Condensation Risk in Façade Construction

This Technical Note reviews the risk on condensation in modern façade construction. It covers the cause and effect of condensation, design elements that lead to a risk of condensation, the boundary conditions that effect condensation and the calculations used to analyse the risk of condensation in a façade.

Introduction

Modern façade engineering is continually evolving, to a point that could arguably be described as "extreme engineering". The materials are continually being developed and refined to perform better and at lower cost- to both the budget and the planet. However, as our buildings become better insulated and more airtight, the internal conditions become more conducive to condensation. This risk of condensation can be assessed and design features can be adapted to reduce the risk, or to eliminate it all together.

Condensation and how it forms

Condensation is made up of water droplets that appear on cold surfaces such as: windows, thresholds and cills. It can likewise develop on porous surfaces such as carpet or plasterboard where it may not be seen. Condensation can also be generated in between layers in a building envelope, this is called interstitial condensation. Condensation forms when warm humid air hits a cool surface, the moisture in the air condenses out and forms droplets. The main causes of moisture in a building are the activities of those people using the space in the building.

> *A family of four can add a half-pint of water vapor every hour to a home just through normal breathing and perspiration. And if you take a five-minute shower; you produce another half-pint of water vapor. Gas and propane release a lot of moisture when they burn, so the fireplace will increase the moisture level in your home. Even cooking dinner on a gas stove can produce 2 ½ pints of water. It's all a part of our lives and the places in which we live.*[1]

A typical example of surface condensation. Mould growth can be seen in the corner.

The designated building use conventionally determines the level of relative humidity that we would expect to see in a building. The greater the level of relative humidity the higher the surface temperature needs to be to avoid surface condensation.

[1] Mike Bowie, Why Should You Avoid Window Condensation? Nov 29 2016.

The effect of condensation.

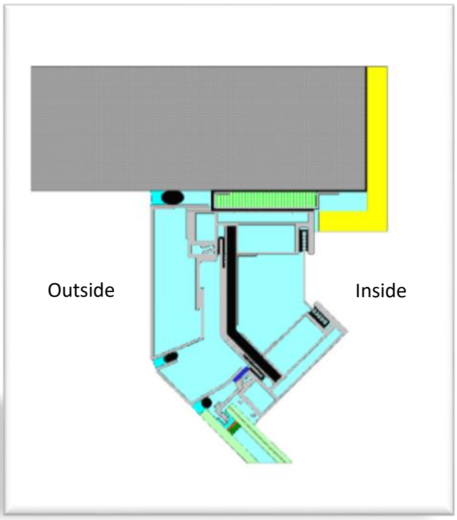
The most immediate effect of condensation is its unsightly appearance, not desirable in a multi-million pound development. More serious consequences are the potential for mould growth (as can be clearly seen in the image above), damage to finishes and insulation elements, or even potential structural failure of timber and metal through rot and rust respectively.

Offices and apartments with facades often incorporate complex metal and concrete load bearing structures. Where a façade, window or door or rainscreen attaches to this substructure we often find cold spots. It is surprisingly easy to generate large amounts of condensation within multi-million pound buildings, often in plain sight or at structurally important locations. This risk can be quantified and mitigated, as we will explain now.

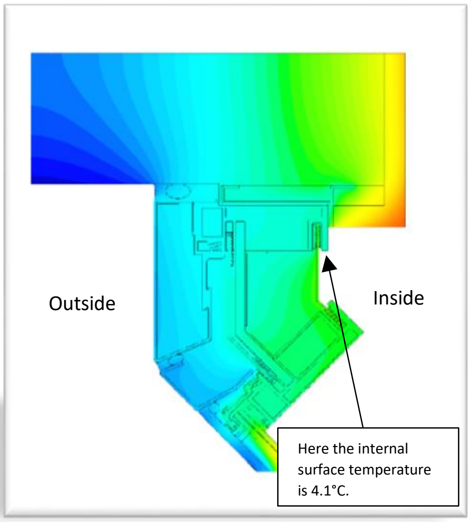
Design and condensation

Building envelopes are designed to create a beautiful exterior that is resistant to weather and thermally insulates the inside from the outside elements. These façades are attached to the load bearing element in many ways and these brackets are a known weak spot in the insulation of the building (cold bridge). Where we have cold bridges we see a reduced internal surface temperature; these cooler internal surface temperatures are where we would see condensation form if they are cool enough. The temperature at which condensation forms is called the dew point.

In order to keep the internal surface temperature above the dew point temperature we use thermal breaks, whose purpose is to stop the cold from 'getting in' and keep the internal surface temperature above the dew point. Below is a real life example of a cold bridge and the solution employed. Numerical Thermal Modelling was used to assess the risk of condensation and test design changes prior to fabrication of the façade.

