БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ • BULGARIAN ACADEMY OF SCIENCES

ПРОБЛЕМИ НА ТЕХНИЧЕСКАТА КИБЕРНЕТИКА И РОБОТИКАТА, **67**
PROBLEMS OF ENGINEERING CYBERNETICS AND ROBOTICS, **67**

София • 2016 • Sofia

Moisture control in buildings. Condensation managing in surrounding constructions

Veneta Christova-Yosifova

Institute of Information and Communication Technologies, 1113 Sofia, Bulgaria
Email: veneta.christova@gmail.com

Abstract: *Moisture control is fundamental to the proper functioning of any building. Controlling moisture is important to protect occupants from adverse health effects and to protect the building, its mechanical systems and its contents from physical or chemical damage.*

Key words: moisture, humidity, condensation, temperature, insolation, thermal bridges, surrounding construction

1 Moisture Damage in Buildings

In addition to causing health problems, moisture can damage building materials and components [1]:

• Prolonged damp conditions can lead to the colonization of building materials by molds, bacteria, wood-decaying molds and insect pests (e.g., termites and carpenter ants) – fig. 1.
• Chemical reactions with building materials and components can cause, for example, structural fasteners, wiring, metal roofing and conditioning coils to corrode and flooring or roofing adhesives to fail – fig. 2.
• Water-soluble building materials (e.g., gypsum board) can return to solution.
• Wooden materials can warp, swell or rot – fig. 3.
• Brick or concrete can be damaged during freeze cycles and by sub-surface salt deposition.
• Paints and varnishes can be damaged.
• The insulating value of thermal insulation can be reduced.

Fig. 1. Damaged wall by mold.

Fig. 2. Corrosion on steel reinforcement.

Fig. 3. Inflated flooring due to high inside humidity.

Causes of High Humidity [1]:

- Cooking, drying clothes, showering and bathing
- Lack of air circulation and ventilation
- Moisture-producing areas such as indoor greenhouses, indoor pools and hot tubs
- Exposed earth in basements or crawlspaces

- Outside air supply to heating system is blocked or does not exist
- No exhaust fans or underutilized exhaust fans
- No Heat Recovery Ventilator (HRV)
- Faulty or plugged chimney serving any fuel-fired appliance, such as a furnace or hot water heater
- Extensive air sealing done to lower fuel consumption and cost
- Eliminating or blocking off a chimney
- Flooded basement or crawl space
- Minor leaks and water sources

Control Principles:

1. Control of Liquid Water — keeping liquid water out of the building. Sheltering occupants from water is a primary purpose of building assemblies including roofs, walls and foundations. Among the sources of water from outside a building are:
    - Rain and melting snow, ice or frost;
    - Groundwater and surface runoff;
    - Water brought into the building by plumbing;
    - Wet materials enclosed in building assemblies during construction.

2. Using moisture-tolerant materials — materials that can withstand repeated wetting in areas that are expected to get wet and designing assemblies that dry quickly. Moisture-tolerant materials should be used in areas that are getting wet by design or are likely to get wet by accident.

3. Managing Condensation — this is the most crucial point and the most important designing step in order to avoid building materials and construction damage [1].

2 Condensation

Air contains invisible water vapor. The higher the air temperature, the more water vapor it can hold. The lower the air temperature, the less water it can hold. Condensation occurs in buildings where the air temperature rises and becomes warmer and then contacts a cold surface. The air then cools as it contacts the cold surface and produces visible water droplets on the cold surface. Water that is formed is known as “condensate” and the process called “condensation”. If more water vapor (warmer air) is present, further condensation will occur. The condensation occurrence in buildings is the result of complex interactions between the environment, construction methods and building occupant behavior. The process of condensation in buildings is reversible. Where construction material surfaces are warmer or ventilated, condensation may evaporate.
Risks of excessive relative humidity and condensation are not confined to colder climates or seasons. They can happen in mild climates when water vapor is at its lowest level for the year but temperatures are also down. They can occur in the summer wet season of the humid tropics, when there is so much water vapor in the

atmosphere that relative humidity is already high and even a small fall in temperature is enough to trigger condensation. In both situations, the critical drop in temperature can be caused by cold outdoor conditions or by the use of artificial cooling indoors. Refrigerated air conditioning has open new frontiers for water vapor to cause problems in situations where it would previously have been unlikely, by cooling building surfaces to temperatures below the usual reach of the natural environment. With growing use of air conditioning in many types of buildings, the effects of artificially cooled interiors and of naturally cool outdoor climates both need to be considered – fig. 4, [2].

