The Effectiveness Of An Intelligent System For Real-Time Hygrothermal Management In Low Energy Buildings

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ABSTRACT

This paper proposes an intelligent model for real-time control of the hygrothermal behaviour in low energy buildings. Through the management of information related to internal and external conditions combined with the design and context data, the built network lead to assess the correct strategy for an adequate hygrothermal behaviour (choosing between active and passive systems for control of indoor air-quality). The expected benefits are a healthy environment, the stable performances of materials, the containment of maintenance costs, the reduction of the use of passive systems in order to cut CO2 emissions.

Keywords -
Low energy buildings, intelligent system, CO2 emissions.

1 Introduction

This paper describes the early stages of the analyzes conducted to define an intelligent model for real-time control of hygrothermal behaviour of the building elements, in particular in low energy buildings.

We started from the premise that, it may occur, in the elements of the envelope, the formation of condensation and mold, even if the hygrothermal assessment, carried out in the design phase, have given positive results.

So it was analyzed the hygrothermal assessment method currently used in the design of the building and it was highlighted the limitations of this method and the new developments in the technical standards.

The next step involved the identification of the actual external and internal climatic conditions that lead to the formation of condensation in the envelope elements for which the assessment, carried out in the design phase, gave positive result.

The causes of these problems were then summarized. The main reason is the excess of indoor humidity due to the lack of air changes. In particular, the increasing tightness of building envelopes makes increasingly difficult the respect of minimum air changes. This fact denotes, often, poor management of ventilation provided to internal environment, resulting in the formation of condensation and mould and poor healthy indoor air.

Consequently, were analyzed the possible strategies to be implemented through the alternation of passive or mechanical control of the indoor climate. In this phase, it has been highlighted as it may be complicated to manage the above-mentioned strategies.

The aim of these analysis is the first definition of actions that intelligent system should be able to perform, finalised to the control of the combination of passive and mechanical systems, in order to reduce or even eliminate the possibility of condensation in the envelope.

The hypothesized intelligent system uses sensors placed at several points of the building, which ensure the ability to monitor in real time the internal and external climate data, in particular temperature, pressure and relative humidity, as well as the relief of the direction and the intensity of the wind, necessary for the management of the hygrothermal behaviour of the envelope.

It is thought that the data collected and the analyzes conducted in the first period of observation will be useful to check if the implemented strategies are correct and, otherwise, will be useful to change the structure of the system for reach better results.

2 Passive or mechanical systems for the management of the internal conditions

Currently, the benchmark for quality construction is the nearly zero-energy building, a building that has a very high energetic performance, so that the very low amount of energy required should be covered to a very significant extent by energy from renewable sources. Consequently it was started by Sardinian companies the introduction of innovative construction systems characterized by very high efficiency, finalized to ensure the reduction of energy loss through the envelope. The import of construction methods studied in other climates and other contexts can lead to incorrect applications related to the insufficient experience and poor experimentation in the local context. It often happens that buildings designed for high efficiency have unexpected deficits. In particular it may occur, in the elements of the envelope, the formation of condensation and mold, even if the hygrothermal assessment, carried out in the design phase, have given positive results [1]. These factors affect the health of the environment and the wellness of the users, the performance of the materials, their durability and consequently cause diseconomies due to the need for frequent maintenance.

The risk of surface condensation was analyzed using the conditions imposed by Italian regulations (Legislative Decree n. 192/05 and DPR 59/2009) which provides the absence of surface condensation supposing fixed conditions of internal air temperature (T.in = 20°C), and relative humidity (RH.in = 65 %).

Actually, such data are constantly changing on the basis of many variables related to the real climate (days unusually wet or cold) and the design data.

In particular, the increasing tightness of the envelope and of the windows has significantly reduced the air changes necessary to ensure the health of the indoor environment and to prevent that the increase in relative humidity causes formation of surface and interstitial condensation, with consequent mold and deterioration of the building elements.

Considering that the air changes guaranteed by the permeability of the envelope are now insufficient, it is necessary the integration with the system of natural or mechanical ventilation.

The natural ventilation during the winter (0,3 vol/h according to the UNI/TS 11300-1:2008 [2]) can be easily activated by opening the windows for a few minutes (2 to 6) so that it can reduce the rate of relative humidity, but the temperature does not drop excessively. An excessive lowering of the temperature would have two negative consequences:

- The increase in energy consumption.
- The decrease in the percentage of indoor relative humidity at which may occur condensation interstitial and superficial.

