An innovative passive system for preventive conservation of the ancient stained glass windows in the Assisi’s St. Francis Basilica Superior Church

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ABSTRACT

The paper describes methodology and results collected from a professional and research experience oriented to design, build up and monitor an innovative passive system for the preventive conservation of the ancient stained glass windows in the Assisi’s St. Francis Basilica Superior Church.

1. THE PROBLEM TO SOLVE

The magnificent *Corpus Vitrearum* of St. Francis' Basilica in Assisi (Italy) is one of the most important and oldest in the world, dated from the 13th century (Figs. 1 and 2). A number of windows constituted by stained glasses illustrates biblical stories and saints lives.

Ancient stained glasses are a complex mosaic of pieces of coloured glass. They are decorated following the medieval technique of grisalles and joined with lead into an intricate pattern that gives as result a sort of translucent picture.

In order to ensure windows protection against hurts and weather solicitations, external protective glazing have been installed in 1979.

Such windows, basically constituted by an iron made frame, single glass pane and a metal net, created a sort of external barrier which have affected the ancient glass perception, without providing an effective climate control (Fig. 3).

Along the years such protection has progressively reduced and lost its functions and emerging problems occurred both in relation with thermal and visual performance.

Water tightness was no more assured and rain could enter the Basilica damaging the famous whole of Giotto’s frescoes representing St. Francis' life, located just under the windows.

The need to substitute the ancient external protective glazing has been the occasion to conceive a new passive system that could satisfy the different needs related to ancient window protection without affecting the perception of such piece of art and encountering preventive conservation requirements.

Figure 1: St. Francis Basilica Superior Church in Assisi (south oriented façade).

Figure 2: Detail of a XIII century stained panel from window IX.

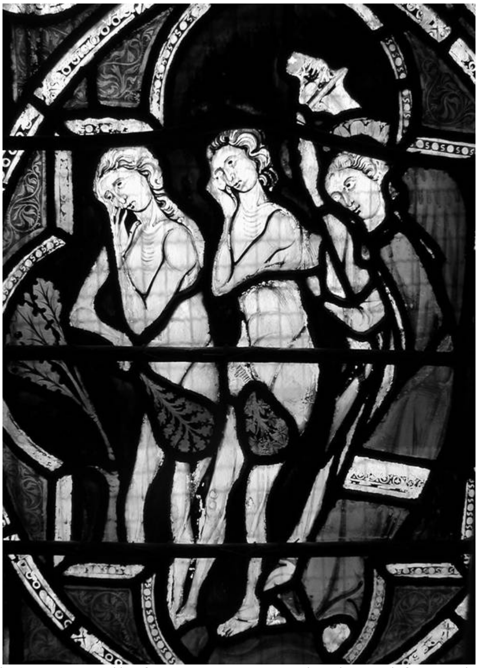
Figure 3: Detail of a XIII century stained panel from window IX; the external protection metal net of the old protective system affects visual perception.

The system has been designed and monitored by *Ricerca & Progetto – Galassi, Mingozzi e associati, in Bologna* (under the coordination of Ph.D. eng. Angelo Mingozzi); window restoration has been performed by *A.R.C.A.* Bologna, (Gianni Mecozzi) and the general supervision has been carried out by the *Soprintendenza per i beni ambientali, architettonici, artistici e storici dell'Umbria* (Dott.ssa Francesca Cristoferi).

2. NEEDS AND METHODOLOGICAL APPROACH

In order to define a general design method for rehabilitation and preservation of ancient stained windows a specific methodology has been set up and tested, aiming to organize and guide different steps of the process.

First of all the system to be installed had to re-constitute its original window function as a natural light source and protection against weather considering the special conservation needs of Giotto's frescoes.

As concerns preventive conservation the goal is to protect stained glasses against external climate (temperature, rain, relative humidity, U.V. radiation, etc.) and also from the intrusion of air gaseous and solid pollutants.

Last but not least new passive system had to guarantee a considerable aesthetic value and visual performances.

The mystic atmosphere inside the church is basically due to the contrast of shadows and lights of sun rays and diffuse light passing through stained glasses.

The luminance contrast between bright glazing and dark walls has to be maintained and enhanced by removing external metal grid to avoid any shadows on the glass and keep the quality of the incoming daylight.

The work has been performed by a multi skill working group including, engineers, architects historians and experts about conservations.

Aiming to a common goal and trying to enhance the different expertises it has been possible to define and organize climatic and non climatic objectives, to analyze the requirements (Table 1) for functional, technical and aesthetical rehabilitation, to choose a specific intervention technique and at last to plan tests procedures to monitor devices' performances.