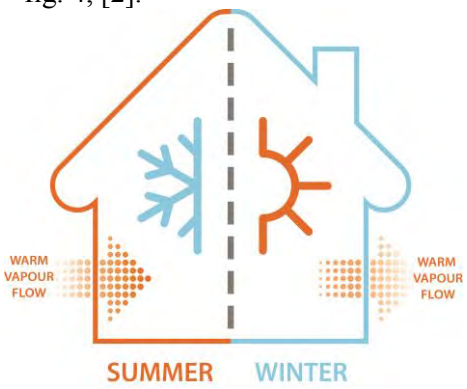

Fig. 4. Critical temperatures driven by artificial cooling indoors or by the climate outdoors.

Condensation on windows

Windows are usually one of the coldest surfaces in a house. Condensation forms on a window when warm moist air that contacts it cools rapidly. Like glass, metal is a poor insulator. If a window has a metal frame, condensation can also occur on the frame. Condensation on windows can be reduced and often eliminated by adding inside or outside storm windows or by installing multiple-glazed windows [3].

Hidden condensation

Hidden condensation can occur when warm, moist air migrates into the walls, attic or other interior areas of the structure. Most of the moisture is carried into walls and attics by air leaking through openings for plumbing, piping, electrical boxes and wires, gaps between framing and drywall, attic hatches and other openings. If at some area in the walls or attic the moist air encounters a temperature below the dew point, condensation will occur. If the temperature is low enough, moisture may deposit as ice or frost. If the amount of moisture is small, it may change back into water vapor with a rise in temperature and be carried away by natural air movement. However, large deposits of ice can melt and soak insulation materials, ruin interior and exterior finishes, and lead to structural deterioration.
To minimize problems in attic and wall cavities, it is important to seal these cavities from the interior of the home to minimize the movement of moisture into these areas. It is also important that the cavities are vented to the outside through attic

vents and 'breathable' exterior siding. This will allow small amounts of moisture that do get into the cavity to escape, as is shown on fig. 5, fig. 6 and fig. 7, [5, 6].

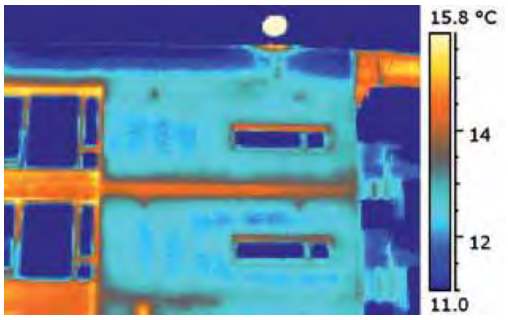

Fig. 5. Thermal bridge at one of the floors.

Fig. 6. Thermal bridges between the roof beams and adjacent walls.

Fig. 7. Moisture intrusion in floor.

3 Calculation of the surrounding constructions in buildings for moisture and condensation

Goals:

1. To avoid condensation in the construction layers.
2. To guarantee that the condense humidity gathered true the cold season will evaporate during the hot season.

For construction of multiple layers (insolation, veneer, concrete, bricks etc.) a model with the temperatures (t_k) in the different layers is build. The line between the different temperatures is called a temperature curve – fig. 8, [4, 6, 7].

Every layer has diffuse equivalent thickness:

$$S_d = \mu.d;$$

Where: μ - material's water vapor diffuse resistance (is specific for every material);
d - actual thickness.

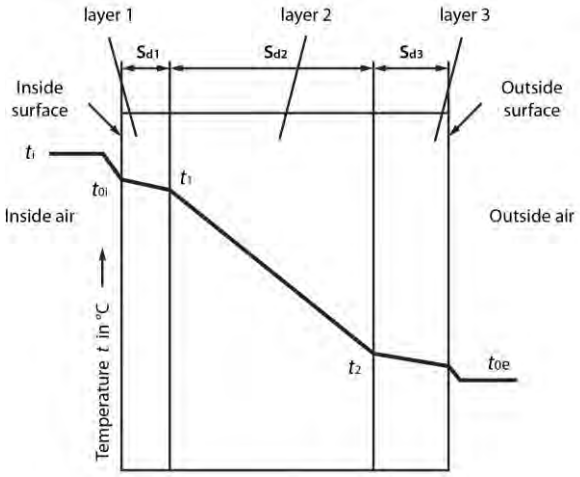

Fig. 8. Temperature curve scheme.

Based on the temperature distribution, the maximum vapor pressure P_{max} can be determined from Table 2, application 7 of Regulation №7, - fig. 9, [4].

