

Natural light in new underground areas of a historical building: an example of application of double light pipes in preservation of the architectonic heritage.

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ABSTRACT: Daylight plays a significant role in the knowledge process of an ancient building, for its contribution to understanding the past. Furthermore its function in preservation of architectonic heritage is particularly noteworthy, involving energy saving aspects and allowing to guarantee visual well-being conditions.

In a restoration plan, the demand to add further activities often leads to think about new underground spaces in order not to modify the architectonic features of the building.

In hypogeal areas daylight is absent, because there is not direct visual interface with the sky, so the unique way to furnish daylight to the interior spaces is to install some technological devices like the light pipes.

In this work a new typology of light pipe is proposed by the authors, called Double Light Pipe (DLP), which is able to transport daylight from the captator to the diffuser like a traditional one, and to simultaneously illuminate the intermediate rooms crossed by the system.

DLP has been applied in the restoration of the noble palace of Spinete (CB), Molise, Italy, in which the requirement to integrate new activities was satisfied adjoining hypogeal spaces, respecting the ancient walls and the earth line delivered to us from the past.

DLP manages the luminous phenomenon as an architectonic component able to model the space, distributing light in all the crossed spaces and transforming the restoration plan into an opportunity for a different dialogue between the monument and the environment in a historical context by means of an innovative technological device for daylight transport.

Keywords: daylight, light pipe, double light pipe.

NOMENCLATURE

Symbol	Description	[Units]
E	Illuminance	[lux]
E _{ext}	External Illuminance	[lux]

INTRODUCTION

The preservation of architectonic heritage is a very important theme particularly in Italy where, not only in the biggest cities but also in small urban agglomerates, numerous historical buildings are present. It is the case of Spinete, a small centre in Molise in which the palace object of this work is located.

The restoration plan of the noble palace of Spinete provides the adjoint of further activities such as administration offices and cultural spaces. This demand leads to think about new underground areas in order not to modify the architectonic features, with respect to the ancient walls and the earth line delivered to us from the past.

The idea to distribute daylight in these new hypogeal locals derives from the requirement to effect a significant energy saving intervention, contemporarily guaranteeing visual comfort conditions.

Traditional light pipes are able to introduce daylight in underground spaces far away from the captator positioned on the rooftop of the building but they are bulky technological systems into the passage rooms.

To give a way out to this problem the authors present an innovative system for daylight transport named Double Light Pipe (DLP), consisting in two concentric pipes: the first one, internal, transports light from the captation point to the diffuser like a traditional light pipe, and the second one, external, is made of a plastic transparent material covered by a diffusing film and it diffuses light into the spaces crossed by the device.

In this work DLP has been successfully applied to a restoration plan in which it is an efficient answer to the demand of illuminating new underground areas, well combining with architectonical features of passage spaces. The efficiency of the system has been shown by the authors in [8] comparing experimental results on a reduced scale model with numerical ones.

Furthermore in this work photorealistic pictures of the system are presented as results of the numerical analysis.

2. DESCRIPTION OF THE BUILDING

The building examined in this work is located in Spinete (CB) a small town in Molise (Italy). It is an ancient Norman fortalice, turned into a nobiliary residence in the 17th century and inhabited up to the half of 20th century.

At the present time the building is expanding on a 700 m² plant surface and the deterioration condition are more determined by the neglect than by structural instability. Thanks to the imposing disposition of volumes and the strategic position in the centre, it lays itself open to a restoration plan, in which the requirement to integrate new activities to the building and the will to less possible interfere with the existing architecture oriented the choice towards a hypogeal architecture which respects the ancient walls and the earth line that characterizes the building.

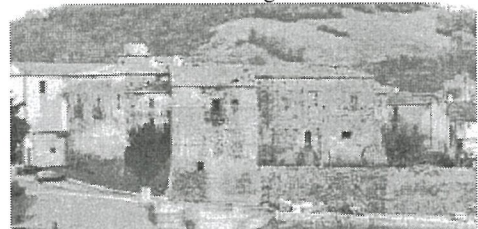


Figure 1: The noble palace of Spinete (CB)

3. THE INNOVATIVE DAYLIGHTING SYSTEM

The innovative device of daylight transport named Double Light Pipe (DLP) has been studied at the Laboratory of Technical Physics, University "G. D'Annunzio" of Pescara (Italy).

The authors present in [8] the results of a numerical and reduced scale experimental analysis of DLP performances, on the base of which the idea of application in a restoration plan has been generated.

In Fig. 2 a graphic three-dimensional representation of the reduced scale (1:10) model of the system is shown in which its constituting parts are highlighted.

It consists of two concentric tubes, the interior one, $\phi = 30$ mm, is realized covering both its internal and external surfaces with a very reflective film ($\rho=99,5$ %) while the exterior one is a transparent polycarbonate tube covered on its internal face by a thin flexible film, named Optical Lighting Film (OLF), characterized by very precise 90° micro-prisms on one side and smooth on the other. It is able to diffuse light arriving by the source, that is daylight captured on the rooftop by the captation device.

