) indicates that hotels and motels should generally follow recommendations for warm humid climates in most areas of the United States. The use of vinyl wallpapers on the interior of guest rooms appears to aggravate the formation of mold and mildew by trapping moisture. Cold storage facilities and ice rinks may also see similar problems, since the water vapor pressures during the summer in most climates are above the saturation pressures corresponding to the wall temperatures.

In warm humid climates the interior space should first be adequately dehumidified. Properly sized air-conditioning equipment will help reduce indoor humidity – oversized units should be avoided since they either cycle on and off too frequently or are off for too long a time to effectively dehumidify. Air infiltration should be minimized to reduce the entrance of moisture-laden air into the cooler interior.

Unlike heating climates, buildings in cooling climates should be operated at a slight positive pressure to prevent infiltration of outdoor air. Likewise, exterior surfaces in cooling dominated climates should have a lower vapor permeance (i.e., higher resistance to water vapor flow) than should interior coverings. Air and water vapor retarders, when used, should be placed on the exterior of the insulation layer. Faced insulations should be installed with the facing toward the exterior of the wall whenever possible.

In humid climates, moisture may condense on wall exteriors, because the wall temperature can be below the ambient dew point. Areas such as shaded reentrant building corners are more difficult to dry, since they do not have the benefit of sun and wind for evaporation. In addition, extra care is required for building components prone to thermal bridging, such as slab edges and parapets (see reference 5 for more information on control of thermal bridges).

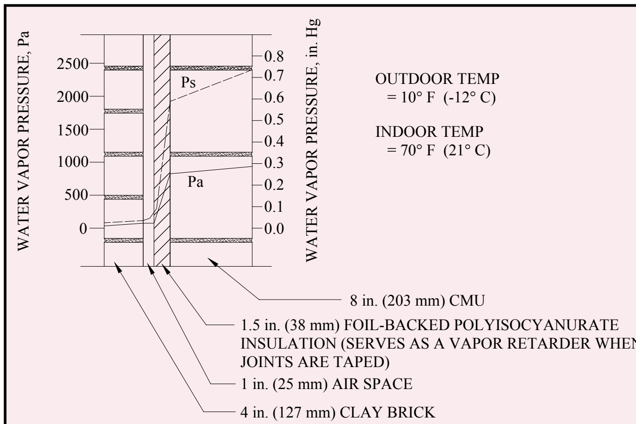
Mixed Climates

Buildings in mixed climates may have high outdoor humidity levels during summer months and high indoor humidity in the winter. However, cooling and heating for human comfort do not usually create serious vapor problems in exterior walls in these areas. Consequently, vapor retarders are not considered as necessary in mixed climates as they are in heating climates or in cooling climates. As with other climate. zones, however, airtight construction is beneficial.

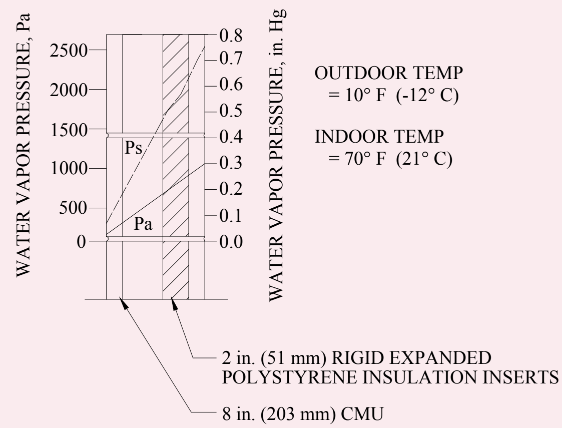
If used, the vapor retarder should be placed to protect against the more serious condensation potential. Vapor retarders should not be placed on both the interior and exterior of the insulation, as this will trap moisture within the wall.

The placement of wall materials, including airflow and vapor retarders, should allow any accumulated moisture to dry. For example, a wall with an interior vapor retarder should have an exterior airflow retarder which is permeable enough to allow drying.

