67. Building envelope and preventive conservation.

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Abstract The results of an environmental assessment made at the Protocol Archive of the Association of Notaries of the Province of Buenos Aires, Argentina, showed the opportunity of taking advantage of using the building´s characteristics to improve preventive conservation of documents. To demonstrate this association, a correlation test is performed using 33 study cases, where temperature and relative humidity monitoring was performed for a year. Firstly, indicators to assess the performance of the wards, called dependent variables are explained; then are calculated for each case these factors: heaviness or mass, attachment, transparency and thermal transmittance weighted, called independent variables. Conclusions show that adding these design variables to the existing recommendations for the design of new conservation spaces, or taking advantage of the natural properties of the envelope, hygrothermal quality might be improved, in addition to the reduce of energy demand on heating and cooling.

Keywords Libraries, Cultural Heritage, Preventive Conservation, Passive Design

1 Introduction

In the frame of an agreement between the Laboratory of Architecture and Sustainable Habitat (LAyHS) and the Notaries Association of the Province of Buenos Aires (ColEscBA), it was performed a study to deep in the environmental behavior of a new construction regarding of the parameters of paper conservation. LAyHS develops the research project U143 Contingency plan for libraries, archives and museums towards climate change; and U141 Certification of sustainability for buildings for the adaptation and mitigation of climate change; financed by National University of La Plata between 2014 and 2018. In this context, an assessment program is made on the behavior of one single kind of envelope. The ColEscBA has the mission of keeping custody and conserve the protocol volumes, dating from 1778.

Temperature, relative humidity, illumination, among others, are agents of decay that must be controlled in environments where the materials kept inside are unique and valuable, because both extreme values as oscillations in short periods of time favor degradation. Environmental monitoring is a measure that allow verifying if those variables rely inside the safe ranges for conservation or if corrective measures must be taken.

The conclusions of that study showed e clear influence of the effect of the mass of the envelope on the interior microenvironment. That finding motivated the study of other physical influencing factors that may be used as a profit, facing the design of buildings for conservation using passive measures of air conditioning.

2 Study Case: the Protocol archive of ColEscBA

The Protocol Archive of ColEscBA is located in the suburbs of La Plata City, with latitude 34.8 South, the City has warm summer ($t_{máx}$med= 28.5°C) and mild winters ($t_{mín}$med= 6.7°C) with high ambient humidity (RH= 71 y 86%). Maximum design temperature is 35.5°C (percentile 99% IRAM 11603) and minimum design temperature for winter is -2.4°C (percentile 1% IRAM 11603). The 71% of a statistical year, medium temperature is below level of comfort.

The building sector destined to the archive consist of four warehouses of 1878 m^2 connected by a lateral corridor and does not have HVAC system. The envelope is light: sandwich panel in the roof and cellular concrete on the external walls. The openings, made of aluminum with simple glassing, are placed higher than the shelves with the objective of avoiding the incidence of direct light in the spine of the protocols.

To calculate the thermal transmittance of the envelope and then compare it with the reference parameters of winter design temperature the IRAM standards 11601 and 11605 are used (IRAM, 2002, 1996). Also, the mass of the envelope is calculated to determine the potential energy accumulation. Result show that the envelope is light: the mass for walls and floor is 153 y 774 Kg/m^2 respectively. The floor was filled with rough, increasing its mass to 3330 kg/m^2; the thermal transmittance is low, level A of IRAM Standard 11605.

Following international monitoring protocols (UNI, 1999, 1997) an environmental monitoring campaign is addressed in four periods of a year to observe results under different exterior climatic conditions. In the essay the results commented belong to the summer period. Onset dataloggers (DL) are set, and configured to register and record temperature (T) and relative humidity (RH) each 30 minutes. After 30 days, DL are collected and downloaded and process in a computer. The instruments are Hobo U10-003 temp/rh; Hobo U12-012 Temp/RH/light/ext; Hobo U23-001 temp/RH with an accuracy of +/-2.5% y +/-0.35°C.

