Doctoral School on Engineering Sciences
Università Politecnica delle Marche

HYGROMETRIC BEHAVIOUR OF WELL INSULATED BUILDING ENVELOPES

Curriculum: Architecture, Building and Structure

Author

Ilaria Persico

Tutor(s)

Marco D'Orazio

Alessandro Stazi

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Abstract. *In order to meet energy saving standards an analytical comparative study has been carried out to evaluate the different hygrometric efficiency between massive inertial walls and light walls, as well as the dynamic behaviour of the two when exposed to internal stresses. The capacity of passive control systems to reduce the variation of relative humidity in inhabited buildings has been also analysed. Analytical results have shown that the envelope is no means for transmitting vapour towards the outside, but it can interact dynamically with the environment and develop a differentiated hygrometric behaviour when it is exposed to vapour loads. Results have proven that the internal and the external part of the envelope have a different reaction in front of dynamic stresses, and the quantity of vapour being transferred to the outside from the middle part of the wall is very low.*

Keywords. Hygroscopicity, Indoor climate, Moisture buffering capacity, Building envelope, Moisture transport.

1 Problem statement and objectives

In order to comply with the Directive 2002/91/EC on the "Energy Performance of Buildings" Italian Government has published the decree DLgs 192/05, which has been then supplemented with the DLgs 311/06 on "corrective and additional disposition to DLgs 192/05" and more recently with the DPR 59/09. These new regulations focus on the performances of building systems and of single building components and they are aimed at reducing energy consumption and emissions of polluting gases. While the building material industry (especially in the thermo-insulating sector) is promoting natural construction materials of limited environmental impact in the pursue of eco-sustainable buildings and in order to address the environmental issue, these regulations impose transmittance limits to the opaque structures, which force designers and constructors to develop "watertight" building components of low vapour permeability. Most of the times this target is reached using "super-insulated" or "ultra-light" outside walling, made of very thick insulation. As a result of this, the function of the building envelope changes radically. The building envelope is no longer responsible for transmitting vapour towards the outside. In fact its components interact with the vapour produced through internal and external conditions in a very differentiated way (that is separately and independently). Its function is further endangered by many of the highly hygroscopic natural materials, which are being introduced according to the principles of green building. Such materials which can store and release vapour are often responsible for water collection within the opaque envelope. When the vapour load produced within the environment cannot be dispersed through the envelope, we reach high values of relative indoor humidity which can deteriorate building materials and affect the health of the inhabitants.

Several international studies have demonstrated that indoor relative humidity is an important factor which influences environmental thermal and breathing comfort of people, perceived air quality, and heat conduction throughout the elements of the opaque envelope, as well as durability of building components and proliferation of biological organisms such as fungi, bacteria, and moulds that can be dangerous and toxic to humans. Due to the key role covered by relative humidity, recent international studies, mainly carried out in Northern Europe, have focused on the applications of hygroscopic materials in buildings and on the capacity they have in moderating variations of indoor relative humidity. Since the early 80's research has been investigating the capacity of porous materials to interact dynamically with indoor air, as hygrometric performances of building materials have become basic issues to be faced when analysing or designing new buildings. Accordingly many modelling and simulation tools have been developed and validated in the field of the integrated heat-air and moisture transport which takes place among the elements of the envelope and within the environment. Based on evidence and literature provided through international research [1-10], main purpose of this doctoral thesis is to demonstrate that vertical opaque envelope cannot transmit vapour, but some of its elements can interact dynamically with the surrounding environment and develop a differentiated hygrometric behaviour according to the flow of vapour. Secondly this thesis provides detailed dynamic evaluations of the reaction of the opaque envelope when different internal loads are applied. Besides it also concentrates on the effect that those highly vapour permeable elements of the opaque envelope (brick walling or light padding) have on the quantity of vapour transmitted and on the quality of indoor climatic conditions. Additionally this thesis is aimed at identifying the most suitable superficial internal finishing for passive systems which control R.H. peaks. These systems are based on the property of vapour absorption of porous building materials, also known as "Moisture Buffering Effect".

2 Research planning and activities

This exclusively analytic study has been carried out by means of dynamic hygrometric softwares, able to simulate indoor climatic conditions (temperature and R.H) once having set outdoor climatic conditions and those of the building envelope. The calculation method to determine the dynamic load of inner vapour has been given by the creation of a sinusoidal law which takes into account the number of people in the room, considering their time of stay and the production of vapour per hour, according to the kind of activity they are doing. The first step of simulation focused on the evaluation of the dynamic hygrometric behaviour of the opaque element in relation to the issues linked to the DLgs. 311/06: year's simulations have been done in order to compare different building solutions (inertial/light). Such solutions differing in presence/absence of mass, insulating technology (more or less hygroscopic), presence of vapour barrier, external climatic conditions, and level of air tightness within the building.

After having checked the hygrometric functioning of massive and light construction layers, keeping the same set of boundary conditions and the same thermal transmittance for the envelope, the interaction between building envelope and indoor environment has been analysed according to the application of different internal dynamic loads (long lasting vapour load (almost one day), heavy vapour load in a short time and medium vapour load). Predictive dynamic hygrometric softwares used (Champs Bees 1.6 + Champs Multizone 1.4.1) allowed simulations on the hygrometric behaviour of buildings with a good level of detail. Since there are many different parameters affecting the interaction between opaque element and indoor environment, the effect of the finishing has been evaluated grouping simulations according to issue categories, that is: hygrometric separation of the opaque element, the role of a more permeable envelope, and the optimisation of the capacity of storing and releasing vapour (*moisture buffering*) in internal finishes made of lime-cement plaster. Hygrometric feedback of well insulated massive/light walls has been then investigated, keeping the same thermal transmittance of the envelope, but varying internal dynamic loads and outdoor climatic conditions. Finally it has been analysed the impact of different kinds of internal finishing (with different "Moisture Buffering Capacity") when applied to traditional single layer with cladding in internal environments exposed to high internal dynamic vapour loads.