The control of natural ventilation is entrusted to inhabitants in the apartment that, due to lack of knowledge of the subject or to neglect, are not always able to ensure adequate natural ventilation.

The simplest solution would be the introduction of mechanical ventilation systems, supported by use of sensors such as hygrostats, to ensure quality control of air and moisture, entering indoor air taken from the outside. To reduce energy consumption, the pre-heating of the air introduced could be carried out by integrating various ventilation systems, also each other combined, as the heat recuperators, or the underground heat exchangers.

However, the exclusive use of mechanical systems to control humidity would increase the energy consumption of buildings and CO_2 emissions. Such systems should instead be used when the passive systems are not able to manage the adjustment of the internal conditions.

3 The hygrothermal assessment method

3.1 Purposes

Even today it often happens that buildings designed to ensure high efficiency behaviours show unexpected deficits, such as condensation and mold, despite the hygrothermal assessment has given positive results. These phenomena are, unfortunately, often the cause of the reduction of indoor air quality, premature wear of the structures and diseconomies linked to frequent maintenance.

Let us understand the reasons behind these phenomena and then outline strategies to solve them.

The method of Glaser [3] is definitely the most used tool for the study of the hygrothermal behavior of the envelope relative to interstitial condensation.

With the method of Glaser, it is possible to check what happens, from the physical point of view, within a opaque component of envelope when, as a result of a pressure gradient, a certain amount of water vapor passes through the itself component. During this step it is possible that the water vapor encounters the areas in which the vapor pressure is greater than its saturation limit. This involves the formation of a front of condensation with the consequent presence of liquid water within the layers or on the surface. This quantity of condensate is evaluated for each material that constitutes the element analyzed and the verification is deemed to be fulfilled if the condensate formed during a year is less than the maximum amount indicated in the prospectus NA.2 of the UNI EN ISO 13788: 2013 [4]. The logic on which the verification is based is that the component, during the summer, is able to dispose of any interstitial condensation produced during the winter period.

3.2 Criticality

The hygrothermal assessment of the building elements, carried out according to the UNI EN ISO 13788: 2013 with the method of Glaser, proposes a simplified method of calculation which considers only the vapor transport by diffusion, and uses, for the extreme slowness of such phenomenon, monthly climate data for the outside conditions of temperature and relative humidity. In Italy, these data are given in the UNI 10349:1994 [5]. The internal conditions of inside temperature and humidity are fixed, in accordance with the Presidential Decree 59/2009.

The UNI EN ISO 13788 states that this is a simplified calculation method, steady-state, in which they material properties, such as thermal conductivity, are considered constant, instead this parameter varies according to the humidity. Moreover phenomena such as lifts capillary, the movement of humidity in the liquid phase and the hygroscopicity of the material are neglected.

Generally it is a precautionary standard; for example, the fact that it is not considered the hygroscopicity of the materials could lead to an overestimation of the risk of condensation. On the other hand, the fact that it is not considered the transport of moisture associated with convective motions of moist air can lead to an underestimation.

In the UNI EN ISO 13788 is then given the option to use more accurate calculation methods, currently codified in the UNI EN 15026: 2008 [6]. It is a method of analysis in variable regime that takes into account the accumulation of heat and humidity, the effect of the latent heat, the transport of moisture in the liquid state and through the convective motions under realistic conditions. Using this standard it is possible to evaluate the influence of radiation and rain on the migration of vapor, the phenomena associated with drying of the elements of the envelope and the behavior of users. In order to conduct this type of analysis, it is necessary to have a complete picture of the hourly climatic data and of the material characteristics, especially regarding the hygroscopic behavior. As regards the internal conditions of humidity and temperature, these are measured, in a simplified way, according to the variation of the external temperature and the use of the rooms.

In both cases, it is a predictive method, more or less reliable, that does not allow to avoid, in the use of real buildings, those extreme situations, closely related to the behaviour of the user, which, as will be seen, are the main cause of condensation and mold.