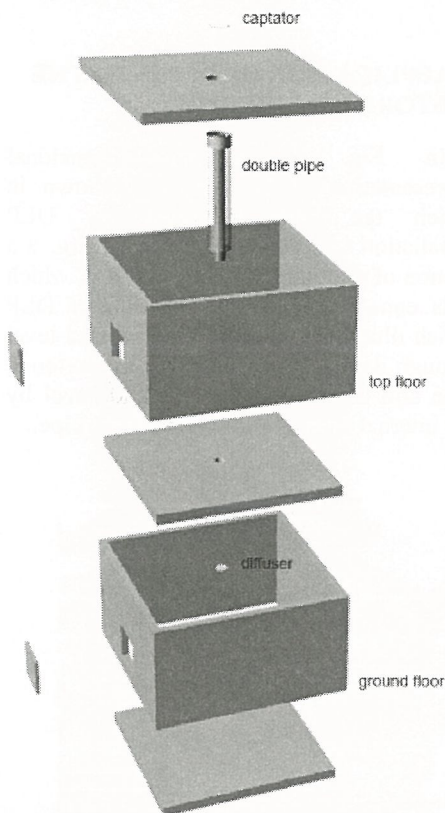


Figure 2: Three-dimensional representation of the reduced scale model used for experimental analysis of DLP performances

In Fig. 3 and Fig. 4 two photos of the system during the experimental tests are shown in which the diffusing effect of OLF is observed comparing the obtainable performances of DLP with and without OLF applied in quite analogous external conditions, respectively 44000 and 49000 lux.

Particularly in Fig. 3 illuminance is more uniformly distributed on the work-plane while it is evident an attenuation of reflections by boundary walls observable in Fig. 4 in the solution without OLF. In this last case reflections from boundary walls and the direct component of sun radiation seem to significantly influence illuminance distribution over the work-plane.

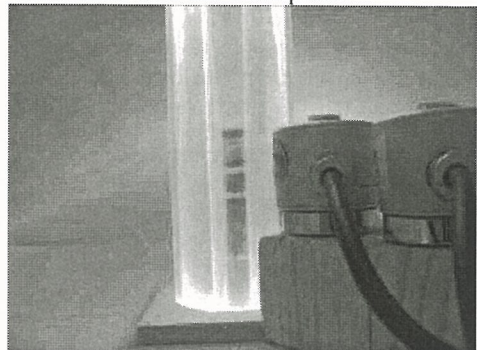


Figure 3: Reduced scale DLP with OLF during experimental test - $E_{\text{ext}} \approx 44000$ lux

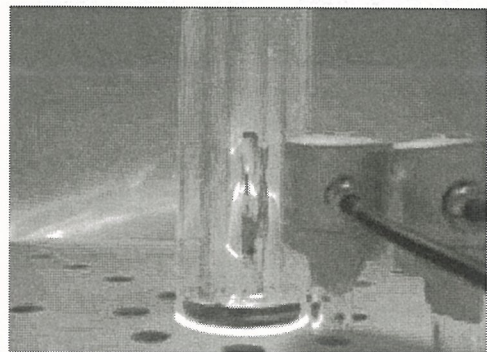


Figure 4: Reduced scale DLP without OLF during experimental test - $E_{\text{ext}} \approx 49000$ lux

3. NUMERICAL ANALYSIS

In Fig. 5 data from numerical analysis by Ecotect are presented in CIE Overcast sky ($E_{\text{ext}}=14000$ lux), while in Fig. 6 in Intermediate sky conditions ($E_{\text{ext}}=45000$ lux).

Quite a symmetrical distribution of light is obtained on the work-plane in both cases probably thanks to OLF optical properties, particularly in Overcast sky conditions, but a lower level of uniformity is realized, while increasing external illuminance (e. g. Fig. 6). This effect is improved with elevate external illuminance values such as in summer conditions.

In this case the direct component of solar radiation is refracted by the external pipe and peak values are obtained equally distanced in time in measure positions selected on the work-plane, as shown in [8]

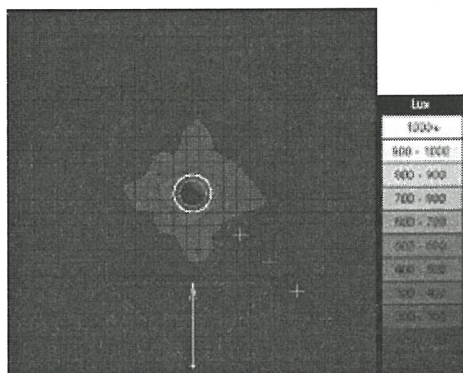


Figure 5: Ecotect numerical analysis - CIE Overcast sky ($E_{\text{ext}}=14000$ lux)