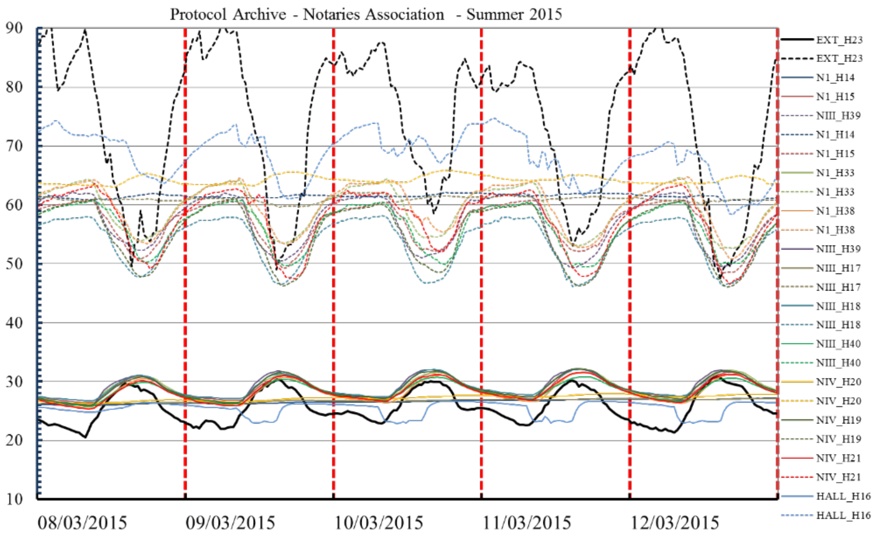

Fig. 1 A course of 5 days in summer

Figure 1 shows a temporal axis in which each line represents one evaluated variable. RH lines are drawn with dashed lines, and T lines with continuous lines. Each color represents the same sensor. The figure shows a detail of the summer period when inner temperature is higher than the exterior, even at nights when temperature decays 5°C.

In the interior of the warehouses, sensors 14 and 17, placed at 0.60m above level, suffer the effect of the pavement mass that reduces dispersion of temperature, stabilizing also relative humidity.

No significative differences are observed between sensors placed on the east zone and west zone, besides the delay produced by the different hours or radiation. It is observed that on summer, inner temperature is higher than ideal for a conservation deposit, the minimum T registered is 24°C, and RH is most of the time inside de expected range, between 50 and 65%. Thermal inertia given by the accumulation mass of the ground to the inner environment is an asset to take in consideration in the construction of new deposits, to add in perimeter walls or internal partitions. The need of implement a night ventilation system to take profit of the inner outer temperature difference becomes evident (Diulio et al., 2015).

3 Description of the study

To detect the main influencing characteristics on the conservation microclimate it is necessary to define indicators that allow establish environmental quality levels. These indicators are obtained from the annual hygro-thermal monitoring of 33 rooms in 11 libraries in La Plata, Argentina. Then, according to the performance found in each room through the annual monitoring, a value between 0 and 1 is determined, indicating the similarity respect of the ideal T and RH for conservation.

Variables related to the type of construction are associated to the effect of mass, attaching, transparency and thermal transmittance. Finally, a method of association is proposed to stablish dependence relationships between morphologic variables and hygro-thermal performance obtained.

3.1 Dependent variables

3.1.1 Position index

Position index express the ratio between the records with T and RH inside de conservation range adopted to that particular room and the total amount of records in the period (Corgnati et al., 2009; Corgnati and Filippi, 2010). The concept of positions comes from the location of the obtained records respect the reference values.

$$PoI = r_{cons} / R \qquad (1)$$

Where PoI represents the position index; r_{cons} are records that meet the condition; and R is the total amount of records in the period.

3.1.2 Resilience index

Using as input the data files obtained by the environmental monitoring, the variation of T and RH in a unit of time is calculated. Resilience index (Eq. 2) indicates the ratio of days where daily amplitude of T and RH is less than the maximum allowed and the total amount of analyzed days (Diulio and Gómez, 2014).

$$RI = d_{cons} / D \qquad (2)$$

Where RI represents the resilience index; d_{cons} the days of monitoring when the amplitude met the conservation condition; and D, the total amount of monitoring days.