Design process has been organized according to the following steps:

- detailed analysis about the state of the art in terms of similar cases, preventive conservation methods, optimal conservation suggested values, etc…
- survey and monitoring of existing protective glazing system to evaluate their residual performances; chemical analysis on the ancient glass to evaluate degradation status and main causes;
- restoration of the ancient glass and "grisalles";
- definition of the needs to be satisfied and of a "performance programme" including the different requirements to be fulfilled in terms of preventive conservation, functional aspects, visual and aesthetics features;
- preliminary design hypothesis and simulations;
- final executive design and installation of a prototype;
- monitoring, results evaluation and guidelines for future installations.

Table 1: Requirements to be fulfilled by the new passive system.

Preventive conservation requirements
Air Temperature
Surface temperature
Daily temperature variation
Seasonally temperature variation
Relative humidity
Daily relative humidity variation
Seasonally relative humidity variation
Equilibrium moisture content
Air speed
Illuminance levels
Yearly maximum illuminance exposure
U.V. radiation
Solid pollutants concentration
Gas pollutants concentration
Functional requirements
Water tightness
Air tightness
Dust tightness
Thermal insulation
Condensation prevention
Thermal stability
Humidity stability
Mechanical stability
Resistance to mechanical actions
Resistance against hurts
Resistance against solicitations
Maintenance
Duration performance
Visual perception
General appearance
Shadows control
Light flux control
Luminance balance control
Chromatic quality

3. THE SYSTEM

New passive system has as main goal the implementation of preventive conservation and visual requirements.

The system (Figs. 4 and 5) is constituted by a new external protective glazing integrated to the ancient one, in order to create a system that allows natural ventilation of the interspace from the church interior and a perfect shelter from external stresses.

The idea is to create a whole passive system able to reduce and balance thermal loads in order to obtain similar conditions on both sides of the ancient glass, preventing extreme temperatures and humidity in the air gap between new and ancient glass and avoiding condensation.

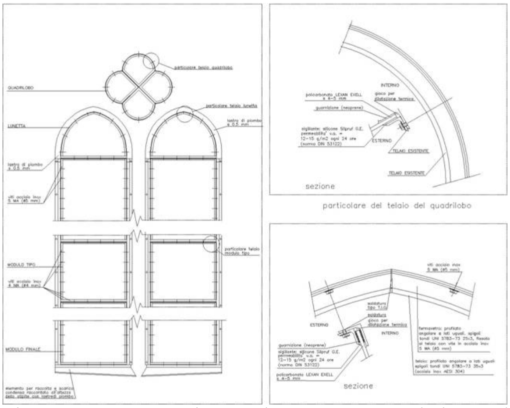

Figure 4: New protective passive system general view and some details.

In order to reduce ancient glass overheating, an innovative system to ventilate the interspace has been created. A large set of small apertures located along window borders allows air exchanges with the inside of the church.

In the bottom of the interspace a dedicated device permits to collect and evacuate moisture that could occur in case of extreme climate situations.

The new external glazing protective system is made of an iron painted frame and the glass is of polycarbonate specially treated on surface. Polycarbonate doesn't produce any reflections, doesn't affect daylight, provides UV protection and moreover is light weight, safe and easy to be mounted and substituted (Fig. 6).

Air tightness is assured by a perfect sealing of the different parts.

4. MONITORING CAMPAIGN

The first prototype has been installed on 1995 and during the following years other installations have been set up (Fig. 7).

In order to test results on the spot, two different monitoring campaigns have been carried out on 1995 (window XI) and 1999 (window XII), during different representative seasons.

On 2002-03 another monitoring campaign was carried out (window IX) to evaluate residual performance of the old protective glazing system.