Although in the premises of the UNI EN ISO 13788 it is stated that, in the majority of cases the method of Glaser is prudent, a series of case studies (analyzed in the research project entitled "Innovative approaches to the construction process of energy efficient buildings to increase the competitiveness of Sardinian companies" developed in collaboration with the network of three Sardinian companies "Domu Noa", through a research grant financed from the resources of R.O.P. SARDINIA E.S.F. 2007-2013 - Objective Regional competitiveness and employment, Priority IV Human Capital, Lines of Activities l.1.1. and l.3.1"), which will briefly listed below , confirm limits and criticality of a hygrothermal analysis based on monthly averages. In particular, in all of the above cases, although the hygrothermal assessment during the planning had given a positive result, the building elements at show serious consequences of the formation of condensate (mold and efflorescence). In these cases, one must also take account of the fact that the formation of interstitial condensation generates, in addition to the immediate deterioration of the internal conditions, a decay in time of the performance and the durability of the materials constituting the component and, consequently, the increase in costs maintenance.

To avoid these unexpected phenomena is necessary to identify the internal and external conditions that can cause condensation, especially the interstitial condensation. The selection of these critical conditions can be carried out through the analysis of the pressure (Pr), and its saturation limit (Ps), within an element of the envelope. The purpose of this first part of the study is not, therefore, the calculation of the amount of the annual condensate, but simply the identification of that combination of internal and external conditions which, if repeated over time, can trigger these phenomena, in order to intervene with the appropriate system at the right time with the support of a continuous monitoring of the environmental conditions inside and outside.

4 The identify of critical conditions

In the figure 1 the layers of the building component on which we have conducted the analyzes are shown.

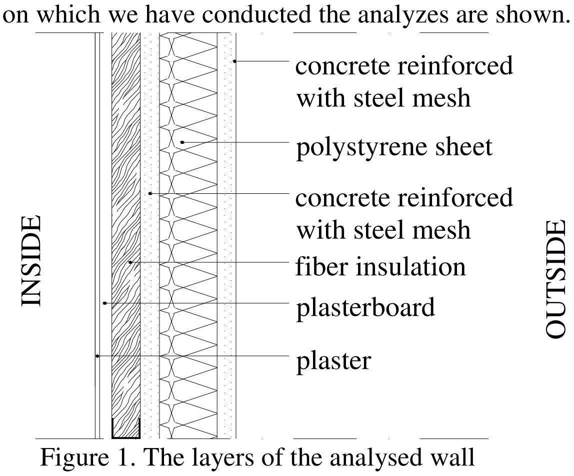
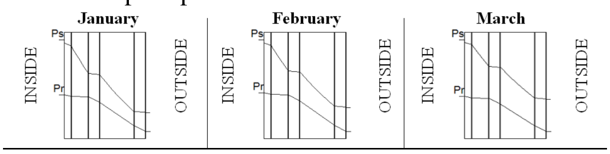


Figure 1. The layers of the analysed wall

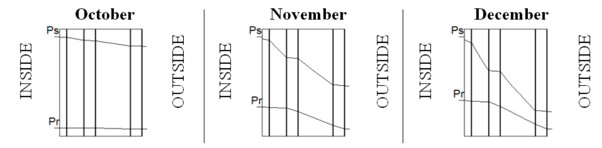
The hygrothermal analysis, conducted successfully, in the planning phase, according to the method of Glaser, concluded that, based on the monthly average of the specific location (UNI 10349) and by setting the internal conditions provided for by law, there would not be risk of condensation. In this regard, the output of such verification concerning the winter months, notoriously the most critical as regards the possible formation of interstitial condensation, is shown below (table 1 and 2).

Table 1. The trend of vapour pressure and saturation vapour pressure in standard conditions



	January	February	March
T.in [°C]	20,0	20,0	20,0
Ps.in [Pa]	2337,0	2337,0	2337,0
Pr.in[Pa]	1519,0	1519,0	1519,0
RH.in %	65,0	65,0	65,0
T.out [°C]	10,3	10,8	12,8
Ps.out [Pa]	1252,2	1294,7	1477,5
Pr.out [Pa]	973,0	923,1	1010,6
RH.out %	77,7	71,3	68,4

Table 2. The trend of vapour pressure and saturation vapour pressure in standard conditions



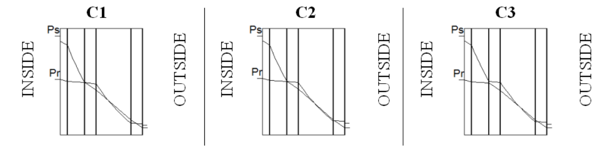
	October	November	December
T.in [°C]	20,0	20,0	20,0
Ps.in [Pa]	2337,0	2337,0	2337,0
Pr.in[Pa]	1519,0	1519,0	1519,0
RH.in %	65,0	65,0	65,0
T.out [°C]	19,4	15,5	11,7
Ps.out [Pa]	2251,6	1760,1	1374,3
Pr.out [Pa]	1508,5	1258,4	1151,7
RH.out %	67,0	71,5	83,8

As can be seen, the saturation vapour pressure are always superior to the pressure, confirming a condition far from that of formation of interstitial condensation.