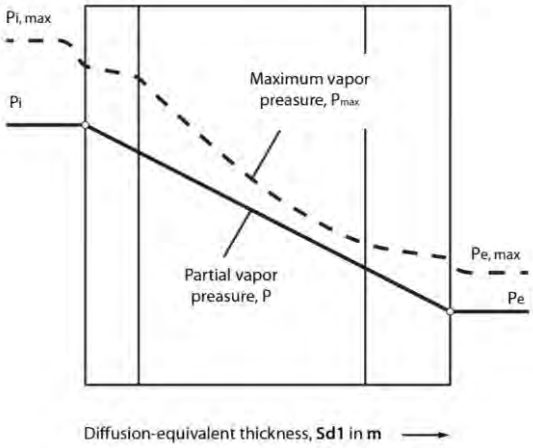

Fig. 9. Maximum vapor pressure scheme.

$$P_i = \varphi_i . \frac{P_{max,i}}{100}$$

$$P_e = \varphi_e . \frac{P_{max,e}}{100}$$

Where φ - air humidity in %

If the lines [P_i; P_e] and [$P_{max,i}$; $P_{max,e}$] doesn't touch or cross — there isn't condition for a condensation to occur. If they touch or cross — there is an appropriate condition for a condensation to occur [4].

The next step is to determine if the condense humidity gathered true the cold season will evaporate during the hot season

Cold season

Condensation zone — form by the crossing points of line [$P_{max,i}$; $P_{max,e}$] and the tangents to it true points P_i and P_e.
Density of the diffusion stream — g
From the condensation zone to the inside:

$$g_i = \frac{P_i - P_{max}'}{z_i}$$

From the condensation zone to the outside:

$$g_i = \frac{P_{max}'' - P_e}{z_e}$$

Where: z [m^2hPa/kg] — resistance to diffusion of water vapor passage;
$z_i = 1{,}5.10^6.S_d$' ;
$z_e = 1{,}5.10^6.S_d$'';
W_k - Condensate humidity;
$W_k = (g_i - g_e).T$ [kg/m^2];
T - condensation period.

Hot Season

$$g_i = \frac{P_{max} - P_i}{z_i + 0{,}5.z_k}$$

$$g_e = \frac{P_{max} - P_e}{z_e + 0{,}5.z_k}$$

Vaporate humidity W_k:

$$W_k = (g_i + g_e).T \text{ [kg/m}^2\text{]}$$

If $W_n > W_k$, the condense humidity gathered true the cold season will evaporate during the hot season and our surrounding construction is out of danger.
If this inequality is not correct, additional measures should be taken inconsideration. For example [5]:

- Consideration of undercut doors, install vents etc.
- Creating air spaces and ventilate cavities where hardboard, cement sheet or other solid materials used for external wall claddings
- Keeping building materials dry during construction
- Minimizing use of cold surface materials that directly contact with conditioned warm air spaces
- Ventilation of spaces between cold surface materials and conditioned warm air spaces
- Application of outside layer of insulation

Conclusion

Moisture control and condensation problems shouldn't be neglected. This may lead to serious health issues and construction damage. Factors such as geographical location, average season temperatures, sunshine direction, climate should be taken into consideration. Designers and engineers should take beforehand measures in calculating the ventilation system, insolation and the outside openings in order to achieve balanced, well ventilated and healthy surrounding.

References:

1. Moisture Control Guidance for Building Design, Construction and Maintenance — U.S. Environmental Protection Agency December 2013.
2. Australian Building Codes Board— Condensation in Buildings Handbook 2014 Second Edition
3. Humidity and Condensation in Your Home — Energy Solutions Centre, Yukon (Canada).
4. REGULATION № 7 from December 15 2004. For energy efficiency, heat preservation and energy savings in buildings (In Bulgarian).
5. Condensation in Buildings Tasmanian Designers' Guide — Building Standards and Occupational Licensing.
6. Thermal Imaging Guidebook For Building and Renewable Energy Applications — FLIR Systems Co. Ltd.
7. Stoimenov N., Karastoyanov D., Vukov A., Neshkov T., Klochkov L., Gyoshev S., Thermographic Study Of Rolls on Roller Batteries., XII International SAUM Conference on Systems, Automatic Control and Measurements., Nis, Serbia, November 12th-14th, 2014., pp 25-28, ISBN 978-86-6125-117-7.

Контроль влажности в зданиях. Управление конденсацией в окружающих конструкциях

Венета Христова-Йосифова

Резюме

Контроль влажности имеет основополагающее значение для надлежащего функционирования любого здания. Контроль влаги имеет важное значение для защиты живущих от неблагоприятных последствий для здоровья и для защиты здания, его механические системы и его содержимое от физического либо химического повреждения.