During the different monitoring campaign a

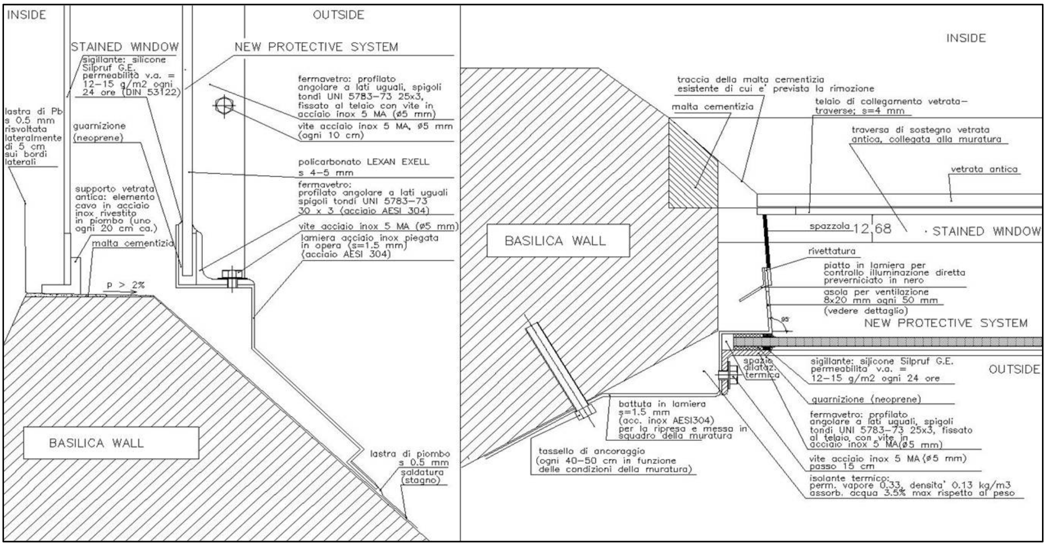

Figure 5: New protective passive system, details of longitudinal and cross sections.

large set of climatic parameters have been monitored. Sensors have been installed in order to get data about the climate outside the church, inside the church and in the interspace between new polycarbonate external protection and ancient window. In order to consider stratification and stack effects due to the length of the ancient stained windows (about 8 meters) separate values have been collected at two different heights inside the interspace.

Surface temperatures have been monitored in different positions (facing indoor and interspace) and at the same time glasses with different colours have been measured.

Measurements have been conceived with the following objectives:
- to provide data on the environmental impact and stress levels against the ancient window;
- to evaluate how the climate conditions inside the interspace are related with the ones occurring inside the church;

Figure 6: Old protective glazing system and new passive system installed in two different windows with the same orientation.

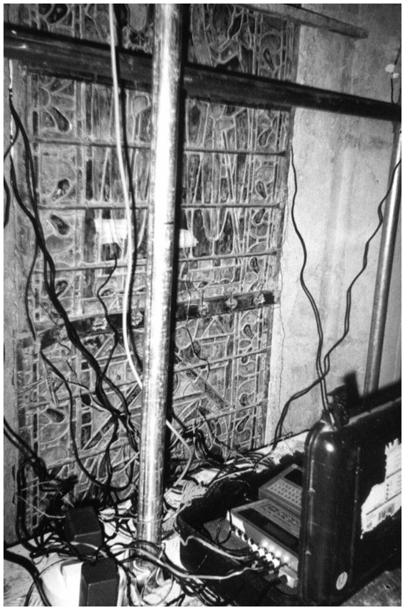

Figure 7: Monitoring campaign, view of the ancient stained glass from inside of the church.

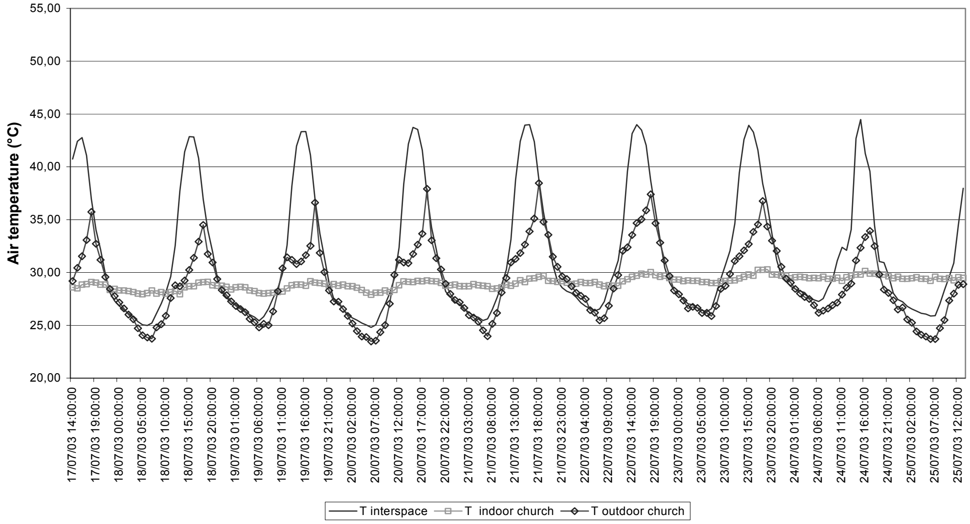

Figure 8: Outdoor, indoor and interspace temperatures measured the 21st of July in Window IX provided with the old protective glazing system.

- to compare environmental stress at different heights of the window;
- to evaluate global benefits in terms of preventive conservation, comparing the results with those evaluated in the same conditions for the window with ancient protective glazing system;
- to set up design guidelines to orient future interventions.

