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Humidity Control to Reduce the Degradation Risks of Manuscripts in Necip Paşa Library Tire-İzmir, Turkey

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Abstract

The indoor climate of libraries is expected to have critical negative impacts on the conservation of books and manuscript. Therefore, paper-based collections stored in libraries can possibly face to the chemical, mechanical and biological degradation phenomena if the indoor climate shows insufficient trend with respect to the instructions given in standards or norms. In this study, indoor microclimate of Necip Paşa Library, a historic building located in Tire-Izmir, Turkey, was investigated from the perspective of preventive conservation of manuscripts. The library, which was modeled with the help of building performance simulation tool, DesignBuilder, has no heating, cooling or ventilation system. The thermo-hygrometric parameters temperature and relative humidity) were monitored via data loggers throughout one year period and later used to calibrate the building energy performance model. The measurements showed high chemical degradation risk on manuscripts from April to November. In order to reduce the degradation risks on manuscripts, two measures were proposed: humidity control (humidification and dehumidification) and natural ventilation system. The model was simulated for each measure via building energy performance simulation tool. The results of humidity control system show that the new trend of indoor microclimate of the space in which manuscripts are stored cause less risk of chemical degradation.

Keywords – preventive conservation; manuscripts; humidity control; historic library; degradation

1. Introduction

Historic buildings have housed cultural properties such as paintings, manuscripts and furniture, for ages. It is known that the collections having cultural heritage values can deteriorate in the places they have been stored or exhibited [1]. Indoor microclimate conditions of historic buildings might not be suitable for the conservation and cause irreversible deformations on such cultural properties. Therefore, conservation approaches have been improved to preserve and extend the lifespan of the collections. Conservation can be implemented with direct and indirect physical interventions which are subject to curative and preventive conservation, respectively. Curative conservation can be exemplified with the actions such as stabilization, consolidation and disinfestation while preventive conservation mainly deals with environmental monitoring and control of storage area, good housekeeping, pest management and education of staff [2]. In this study, conservation of manuscripts in a historic library will be investigated from the preventive point of view.

In the literature, studies which investigated preventive conservation of paper-based collections mainly comprise the mechanical, chemical and biological degradation phenomena [1-3]. The manuscripts that constitute the collections show reactions to temperature (T) and relative humidity (RH), which might trigger the degradations. Mechanical degradation is induced mainly due to T and RH variations, which in turn causes dimensional alterations, shrinking and swelling. Chemical degradation, which is highly dependent on the amount of moisture content in hygroscopic materials, might cause discoloration in papers and deterioration in text. Besides, it is known that chemical processes slow down at low temperatures. Biological degradation is associated with T, RH and substrate. Due to the natural hygroscopic properties of paper, manuscripts can be referred as a good source of nourishment for mould. The existence of these parameters in optimal critical conditions over a certain time stimulates the mould growth. In order to avoid the degradations, thermo-hygrometric parameters of indoor microclimate (T and RH) need to be controlled according to the given instructions [2,4,5]. With the developing technology, novel climate control systems are frequently implemented in historic buildings to provide suitable indoor environment in preventive conservation manner.

The motivation for conducting this study is to find ways to preserve the manuscripts in Necip Paşa Library, Tire-İzmir, Turkey. The library contains 1156 manuscripts, 1312 books printed in the era of Ottoman Empire and more than 9000 books in Latin letters [6]. Necip Paşa Library has no HVAC system in the main hall and is naturally ventilated by opening the windows and doors (Fig 1). The manuscripts are separately preserved in a cage-like-structure which was made out of wooden shutters and has an octagonal shape (Fig 1). The manuscripts are kept in free-floating microclimate. Results of the preliminary study run in the historic library indicated that the indoor microclimate might cause chemical degradation risk for the manuscript while almost no mechanical and biological risks were observed [7].

The aim of this study is to decrease the chemical degradation risk of manuscripts in Necip Paşa Library by introducing two measures which are humidity control and natural ventilation systems with the help of building energy performance simulation (BEP) tool, DesignBuilder [8]. Later, the simulation results of both measures will be compared.