Given that, after two years of the use of the analysed building [1], in various parts of the opaque components occurred mold and efflorescence compatible with the formation of interstitial condensation, we decided to conduct a thorough investigation about the probable causes, focusing on identifying the internal and external climatic conditions which may provoke these problems.

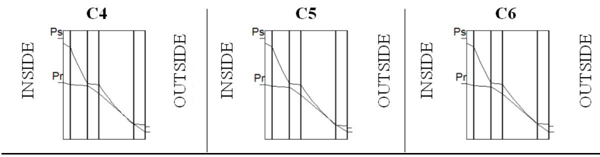
In the first place, keeping fixed the internal standard conditions (T.in = 20 °C and RH.in = 65%), evaluated the specific weather data of the area of interest, we have identified the external conditions that can lead to formation of interstitial condensation (table 3, 4, 5, 6). These limit external conditions were collected by reference to data of "Eurometeo" [7], recorded approximately every 45 minutes.

Table 3. The trend of vapour pressure and saturation vapour pressure in external extreme conditions



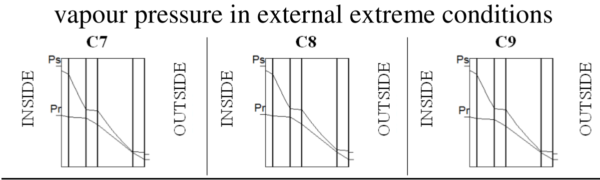
	C1	C2	C3
T.in [°C]	20,0	20,0	20,0
Ps.in [Pa]	2337,0	2337,0	2337,0
Pr.in[Pa]	1519,0	1519,0	1519,0
RH.in %	65,0	65,0	65,0
T.out [°C]	1,0	1,0	2,0
Ps.out [Pa]	656,4	656,4	705,3
Pr.out [Pa]	610,4	564,5	634,8
RH.out %	93,0	86,0	90,0

Table 4. The trend of vapour pressure and saturation vapour pressure in external extreme conditions



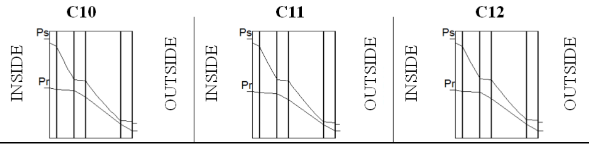
	C4	C5	C6
T.in [°C]	20,0	20,0	20,0
Ps.in [Pa]	2337,0	2337,0	2337,0
Pr.in[Pa]	1519,0	1519,0	1519,0
RH.in %	65,0	65,0	65,0
T.out [°C]	2,0	3,0	3,0
Ps.out [Pa]	705,3	757,4	757,4
Pr.out [Pa]	606,5	681,6	651,4
RH.out %	86,0	90,0	86,0

Table 5. The trend of vapour pressure and saturation vapour pressure in external extreme conditions



	C7	C8	C9
T.in [°C]	20,0	20,0	20,0
Ps.in [Pa]	2337,0	2337,0	2337,0
Pr.in[Pa]	1519,0	1519,0	1519,0
RH.in %	65,0	65,0	65,0
T.out [°C]	5,0	5,0	6,0
Ps.out [Pa]	871,9	871,9	934,6
Pr.out [Pa]	784,7	749,8	841,2
RH.out %	90,0	86,0	90,0

Table 6. The trend of vapour pressure and saturation vapour pressure in external extreme conditions



	C10	C11	C12
T.in [°C]	20,0	20,0	20,0
Ps.in [Pa]	2337,0	2337,0	2337,0
Pr.in[Pa]	1519,0	1519,0	1519,0
RH.in %	65,0	65,0	65,0
T.out [°C]	6,0	7,0	7,0
Ps.out [Pa]	934,6	1001,3	1001,3
Pr.out [Pa]	803,8	901,2	861,2
RH.out %	86,0	90,0	86,0