3 Analysis and discussion of main results

According to main results of the second step of simulation the external and the internal part of the opaque envelope do not react the same in front of dynamic stresses. Based on these results, it has been proposed an average indoor wall thickness which is actually affected by the dynamic phenomenon of vapour storage and release caused by the material it is made of. Though very small, it has been possible to estimate the quantity of vapour transmitted to the outside through the middle part of the wall. The study has demonstrated that the depth of the inner wall, actually interested by the dynamic behaviour of vapour storage and release, does not exceed 10-15 mm thickness of traditional inner finishing. The role of massive and light elements of which the opaque envelope is made has also been investigated, together with its effects on the quantity of vapour released and on the quality of indoor climatic conditions. Finally, once demonstrated the importance of the internal finishing layer, the study went on with the parameterization of the hygrometric features which regulate the capacity of internal plaster finishing of storing and releasing vapour. Based on the results obtained, following assumptions can be made:

– The amount of vapour flow released through the building envelope is so small that it is almost nothing if compared to the vapour flow which is generated through internal dynamic loads of vapour and which involves the internal and external plaster;
– Outer plaster and insulation for the cladding (only for massive external insulations) are only affected by those stresses which stems from outdoor climatic changes;
– Higher permeability of the insulation within the massive wall with external insulation does not influence the behaviour of the envelope. In fact even if thanks to a better permeability of the material we get bigger vapour flow within the external insulation, this cannot actually be released to the outside, then causing a higher water content within the massive material of higher permeability;
– Last, changing the hygrometric parameters of vapour storage and release of internal plaster, it has been verified that a high permeable hygroscopic finishing with high vapour permeability can be useful to keep levels of internal vapour loads under control and to decrease variations of relative humidity. Since these parameters are responsible for the quality of air indoor, it is advisable to foresee such finishing typology.

The second loop of simulations has extended the hygrometric analysis to well insulated building solutions, both massive and light, given the same thermal transmittance but setting different internal dynamic loads and outdoor climatic conditions. These simulations have proven that each building typology, whether massive or light, and with low thermal transmittance develops an independent behaviour in front of vapour flows generated through dynamic loads. Basically only a thin layer of the internal surface is influenced by the different internal loads, whereas the outer part is only affected by outdoor environmental conditions. The vapour flow which is transmitted through the central part of the envelope is nothing if compared to the flow we get on surfaces. The wood layered light building solution has the same hygrometric reaction of the solution which foresees insulation in the interspace, so it has no influence on indoor hygrometric comfort. It has been demonstrated that only those surface finishes which are involved in the process of vapour storage and release play a significant role in the regulation of indoor relative humidity, and that despite the well established trend shared among several companies specialised in green building, hygroscopic buffer made of wood fibre under the first layer of plaster or plasterboard does not improve either vapour release or dispersion. Among the different materials used for internal finishing it is advisable to chose those which are hygroscopic and more vapour permeable since they regulate the levels of internal vapour loads and limit the variations of relative humidity. For example porous lime and cement plaster is better than water-tight plasterboard. In other words they grant better quality of indoor air. Wood fibre buffer is useful only if it is 5 cm thick and if it is placed in direct contact with the internal environment. The choice for the right internal finishing can be of some help in order to keep maximum levels of vapour pressure under control, especially in the environments with impulsive vapour production. That is because the moisture buffering property of the materials has no effect on the average values of relative humidity, but it rather regulates the amplitude and lowers the peaks. Its effect is therefore less evident in front of a continuous source of vapour. According to detailed analysis of the hygrometric reaction of surface finishing layers, the surface which is in direct contact with the indoor environment reacts first and immediately after a vapour dynamic stress is applied, only then the sub-layers. The velocity of the overall system depends from the kind of load and from the type of material sequence of the layers. The calculation of the actual depth reached by humidity penetrating into the layered structure provides no clue to the different behaviour of walls, since it is not particularly affected by the different types of load, and the time variable is not properly considered. It has been also given evidence that generally the materials involved in the phenomenon of vapour storage and release belong to the first two layers and that the right sequence of material layers is important. Since, especially for the light wood padding, the resistive properties of coupled materials are not available, the only useful parameter to define general laws is the assessment of the amount of humidity ("Iw") which is rapidly absorbed and gradually released through one square meter of wall.

Last simulations have shown that moderate ventilation fosters moisture buffering in surface finishing materials on those walls which are involved in the dynamics of vapour storage and release, and it provides interesting case-studies on passive regulation of indoor relative humidity levels. Where we have a discontinuous production of vapour, adsorbent finishes lower the packs of indoor vapour pressure, especially the maximum values, and therefore they improve hygrometric comfort. On the contrary in internal environments with continuous vapour production, adsorbent finishing behaves just as traditional finishes, as it soaks up vapour but does not release it because of the steady high levels of indoor relative humidity.

4 Conclusions

This doctoral thesis has provided detailed analysis of hygrometric dynamic interaction between environment and building envelope with special focus on indoor environmental climatic conditions. Analytic activities have demonstrated the "moisture buffering" capacity for building materials to keep the levels of indoor relative humidity under control, since they are able to store and release vapour within the environment, which tends to become more and more air-tight. Further research will be aimed at optimising the functioning of the system in front of mechanical ventilation and it will also evaluate the role of furniture in the reduction of indoor humidity variations and in the preservation of the building heritage. Future research might concentrate on the characterisation and testing (such as durability test) of coupled materials, and investigate combinations between traditional materials and insulations either of natural origin or of high hygroscopic properties.

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