2. Necip Paşa Library

Necip Paşa Library is a historic library, situated in Tire, Izmir-Turkey. The library was built in the beginning of second quarter of the nineteenth century, has a main hall, an entrance and a manuscript zone which is located inside of the main hall (Fig 1). The library lies on north-south direction. The thickness of external walls change between 1.08 and 1.25 m. The dome shaped roof was constructed with lead covered brickwork. All windows of the library were single glazed with wooden frames. The main hall and manuscript zone have no HVAC system, while an air conditioner heats and cools the entrance where administrator's office is located. The main hall and manuscript zone receive a small number of visitors on weekdays (Fig 1).

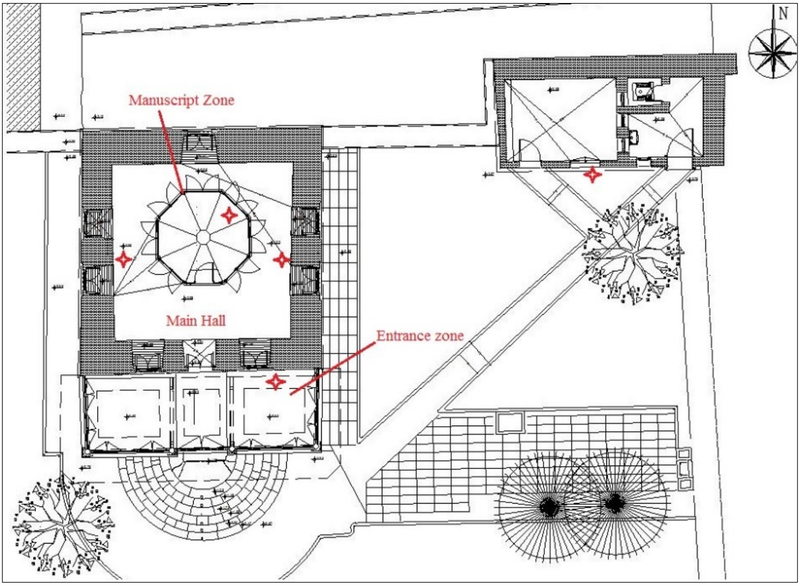

Fig 1.Schematic view of *Necip Paşa Library*

3. Methodology

In this study, the effect of humidity control and natural ventilation control systems on reducing the chemical degradation risk of manuscripts stored in *Necip Paşa Library* will be investigated. The flow diagram of the methodology is given in Fig 2.

3.1. Measurements

Indoor and outdoor microclimates of *Necip Paşa Library* were monitored via automatic sensors from 1 September 2014 to 31 August 2015. Five data loggers, which record data with ten minutes intervals, were used to measure T and RH during one year period. Four of them were placed inside of the library while the last one was placed to outside. Locations of the data loggers are given in Fig 1.