Those are conditions rapidly variable and therefore characterized by limited frequency, for this reason they can not be directly applied to the method of Glaser, where there is, instead, an explicit reference to average values. But, considering that the average daily values of monthly external conditions have led to incorrect predictions (the condensate has then been formed), we proceeded considering the nocturnal winter average . This values have then been compared with the external limit conditions. From this survey it was found that the average conditions at night will be better than the extreme conditions. Therefore, maintaining constant internal standard conditions, the average external climatic conditions (both day and night) can not have provoked critical issues.

Below the nocturnal winter average (table 7 and 8).

Table 7. The average external conditions during the night

	January	February	March
T.out [°C]	6,9	7,1	9,1
Ps.out [Pa]	994,5	1008,2	1155,2
Pr.out [Pa]	853,3	802,6	970,4
RH.out %	85,8	79,6	84,0

Table 8. The average external conditions during the night

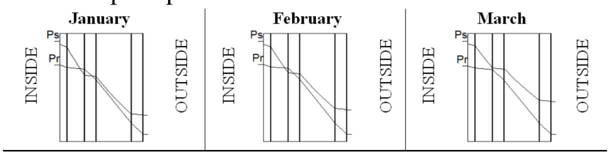
	October	November	December
T.out [°C]	15,2	13,4	9,5
Ps.out [Pa]	1726,5	1536,6	1186,8
Pr.out [Pa]	1338,0	1253,8	942,3
RH.out %	77,5	81,6	79,4

At this point, we proceeded speaking about internal conditions, assuming that they were the main responsible for what occurred.

Thereby, maintaining constant the external conditions (winter average according to legislation) and the internal temperature (20 °C), we carried on by varying first the internal relative humidity.

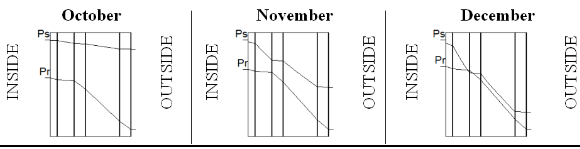
During the colder months there is a risk of interstitial condensation when the indoor relative humidity reaches 85% (table 9 and 10). It is a condition that can occur in cases of overcrowding or in environments with high humidity due to the activities that take place there (bathrooms, kitchens).

Table 9. The trend of vapour pressure and saturation vapour pressure with 85% of internal RH



	January	February	March
T.in [°C]	20,0	20,0	20,0
Ps.in [Pa]	2337,0	2337,0	2337,0
Pr.in[Pa]	1986,4	1986,4	1986,4
RH.in %	85,0	85,0	85,0
T.out [°C]	10,3	10,8	12,8
Ps.out [Pa]	1252,2	1294,7	1477,5
Pr.out [Pa]	973,0	923,1	1010,6
RH.out %	77,7	71,3	68,4

Table 10. The trend of vapour pressure and saturation vapour pressure with 85% of internal RH



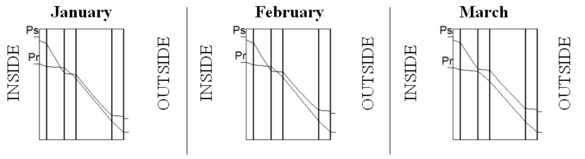
	October	November	December
T.in [°C]	20,0	20,0	20,0
Ps.in [Pa]	2337,0	2337,0	2337,0
Pr.in[Pa]	1986,4	1986,4	1986,4
RH.in %	85,0	85,0	85,0
T.out [°C]	19,4	15,5	11,7
Ps.out [Pa]	2251,6	1760,1	1374,3
Pr.out [Pa]	1508,5	1258,4	1151,7
RH.out %	67,0	71,5	83,8

During the night, the temperature of the buildings is typically kept lower than the daily value, in the case of those public because usually unused, in the case of residential ones because the temperatures of wellbeing in the bedrooms is lower than 20 °C. It is well known that, as a result of the temperature decrease, the saturated vapour pressure decreases; consequently, the percentage of relative humidity increases , even without variations in the pressure.

It was then analyzed the trend of the pressure, considering the nocturnal average external conditions, the internal temperature of 16 °C and the relative inside humidity upper to the conditions provided for by law.