3.1.3 Performance index

The performance index (Eq. 3) can be use to assess the hygro-thermal behaviour of a conservation environment as it incorporates the two main criteria that, according to the corpus, every space for conservation should attend: keeping T and RH between an adopted range, and keeping the daily amplitude below the maximums admitted.

$$PI = (PoI+RI)/2 \qquad (3)$$

3.2 Independent variables

The independent variables are those building characteristics that are studied under the hypothesis that they are capable to influence the inner hygro-thermal behaviour of the environments.

3.2.1 Heaviness or mass

This physical characteristic depends on the constitutive elements of the enclosure and the structure of the building. It is calculated as the mass of the surface of the building divided by the surface of the envelope of the building (Eq. 4), that means that is an average of mass by square meter of enclosure.

$$H = M/S \qquad (4)$$

Where H represents he heaviness, expressed in Kg/m^2; M is mass, expressed in Kg; and S is the Surface, expressed in m^2.

The law of masses indicates that the increase of heaviness implies a better acoustic insulation from the exterior, and a better thermal inertia, and buffer of the variations of the exterior condition. This composition is adequate for continental weather with grand thermal range.

3.2.2 Attachment

The attachment indicates the degree of contact of the external walls of the building with joint constructions. It is calculated as the ratio among the surface attached to joint constructions divided by the global surface of the enclosure (Eq. 5).

$$AT = S_{at} / GS \qquad (5)$$

Where AT represents the attachment coefficient, S_{at} the attached surface; and GS is the global surface of the enclosure.

Pavement´s thermal inertia work as a protection to the building, reducing the impact in external changes. An attached building can work similarly, the sided volume may be conditions, reducing loss trough the envelope. For the same reason is hard to receive solar radiation and generate natural ventilation flows. Is useful in cold and dry climates (Serra Florensa and Coch Roura, 2001, p. 251).

3.2.3 Transparency

The coefficient of transparency (Eq. 6) quantifies the entrance of solar radiation. This indicator represents the proportion of glassing surface over the global surface of the enclosure.

$$TR = TS / GS \qquad (6)$$

Where TR is the transparency coefficient, TS is the transparent surface and GS the global surface.

Increased transparency generates a significantly greater ability to naturally iluminate a room. Glass is a good driver of sound waves, thus a glassed surface permits noise input from the exterior. The transmission of heat through a transparent surface heats the interior volume, and the reflection changes its length wave so it cannot re-cross the glass, creating greenhouse effect.

3.2.4 Weighted thermal transmittance

It is the ability of the envelope to allow the passage of energy through its thickness. This flux is measured in watts (W) per square meter of surface, for every Kelvin of difference of temperature between inside and outside. As the global envelope is an addition of different types of constructions, a weighted thermal transmittance is calculated, proportioned by the surface of each material over the complete global surface.

$$K\ W/(m^2\ K) = 1/R_{total}\ (m^2\ K)/W \qquad (7)$$

With the K value of each type of construction (Eq. 7) the weighted K is calculated, or thermal transmittance coefficient (Eq. 8):

$$K_{pond} = \Sigma\ [(KT_1*ST_1) + (KT_2*ST_2) + (KT_3*ST_3) + (KT_n*ST_n)]/S_{GLOBAL}\ (m^2) \qquad (8)$$

In this equation, KT_1 to KT_n is the thermal transmittance coefficient (K) of each one of the construction types; ST_1 to ST_n is the surface of each construction type; and S_{GLOBAL} is the global surface of the enclosure.

Elements with low thermal transmittance inhibit the income of heat in summer, and avoid heat loss in winter, that is why a good, low, thermal transmittance is desirable in extreme weathers, and in the less favored orientations.

4 Results

Correlation tests are performed by placing the dependent variable values (mass or heaviness, attaching, transparency, thermal transmittance) of each one of the 33 cases in the X axis of a Cartesian system, with Y values corresponding to the dependent variable values obtained (position, resilience, performance).