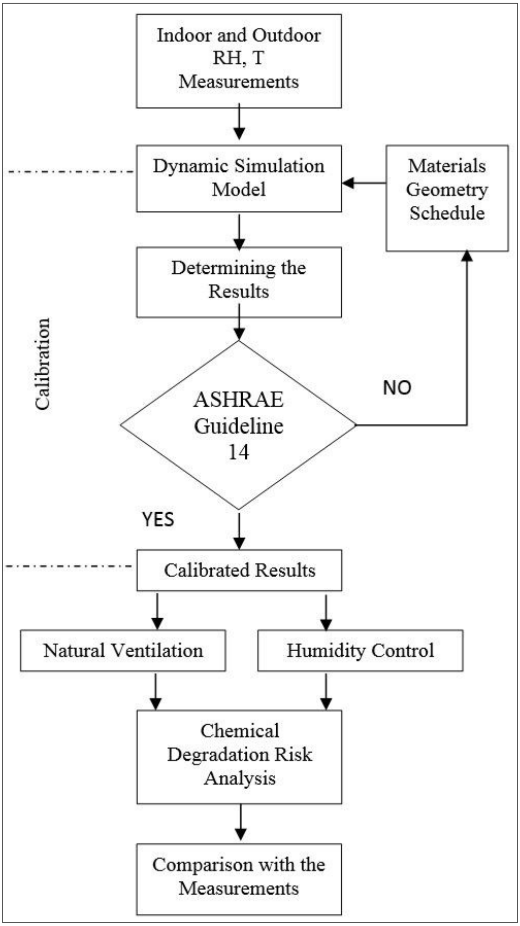

Fig 2. Methodology

3.2. Modelling and Calibration

The building was modelled by using a BEP tool, DesignBuilder (v 4.2.054). Three zones, which are given in Fig 1, were defined for the BEP model. The library lies on north-south direction and was built 1.5m above from ground. Airtightness value for the library was measured by blower door and found as 0.5 h^{-1}. The thickness of external walls, which consist of limestone and brickwork, changes between 1.08 and 1.25 m. The overall heat transfer coefficients are 1.64 W/m^2K, 1.76 W/m^2K and 1.89 W/m^2K for the south/north, west and east wall, respectively. The roof had a shape of dome, was constructed a lead covered brickwork with the heat transfer coefficient of 1.51 W/m^2K. All windows were modelled as wooden frame single glazing, of which heat transfer coefficient is 5.89 W/m^{2}K. The sections of ground floor for the manuscript zone and main hall are almost same while their heat transfer coefficients are 1.24 W/m^{2}K and 1.38 W/m^{2}K, respectively.

a) b)

Fig 3. a) South façade and b) BEP model of *Necip Paşa Library*

Then, the weather data (T and RH) obtained from the outdoor measurements was integrated into the model. Measured hourly T and RH data was compared with simulation results to calibrate the BEP model according to ASHRAE Guideline 14 [9]. Two dimensionless error indicators which are coefficient of variation of root-mean-square error (CV(RMSE)) and mean bias error (MBE) were calculated with (1) and (2), respectively [10]:

$$MBE = \frac{\sum_{i=1}^{N_i}(M_i - S_{i)}}{\sum_{i=1}^{N_i} M_i} \tag{1}$$

$$CV(RMSE) = \frac{\left[\left[\frac{\sum_{i=1}^{N_i}[(M_i - S_i)^2]}{N_i}\right]\right]^{\frac{1}{2}}}{\frac{1}{N_i}\sum_{i=1}^{N_i} M_i} \tag{2}$$

where M_i is measured data, S_i is simulated data at instance i, N_i is the number of used data. According to ASHRAE Guideline 14, BPS models can be assumed calibrated if CV(RMSE) and MBE values calculated based on hourly measurements are below the thresholds 30% and 10%, respectively. In order to finalize the model calibration, input parameters were tuned until the MBE and CV(RMSE) values reasonably satisfy the threshold values. Only the input parameters related with thermal properties of the building envelope and infiltration rate were changed during the calibration process while the building orientation, geometry, areas and dimensions of all envelope surfaces were untouched.

3.3. Simulation (humidity control and natural ventilation)

Humidity control and natural ventilation systems were introduced to the BEP model. Both systems were designed taking into account of the preliminary results which point out that the manuscripts are under high risk of chemical degradation between the dates April 15 and November 1 (Fig. 4). Chemical degradation risk was investigated by the parameter named Lifetime Multiplier (LM) which corresponds to the number of time spans an object remains usable when compared to indoor climate of 20 °C and 50 %RH [4,5]. LM values below 0.75 and over 1 refer to high and low risk, respectively while those are in between correspond to medium risk of degradation [5]. In order to make a general statement over the LM results, an equivalent value (eLM) that represents the average of reciprocal values of LM can be used. Equation (3) and (4) can be used to calculate the LM and eLM, respectively:

$$LM_x = \left(\frac{50\%}{RH_x}\right)^{1.3} \times e^{\frac{E_a}{R}\cdot\left(\frac{1}{T_x+273.15}-\frac{1}{293.15}\right)} \tag{3}$$