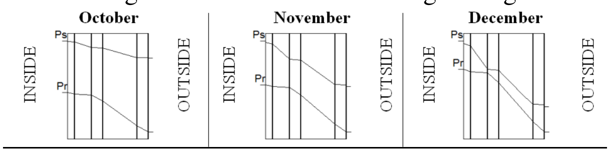
Also in this case, there is the presence of risk of formation of interstitial condensation in the colder months when the indoor relative humidity reaches 85% (table 11 and 12).

Table 11. The trend of vapour pressure and saturation vapour pressure with 16°C of T.in, 85% of RH.in and average external conditions during the night



	January	February	March
T.in [°C]	16,0	16,0	16,0
Ps.in [Pa]	1817,3	1817,3	1817,3
Pr.in[Pa]	1544,7	1544,7	1544,7
RH.in %	85,0	85,0	85,0
T.out [°C]	6,9	7,1	9,1
Ps.out [Pa]	994,5	1008,2	1155,2
Pr.out [Pa]	853,3	802,6	970,4
RH.out %	85,8	79,6	84,0

Table 12. The trend of vapour pressure and saturation vapour pressure with 16°C of T.in, 85% of RH.in and average external conditions during the night.



	October	November	December
T.in [°C]	16,0	16,0	16,0
Ps.in [Pa]	1817,3	1817,3	1817,3
Pr.in[Pa]	1544,7	1544,7	1544,7
RH.in %	85,0	85,0	85,0
T.out [°C]	15,2	13,4	9,5
Ps.out [Pa]	1726,5	1536,6	1186,8
Pr.out [Pa]	1338,0	1253,8	942,3
RH.out %	77,5	81,6	79,4

5 Analysis of possible intervention strategies

The analyzes carried out have confirmed the fact that the formation of interstitial condensation is mainly due to incorrect control of indoor climate conditions, especially to the excess of indoor humidity.

The control of temperature and humidity can be managed with three basic strategies:

1. natural ventilation;
2. mechanical dehumidification;
3. heating system.

These strategies must be selected and combined on the basis of a careful and aware analysis of the internal and external climatic conditions, of the type of use (public, private), of the use momentary (ex. crowded conditions), the time of day.

The analysis of the strategies must always be supported by the respect of the minimum conditions of well-being, for the type of use and for the type of room, according to bioclimatic diagrams.

In cases of high indoor humidity due, for example, to overcrowded (meeting room) or sanitary use (shower) or other activities (kitchen), an immediate solution could be the opening of windows in order to trigger the natural ventilation which ensures the air changes. The evaluation of the appropriateness of the application of this strategy should be set considering several variables:

1. time of the year (currently we focus on the heating period);
2. the time of day; indeed during the night, in the winter is not advisable to open the windows because it is likely that the outside temperatures are very low and humidity is high;
3. the type of use, in fact, not all uses allow to open the windows;
4. the collection of internal and external data of humidity, temperature, wind direction and wind speed, indeed, even during the day, may experience weather conditions that compromise the natural ventilation.

The data obtained from measurements of intensity and direction of wind are a fundamental aspect, because an excessive intensity and inconstancy can not be used for natural ventilation. The ideal would be a constant breeze, characterized by a moderate average speed (1,5 to 3 m / s).

If the wind is less than the breeze, it can trigger the ventilation thanks to the pressure difference between the opposite sides (cross ventilation). In the case in which, for the planimetric conformation and arrangement of the openings, it is not possible to trigger the cross ventilation, it can still be used for the air exchange also the opening of the single-window, which takes a longer time.

The next collection of internal and external climate data allows to verify if the strategy is appropriate to the case.

Only if, after the analysis of all these variables, it is concluded that natural ventilation is not the proper strategy, you may decide to intervene with dehumidification done through mechanical systems of ventilation.

The other condition which can lead equivalence between vapor pressure and the saturated vapor pressure is the lowering of the internal temperatures.