5. MAIN RESULTS

Different monitoring results showed that old protection is affecting visual perception of the stained glass and moreover doesn’t provide any satisfactory defence to outdoor weather and climate solicitations. As it clearly appears from monitoring, temperature of the interspace is deeply depending from outdoor weather and the lack of ventilation produces overheating during summer season (Fig. 8). During winter season high humidity inside the interspace associated to low temperatures increases the risk of condensation.

The monitoring executed where the new passive system has been installed showed much better conditions. The system of apertures allows an efficient air exchange between the inside of the church and the interspace creating much more stable climatic conditions and less dependent on outdoor ones. This permits to reduce temperatures during the summer and increase them during the winter, reducing at the same time relative humidity.

After the interventions both sides of ancient stained glass are exposed to a more stable climate and conditions on the two faces are more similar.

Table 2 summarizes final monitoring results, showing the differences evaluated during each of the two monitoring campaign in two different windows with the same orientation and height.

6. RESULTS INTERPRETATION

In order to investigate the large amount of data obtained during different monitoring campaigns, statistical criteria have been used.

These criteria are especially useful when the obtained environmental values are different from the suitable preventive conservation ones and then it is required to understand how the environmental situation is really damaging for exhibits.

For this purpose “deviation indicators” for the required parameter (ex. T, R.H., etc.) have been calculated. Such indicators permit to calculate the time percentage in which monitored values differ from the acceptance range of the parameter. This can be easily done looking to “per cent cumulate frequency diagram” (Fig. 9), calculated for the reference period (possibly on an hourly basis). With such representation we can decide to accept a deviation from the expected values when it appears for short time.

7. CONCLUSIONS

The defined methodology and result has been successfully verified in St. Francis Basilica.

The different monitoring campaigns carried out before and after the interventions show a elevant improvement of preventive conservation conditions and aesthetic appearance. The experience has demonstrate that, in some cases, preventive conservation targets can be pursued successfully by means of passive systems. It is necessary that the solution proposed solves comprehensively different requirements and a cross disciplinary team has been constituted to define and verify them.

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Table 2: performances comparison of Window IX (old protective glazing system – monitoring executed on 2003) and window XII (new passive protecting system – monitoring executed on 1999).

Monitored Value	Protective glazing system	
	Old protection	New system
Average surface temperature difference between indoor facing stained glass surface and interspace facing one		
Blue glass		
Winter	≤ 17 °C	≤ 0,75 °C
Summer	≤ 3 °C	≤ 0,95 °C
White glass		
Winter	≤ 11 °C	≤ 1,0 °C
Summer	≤ 4,5 °C	≤ 0,4 °C
Average R.H. inside the interspace		
Winter	≤ 85 %	≤ 75 %
Summer	≤ 80 %	≤ 65 %
Risk of condensation during monitoring period		
Winter	high	none
Summer	none	none
Air speed inside the interspace		
Winter	≤ 0,31 m/s	≤ 1 m/s
Summer	≤ 0,2 m/s	≤ 0,4 m/s
	both occurs only during the hottest period of the day	both occurs quite constantly during the whole the day

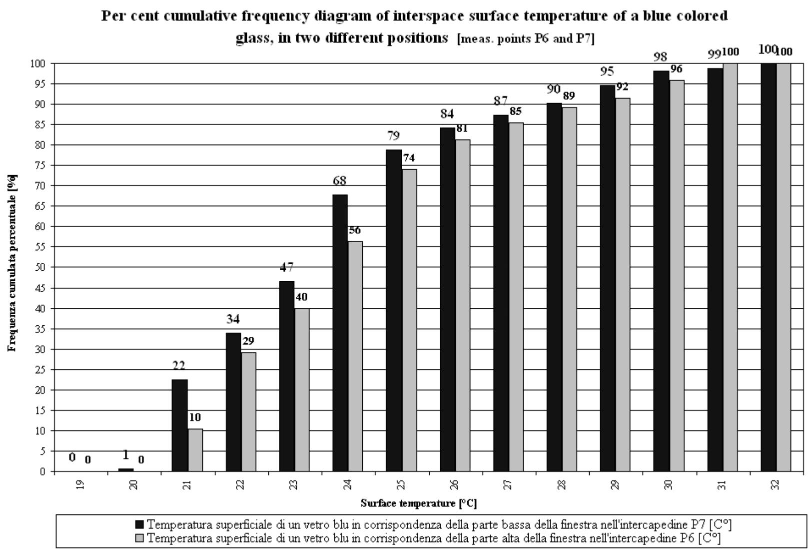

Figure 9: Per cent cumulate frequency diagram.