$$eLM = \frac{1}{\frac{1}{n} \times \sum_{x=1}^{n} \left(\frac{50\%}{RH_x}\right)^{1.3} \times e^{\frac{E_a}{R}\cdot\left(\frac{1}{T_x+273.15}-\frac{1}{293.15}\right)}} \tag{4}$$

where E_a is activation energy (100 kJ/mol for degradation of cellulose), R is gas constant and the indice x indicates the value at instance. Table 1 gives the 5 risk levels for the interpretation of eLM values. It is stated that 5K decrement in T that is around 20 °C duplicates the lifetime for the most objects [11]. Thus, in order to reduce the chemical degradation risk, natural ventilation and humidity control systems were introduced to provide LM values within acceptable limits.

Table 1. Interpretation of the eLM values

	Ideal	Good	Some risk	Potential risk	High risk
eLM	>2.2	[1.7;2.2]	[1;1.7]	[0.75;1]	<0.75

3.4. Comparison

After obtaining the simulation results of humidity control and natural ventilation systems, LM values were compared with each other and measurements. In addition, the results were also compared taking into consideration of the indoor climate risk assessment which comprises the climate class specified in ASHRAE Chapter 21 [5].

4. Results and Discussion

4.1. Measurements

Fig 4 shows the yearly trend of manuscript zone and oudoor temperature. LM values of manuscripts were calculated using (3) and thermo-hygrometric parameters of manuscript zone and superimposed into the Fig 4 in order to better evaluate the results from the perspective of risk levels of which limits were indicated with representative colors. Therefore, LM values within the green, orange and red area indicate that the manuscripts are under low, medium and high risk of chemical degradation, respectively.

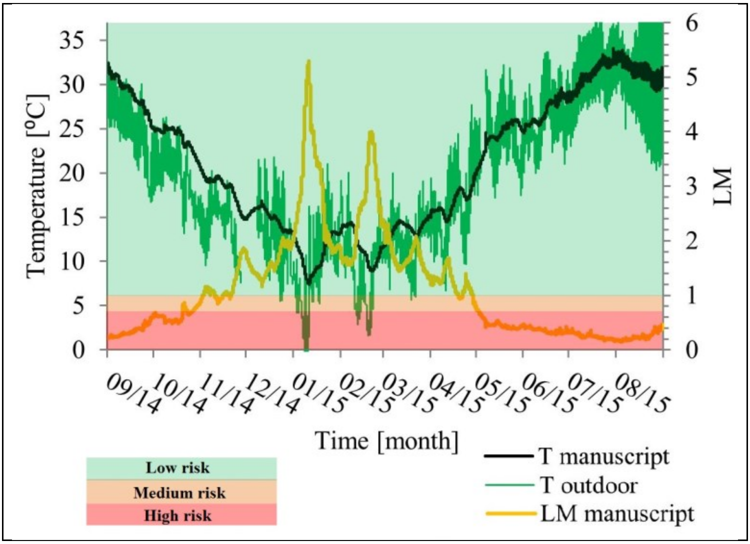

Fig 4. Results of the preliminary study

According to the results, the manuscripts are under medium risk of chemical degradation in months; November and April while high risk between May and October. Maximum and minimum temperatures, in the manuscript zone, were measured as 34 ^oC and 7 ^oC, respectively while daily T difference above 2K is 2%. Besides, the outdoor T values below the T trend of manuscript zone indicate that the library has a great cooling potential which can be benefited using natural ventilation system.

4.2. Modelling and Calibration

Table 2 gives the MBE and CV(RMSE) values which were calculated using the thermo-hygrometric parameters of hourly indoor measurements and the simulation results of one year period at the end of iterative calibration process. Hence, it can be said that the BEP model was calibrated since the both error values of three spaces were below the thresholds based on hourly measurements and satisfy the ASHRAE Guideline 14. However, one should remember that DesignBuilder is a thermal-only simulation tool, which cannot take into account the moisture transfer along with building envelope and the moisture buffering effect of manuscripts. Therefore the results should be interpretted accordingly.