When the distribution of the sample is linear, the force of association can be measured by the R^2 coefficient or determination coefficient. The R^2 takes values between zero and 1 for positive sloping and -1 and 0 for negative sloping. The results with greater absolute values (-1 or 1) show a stronger degree of association and allow to discard the null hypothesis: the variables are independent.

4.1 Relation between heaviness and performance

This simple lineal regression test showed a positive weak linkage between the heaviness of the enclosure and the variables that explain performance (Fig. 2).

Of the 14 cases where the performance index is 0.6 or superior, 12 have envelopes with an average weight is bigger than 400 Kg/m^2, which sets a precedent for associating the average weight of the envelope with performance. Beyond 400 Kg/m^2 no tendency is observed and the lineally of the function gets lost, thus there is no point on add more mass to the enclosure because it does not affect the inner climate.

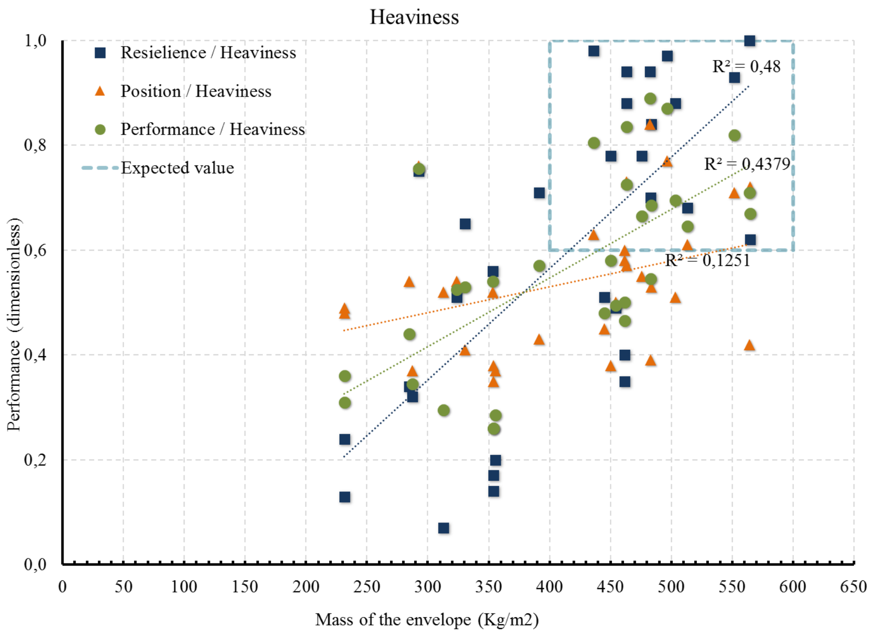

Fig. 2 relation between heaviness and performance index

4.2 Relation between attaching and performance

This regression test is made with the hypothesis of proof the existence of dependence among the attaching degree of the monitored rooms and their hygro thermal behavior (Fig. 3). In the case of the variable "attaching" it was observed that it did not influence in the position index (R^2=0.15), while there is influence respect of the resilience index, or capacity of reducing T and RH oscillations (R^2=0.61). The performance index achieves the determination coefficient value of 0.56.

67% of the sample is constituted by rooms with more than 50% of their envelope surface attached to another room. Less than half of these rooms has a position index bigger than 0.60 (dependency is weak); but 73% has a good resilience index superior to 0.60, and as the R^2 is high, it permits to predict a suitable behavior in rooms with these characteristic.