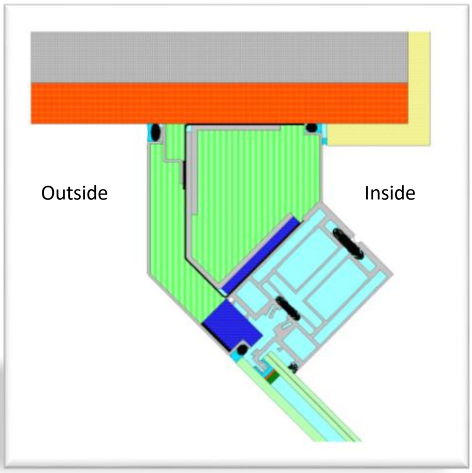


Here we see a façade junction with a concrete wall. There is a clear run of aluminium from the outside of the mullion to the internal surface.

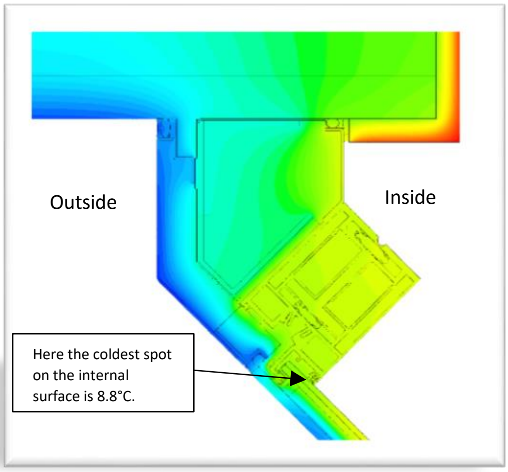


We can see here that the internal surface temperature of the mullion is very low and so will cause a significant risk of condensation.

This initial design was employed to utilise existing façade elements however, as can be seen above, posed a significant risk of internal surface condensation. The clear run of aluminium from the outside to the inside led to a very cold internal surface temperature. The design was changed to insert a significant thermal break, most of the aluminium was removed and replaced with mineralwool insulation, a different mullion was used and separated from the concrete wall to isolate the heat-flow. The results can be seen below.



The façade junction was changed to disrupt the heat flow. The mullion was isolated from the concrete wall and plastic insulation blocks inserted.



The internal surface temperature is now much higher and is above the dew point of 6.9°C.

Boundary conditions

In thermal analysis the Boundary conditions refer to the internal/external air temperatures and internal relative humidity. The colder it is outside the more likely there is to be a risk of condensation. This is because the inside cold spots will be that much colder. An increase in internal relative humidity will also have a major impact of the risk of condensation as it determines how much latent moisture there is available to condense out onto cold surfaces. To calculate the risk of condensation in a reasonably practicable way CWCT (Centre for Window and Cladding Technology) have set the following industry standards for air temperatures and internal relative humidity.

CWCT, Standard for specifying and assessing for condensation risk, 2nd ed. 2.4.1

External	Air Temperature, °C	Relative Humidity, %	Dew-point, °C
Summer	18	65	11.3
Winter	-5	90	-6.3

Internal	Air Temperature, °C	Relative Humidity, %	Dew-point, °C
Houses and flats	20	55	10.7
Offices	20	40	6.1
Schools	20	50	9.3
Factories and warehouses	15	35	-0.4
Textiles	20	70	14.4
Swimming pool halls	25	70	19.2

Analysing the risk

Numerical Thermal Modelling is a process whereby a building design is represented in a computer simulation program to show how it will function thermally. Various elements of the design can be tested in this way and the results given as graphic output as well as text. If the results show that the building will fail the design specification it may be redesigned until the simulation shows that it will comply. These results are then presented to show that the building complies with the requirements.

Numerical Thermal Modelling takes CAD drawings and through several processes builds a virtual specimen section of a detail. The model is then used to calculate heat flow from the warm interior to the cold exterior. This iterative mathematical analysis often requires millions of calculation nodes to best represent what would happen in the real world. It is also possible to build models and run them to analyse time-dependent heat and water vapour flows. This is a well established and reliable method which is regulated by national and international standards, such as BS EN ISO 10211 and, in the case of windows and doors, BS EN ISO 10077-2. These standards clearly establish the software compliance method and rules of operation.

The benefits of numerical thermal modelling

In order to understand condensation risks and mitigate them, different approaches can be taken. Computer numerical modelling is significantly less expensive than the alternative of constructing a sample specimen and transporting it to a facility to be hot box tested.

Thermal modelling can be used to calculate the U-value of existing walls and façades prior to a refurbishment, this ability to assess a current building's thermal performance prior to change-of-use can be extremely beneficial as it will help to inform the technical requirements of the new work. This is important as often the change of use brings upon the building a more stringent application of Part L of the building regulations, e.g. change from 1980's office block to 2016 residential.

In addition, with thermal modelling the design can be altered relatively easily and the simulation rerun to test the design change, this can be repeated many times until the design change that will give the best performance is found.

To sum up, the ability to test a design before a single aluminium rail is brought on site helps companies asses their design when changes can be easily made to ensure compliance and avoid the risk of either surface or interstitial condensation.