Table 2. Discrepancies between the measurements and simulation results

Spaces	Temperature		Relative Humidity	
	MBE	CV(RMSE)	MBE	CV(RMSE)
Entrance Zone	5.6	15.7	1.1	16.8
Main Hall	5.3	10.2	2.6	15.3
Manuscript Zone	4.7	9.7	3.0	17.7
ASHRAE limits	10	30	10	30

4.3. Simulation (humidity control and natural ventilation)

T and RH values of the humidity control system, which only operates in the manuscript zone, were set between 15-19 ^{o}C and 45-55 %RH, respectively. For the natural ventilation system, minimum set point temperature of main hall was arranged at 15 ^{o}C while no RH control was introduced due to the capabilities of the BEP tool. Fig 4 shows that, for the given dates, it is impossible to diminish indoor T up to the minimum set value with the help of natural ventilation system while there is a cooling potential to be assessed. Thus, natural ventilation system was arranged to operate with an air exchange rate of 3 ac/h when outdoor T is at least 2K less than that of main hall which, at the same time, drives the microclimate of manuscript zone.

4.4. Comparison

Fig 5 illustrates the results of chemical degradation risk analysis of humidity control and natural ventilation systems. LM values were superimposed to make comparison of each measurements.

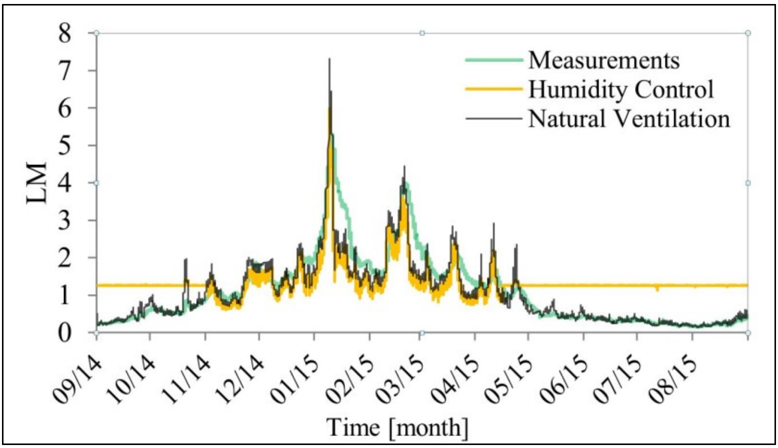

Fig 5. Comparison of the measures

For each measures, eLM values of one year performance were calculated with eqn. (4) and found as 0.54 for measurements, 1.27 for humidity control and 0.55 for natural ventilation system. Results point out that the humidity control system prevents high risk of chemical degradation throughout the risky period (April 15-November 1) while natural ventilation system introduces relatively worse solution to the library.

Fig 6 illustrates the results of indoor climate risk assessment for natural ventilation and humidity control system. The red dotted lines represent the maximum and minimum thresholds of the bandwidth which was calculated according to the ASHRAE climate class of As [5]. It is claimed that temperatures outside of the bandwidth can cause degradations on the manuscripts.