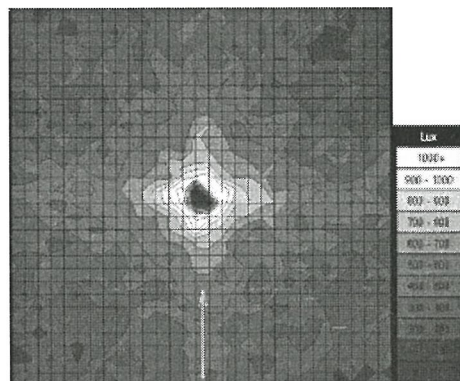


Figure 6: Ecotect numerical analysis - CIE Intermediate sky ($E_{\text{ext}} = 45000$ lux)

Numerical data are generally in good agreement with experimental ones in [8].

4. APPLICATION OF DLP INTO THE HISTORICAL BUILDING

In Fig. 7 a three-dimensional representation of the palace is shown in which the area interested by DLP installation is highlighted, while in Fig. 8 a section of the building is presented in which it is comprehensible the function of DLP which illuminate the first underground level through daylight distributed by the external pipe and the second underground level by the internal tube as a traditional light pipe.

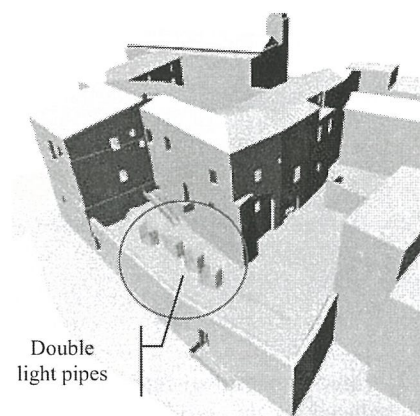


Figure 7: Three-dimensional representation of the building

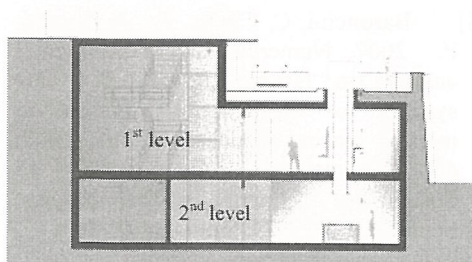


Figure 8: Section of the building

An innovative geometric shape characterized the system applied in this case [e. g. Fig. 9]. It has been studied in order to satisfy the particular architectonic requirements of the palace.

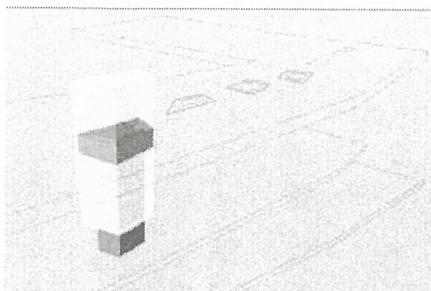


Figure 9: Three-dimensional representation of special geometric shape of DLP

In this way a bulky element such as a light pipe becomes an architectonic component able to successfully integrate itself with the context and to give an efficient contribution to daylight distribution inside the building.

In the restoration plan object of this work four DLP were applied all characterized by a quadrilateral section with lightly different shapes each to the other.

In Fig 10 and Fig. 11 photorealistic representations of the system respectively on the first and second underground level are illustrated in Clear sky conditions.

They are obtained through Radiance software and illustrate the diffusing effect on illuminance on the first level, while a more concentrated light flux is observed in the second level.

The internal pipe produces effects commonly obtainable with traditional light pipes, while the external one generates a more diffuse distribution of illuminance on the work-plane thanks to OLF optical properties.



Figure 10: Photorealistic simulation by Radiance – 1st underground level

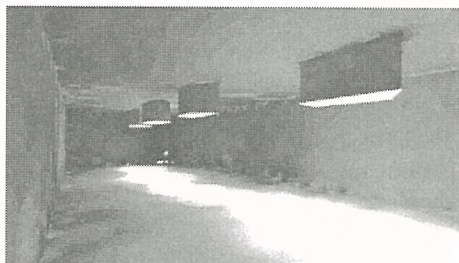


Figure 11: Photorealistic simulation by Radiance – 2nd underground level

5. CONCLUSION

This paper presents the results of a study whose aim id to apply the innovative system for daylight distribution named Double Light Pipe (DLP) in a restoration plan of a historical building located in a small urban agglomerate in Italy.

The authors show how the original idea of DLP evolved in a new architectonic structure in good agreement with the context and contemporarily able to satisfy the suited demand of visual comfort and energy savings.

DLP has been successfully installed in new hypogeal spaces that adjoin new volumes to the building, respecting the ancient walls and the earth line of the

structure. In this case it becomes a pleasure architectural element in good agreement with the context and able to carry out its function of illuminating hypogeal locals without any traditional daylight sources.

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