In this case, the immediate solution should be the use of the air conditioning system. However, this strategy in some cases may not be appropriate. We must then conduct an analysis based on the variables previously seen with further clarifications

The fact that the temperature is below the 20 °C normally expected for hygrothermal assessment could have various reasons:

1. The building is not occupied, it is therefore not appropriate to use the air conditioning system, but the dehumidification system. The natural air changes are not applicable because they presuppose the presence of a person or the installation of mechanical opening systems.
2. The risk of condensation is detected during the night in the bedroom and in such rooms the temperature of well-being is lower than 20 °C. Also in this case it is appropriate to use the dehumidification system. The natural air changes are not applicable because they presuppose the opening of the windows during the night.

It should be noted that the sudden lowering of the temperature can also be caused by an incorrect behavior of the user, for example by prolonged opening of windows for securing the necessary air changes, in case the outside temperatures are very low.

6 The management of intervention strategies

6.1 The study of an intelligent model for hygrothermal behavior management

The combination of the described strategies can be complicated and the average user, due to lack of knowledge of the subject or to negligence, are not always able to manage it properly.

It is proposed, therefore, the study of an intelligent system applied to building behavior[8]. In particular, it can assess when you can use passive systems, for the regulation of the internal conditions, and when it is necessary to integrate them with mechanical systems to control humidity and temperature. The core of this system are the intelligent models that are able to interpret the information obtained from the use of sensors, for monitoring internal and external conditions, and, with the analysis of the input data and design data, guide the user in managing a hybrid system (combination of passive and mechanical systems), evaluating what is the correct strategy to use to avoid condensation in the envelope elements.

Overall, the system must be able to perform the following actions:

1. real-time data collection of temperature, pressure, relative humidity, internal and external, and external ventilation;
2. analysis of the pressure and signal of the presence of risk of interstitial condensation;
3. choice, through an intelligent model, of the best solution to solve your problem;
4. sending to the user of a signal that communicates the action which is to be implemented;
5. verification of the effectiveness of the solution implemented.

This intelligent system is most effectively applied if supported by a user manual, which explains in simple way the rules to follow to enhance the performances of these buildings characterized from the envelope well insulated and increasingly airtight, helping the same user in the interpretation of the signals sent by the system.

6.2 Data collection and positioning of sensors

Is provided the use of sensors for the collection of internal and external climatic data, temperature, pressure and relative humidity, and direction and intensity of the wind, in order to perform the verification of the hygrothermal behavior of opaque elements of the building.

As regards the collection of the external data, will be used a single sensor positioned on the north side of the building, at a minimum height of 2 meters, in an area constantly in shadow. It is indeed necessary, to have reliable indications on the outside temperature, that the sensor does not absorb solar radiation and is not positioned close to the elements characterized by high absorption capacity.

Moreover, the placement of the detectors in the north and in a shaded area is further recommended, because usually the building elements with this exposure present the greatest risk of the formation and accumulation of condensation. The elements mainly sunny, in fact, not only are subject to less condensation, because of the higher temperature which characterizes their layers, but, in the case of condensation, this would evaporate more easily during the summer season.

The collection of climate interiors data must be made in several places. It should be appropriate to choose the rooms exposed to the North and those in which it is expected to be greater internal relative humidity (bathrooms, kitchens, rooms crowded as meeting rooms).

The data collection in each specific time interval is useful especially in the first period of experimentation of the system, also to understand (given the conditions internal and external), if you are implementing correct strategies, what are the best strategies and, after how many minutes of running, the passive systems affect indoor climatic conditions.

All data collected and analyzes conducted in the first period will also be useful for the preparation of the user manual.

7 Conclusions

The next stage will consist in the study of intelligent network to find connections and logical connections between the data collected by sensors, the analysis of the trend of pressure, the conditions of use and the strategies to be adopted.

The purpose is to ensure at any time the full state of healthiness of the environments, while varying environmental conditions (both internal and external), to avoid the formation of condensation and mold on the envelope.

Here then, where, as we have said, the only action of the users of the building is not sufficient for the proper management of the internal ventilation, it is evident how the aid of an intelligent network that, by exploiting the real-time monitoring climate data, signals the need to open a window rather than to start an automatic climate control, can be a valuable tool to support users of the building, as well as to the healthiness of the building itself.

Such a system could be easily applied both in residential buildings and public (offices, public places), ensuring, in the face of initial expense increased by the installation of an intelligent network, the optimization of resources for the management and maintenance of the building itself.

The possibility to mechanize the management of indoor climatic conditions appears, therefore, in line and perfect harmony with the natural tendency towards intelligent buildings, which can improve the quality of life, both for the building and its users. [9][10]

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