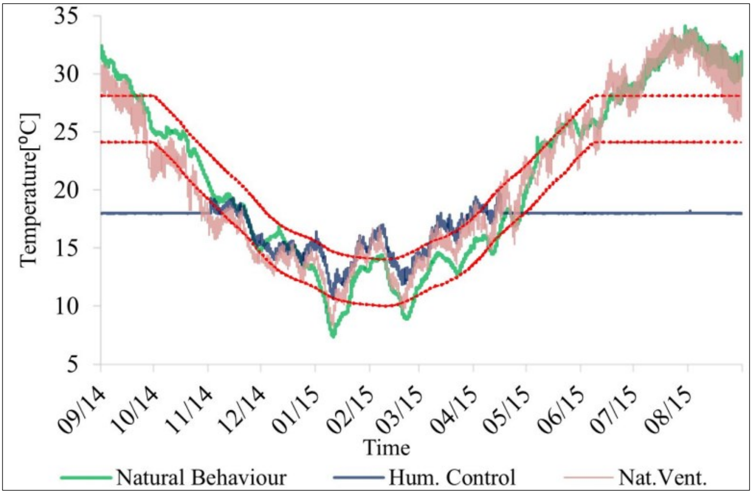

Fig 6. Comparison of the measures according to ASHRAE climate class, As

Fig 6 indicates that natural behavior of the microclimate of manuscript zone exceeded the maximum threshold around summer season. The results of natural behavior of manuscript zone show that T trend is within the bandwidth of 63% while natural ventilation and humidity control systems perform with the value of 52% and 35%, respectively.

5. Conclusions

In this study, the impact of humidity control and natural ventilation system on reducing the high risk of chemical degradation of manuscripts stored in the unconditioned historic Necip Paşa Library was investigated. According to the results, it is possible to achieve some relevant conclusions namely:

- Humidity control produces considerably more helpful solution which almost prevents high risks of chemical degradation on manuscripts. Yet at the same time, one must consider that humidity control system requires investment, operational and maintenance cost from the perspective of techno-economic efficiency.

- Installation time of the humidity control system should be considered carefully since installing it after the hot season will cause higher T fluctuations, which, in turn, might be a source of degradation.
- Distorting the natural hygrothermal behavior of the historic library with mechanical solutions might also be a source of deterioration. Therefore, before introducing heavy mechanical solutions like humidity control, priority should be given to passive architectural or light mechanical solutions, if possible.
- DesignBuilder is a BEP tool which does calculations with a thermal-only heat transfer methodology. Therefore, a simulation tool having hygrothermal (coupled heat and moisture) calculation methodology should be utilized for more reliable and accurate risk analysis of mechanical, chemical and biological degradations. Hence, MBE and CV(RMSE) values can be diminished accordingly.

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References

[1] Krüger, E.L. and Diniz, W., 2011. Relationship between indoor thermal comfort conditions and the Time Weighted Preservation Index (TWPI) in three Brazilian archives. Applied Energy, *88*(3), pp.712-723.
[2] A.E.Bülow. Preventive Conservation for Paper-based Collections in Historic Buildings, PhD thesis, (2002), De Montfort University, Leicester.
[3] K. Fabbri, M. Pretelli, Heritage buildings and historic microclimate without HVAC technology: Malatestiana Library in Cesena, Italy, UNESCO Memory of the World. Energy and Buildings 2014;76: 15-31.
[4] H.E. Silva, F.M.A. Henriques, Preventive conservation of historic buildings in temperate climates. The importance of a risk-based analysis on the decision-making process. Energy and Buildings; 2015; 107: 26-36.
[5] M.H.J. Martens. Climate risk assessment in museums, degradation risks determined from temperature and relative humidity data. PhD thesis, (2012), Eindhoven University of Technology.
[6] A.İ. Yıldırım, Tire Necip Paşa Library Catalogue of Illuminated Manuscripts, Tire (2004) (in Turkish).
[7] C.D. Şahin, Z. Durmuş Arsan, G. Gökçen Akkurt, Preventive conservation of manuscripts in historic libraries via thermo-hygrometric approach: A case study of Necip Paşa Library, Tire-İzmir, Turkey. Building and Environment (under review).
[8] Design Builder, Version 4.2.0.054. Available:
http://www.designbuilder.co.uk/component/option,com_docman/task,doc_details/gid,53/Itemid,30/ (accessed 01.02.2016).
[9] ASHRAE, Guideline 14-2002, Measurement of Energy and Demand Savings,American Society of Heating, Ventilating, and Air Conditioning Engineers,Atlanta, GA, 2002.
[10] A. Kandil, J.A. Love, Signature analysis calibration of a school energy modelusing hourly data, J. Building Perform. Simul. 7 (5) (2014) 326–345.
[11] S. Michalski, Double the life for each five-degree drop, more than double the life for each halving of relative humidity, ICOM committee for conservation, 13th triennial meeting Rio de Janeiro preprints vol. 1, pp 66-72 (2003).