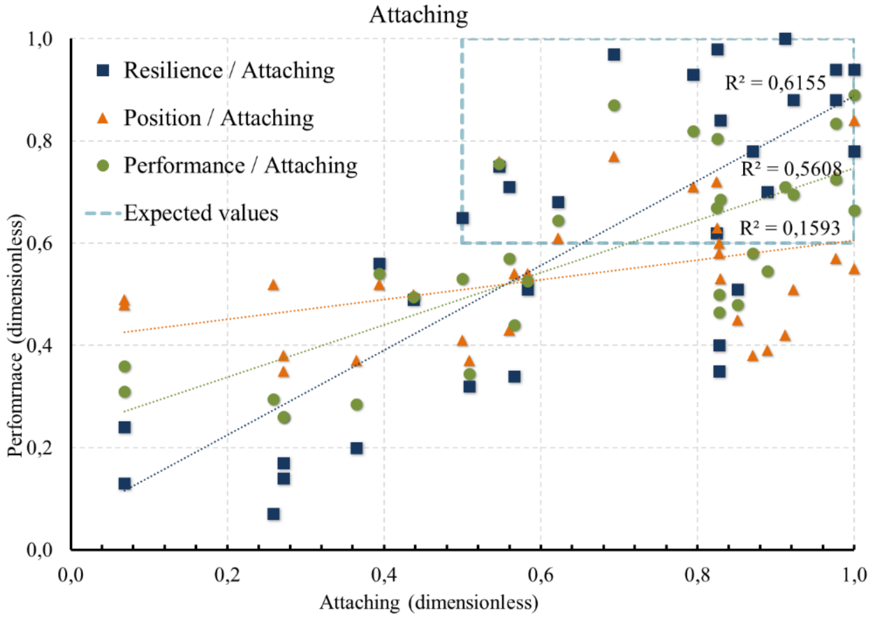

Fig. 3 relation among attaching and performance index

4.3 Relation between transparency and performance

This test has the aim of measure the dependency among the proportion of exterior glassed envelope of the rooms and their hygro thermal performance. The hypothesis is that buildings whom envelope have a big proportion of transparent panels have a deficient hygro thermal performance.

Fig. 4 shows that in position index the incidence of the transparency is weak (R^2=-0.25), that is does not influence on reaching a better hygrothermal standard while there is a moderate dependence (R^2= -0.51) of negative slope on the resilience index. That means that as the transparent panels are bigger respect of the global surface of the envelope, the daily amplitude for T and RH is also bigger and the resilience decays.

No room with exterior glassed surface ratio bigger than 6% has a performance index greater than 0.60. The entire rooms exclusive for documents deposit have less than 5.3% for transparency ratio and performance index from 0.65 onwards. Rooms with more than 10% of transparency ratio are the 21% of the sample and they are for personnel use or for users, or mix uses.

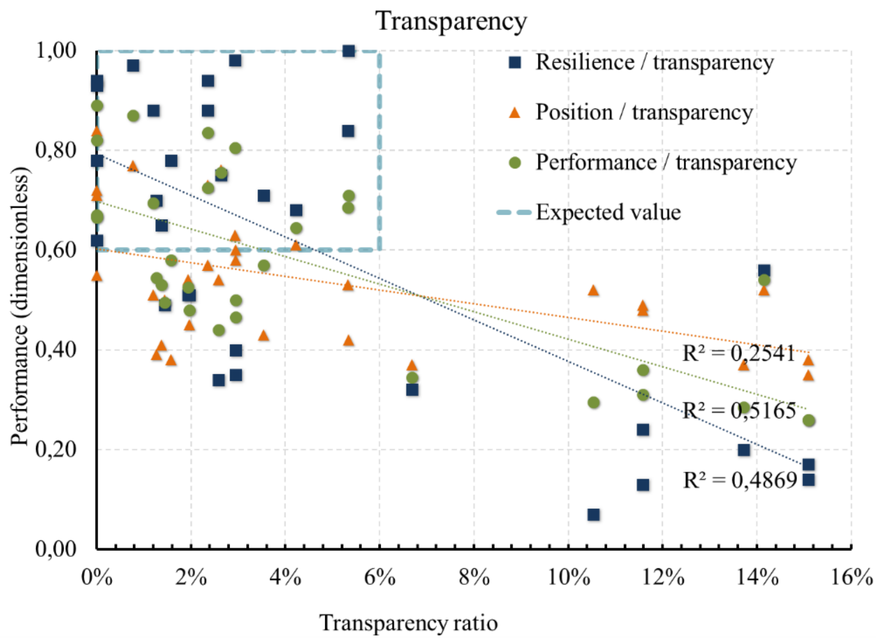

Fig. 4 Relation between transparency and performance

4.4 Relation between weighted thermal transmittance (K´) and performance.

The determination coefficient that links K´ and the variables that represent performance is negative, it means, as K´ increases, performance decays.