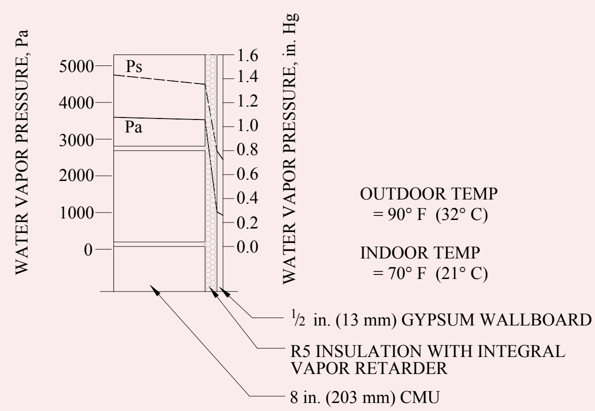
An additional moisture consideration applies to masonry veneers under certain summer conditions. If masonry is untreated for water repellency, water can be absorbed into the masonry during heavy rains. Subsequent solar heating evaporates some of the water, raising the water vapor pressure of air in the wall, and causing condensation in the wall. This can be prevented by using surface or integral water repellents to restrict wetting of the masonry, or by applying parging or sheathing paper on the exterior side of the insulation.



1a: Insulated Cavity Wall, Winter Design Condition



1b: Integral Insulation, Winter Design Condition



1c: Interior Insulation, Summer Design Condition (Warm Humid Climate)

These dew point analyses show P_s, the saturation vapor pressure for each location in the wall based on surface temperatures, and P_a, the calculated actual vapor pressures. Because $P_a < P_s$ in all cases, the analyses indicate that condensation will not occur for the stated design conditions. Note that the three wall systems above use insulation which also acts as a vapor retarder. When a separate vapor retarder is installed, follow the recommendations in the text regarding proper location relative to the insulation.

Figure 1 - Vapor Pressure Gradients For Insulated Concrete Masonry Walls

BASEMENTS

Moisture control in basements begins with proper protection from liquid moisture (rain and wet soil - see reference 7 for detailed recommendations). If the wall is substantially above grade, condensation control recommendations for the appropriate climate, discussed above, should be followed. If substantially below grade, the basement walls will be dampproofed or waterproofed as required by local code, which essentially acts as an exterior vapor retarder. In this case, an additional interior vapor retarder should be avoided, as this may trap moisture within the wall.

Moisture on the interior of basement walls may be caused by either condensation of interior moisture or leakage of liquid water through the wall. To determine the cause, tape a square of impermeable plastic (such as 6 mil polyethylene) on a portion of the wall experiencing the moisture. If there is moisture accumulating under the plastic, leakage should be suspected. If moisture is on top of the plastic, condensation is occurring. In this case, dehumidification is the best alternative to reduce this condensation.

DETERMINING CONDENSATION POTENTIAL

Traditionally, condensation potential has been estimated using steady-state calculations of water vapor pressure and saturation pressures at various points in the wall construction. If the calculated vapor pressure exceeds the saturation pressure, condensation will occur as shown in Figure 1.

This dew point method is a simplified approach which can be used to estimate seasonal mean conditions (rather than daily or even weekly mean conditions) within a wall system. However, this method has several disadvantages. For example, wetting and drying cycles cannot be analyzed, since moisture storage within the building materials is neglected, as is moisture transfer due to airflow. As a result, the results cannot accurately indicate potential damage due to condensation. A complete description of the dew point method is presented in reference 1.

An alternative to steady state calculations are transient computer models, which account for moisture storage in building materials, and can be used to predict daily, or even hourly, moisture conditions within the wall. One readily available program is MOIST, distributed by the National Institute of Standards and Technology (ref. 6). MOIST is a PC-based program to predict one-dimensional heat and moisture transfer in building envelopes. The model has been verified using comparisons to field results.

REFERENCES

1. *ASHRAE Handbook, Fundamentals*. American Society of Heating, Refrigerating, and Air-Conditioning Engineers., Inc., 1997.
2. Lstiburek, J. and J. Carmody, *The Moisture Control Handbook-New Low-Rise Residential Construction*. Oak Ridge National Laboratory, 1991.
3. *International Residential Code*. International Code Council, 2000.
4. *Mold and Mildew in Hotels and Motels*. American Hotel and Motel Association, 1990.
5. *Thermal Bridges in Wall Construction*, TEK 6-13A. National Concrete Masonry Association, 1996.
6. *MOIST*, release 3.0. National Institute of Standards and Technology, 1997.
7. *Residential Concrete Masonry Basement Walls*, TR 134. National Concrete Masonry Association, 1994.