Of the 20 cases with a K´value less than 1.70 W/m^{2}K, the 65% obtains a performance index over 0.6, 55% has a resilience index over 0.60 and 45% has an even bigger value for position index.

For a level B of the IRAM 11605 Standard in La Plata, maximum thermal transmittance is 0.95 W/m^{2}K for walls and 0.77 W/m^{2}K for roofing (IRAM, 1996). Stating that there is a moderate dependence on the hygro thermal performance against the weighted thermal transmittance of the envelope, we can infer that the adaptation of enclosures to current legislation, not only allows rational use of energy in air conditioning, but improves the hygro- thermal quality of conservation areas, increasing life expectancy of materials.

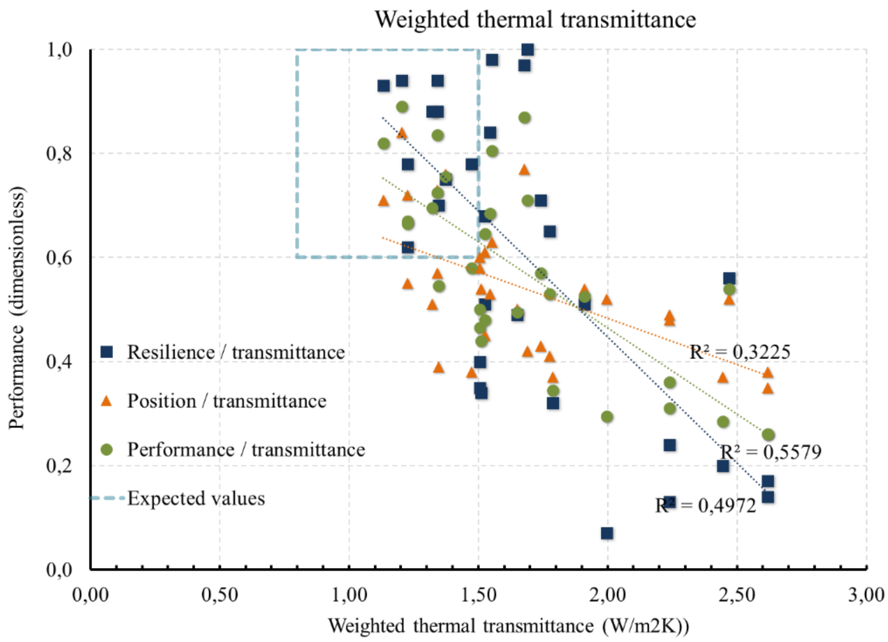

Fig. 5 Relation between weighted thermal transmittance and performance index

5 Conclusions

Aiming to associate a series of building structures to different degrees of hygro-thermal performance, a series of correlation tests were performed with measurements from the ColEscBA and 33 rooms from 11 libraries in La Plata, Argentina, reaching to the following conclusions:

1. The test performed on heaviness show a better performance in buildings with a mass of 400 up to 600 Kg/m^2. Determination coefficients are higher on resilience coefficient, compared with position index and performance index. It means that when the mass is higher, the room gets easily the objective of keeping reduced the oscillations of T and RH.

2. The attachment index quantifies the proportion of enclosure surface in contact with other rooms. The relation between the developed indicators and a positive lineal relation is found, with an association strength of 0.56 (moderate) that constitutes a recommendation, as it is a significate influencing factor. In the analyzed sample, rooms with 50% of their surface attached to other room showed a better resilience index (73% with RI>0.60) respect the detached rooms.

3. Regarding on transparency, a negative linear correlation of -0.51 (moderate) on resilience index. The proportion of glass over the global surface should be limited at 6% in deposit rooms.

4. Hygrothermal performance is inversely proportional to the termal transmittance, with a moderate strength. The PoI and the RI respond to the same trend with a weaker strength of association. Better results are found in enclosures with lower K´ values, wich allow to predict that the consolidation of the shell according to the Standard demands will imply a substancial improvement in the conservation environment.

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