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Integrating New Structures with Historical Constructions - A Transparent Roof Structure above the Centrally Designed Atrium

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Abstract. The architecture initiated during the time of the Austro-Hungarian period was distinctly expressed both in Sarajevo and in the whole region of Bosnia-Herzegovina. A substantial number of these buildings was assessed for their historical, architectural, ambient and aesthetical values and, as such, represent the valuable historic heritage of these regions. Standing among them in its impressive dimension and being of a great national value is the palace of the former Provincial Government, which was designed by Josip Vancaš in Vienna (1884). The aim of the present paper is to emphasize the importance of atrial and open spaces integrated into the volume of the building. These spaces can be used to synthesize and functionally transform spaces into controlled and contextually selected forms, contemporary shapes and materials by applying functional creativity without endangering the ambience and historical values of the building. On the contrary, by closing the courtyard and atrial spaces, it would be possible to ensure a buffer zone between the interior and the exterior as well as to create a micro-climate and eliminate processes that generally occur in façades facing such spaces. These spaces could be synthesized and functionally transformed into useable, controlled and contextually selected forms by creatively applying contemporary shapes and materials without endangering the ambience and historic values of the building. The view towards the sky through a diagonal lattice would present an association to the "lattice window" or "mušebak", creating a comfortable microclimate. Several different structural concepts were studied. The aim of the paper was to evaluate structural concepts in terms of feasibility and energy efficiency measures pay off. There are numerous examples of transparent roof extensions introduced when rehabilitating the existing cultural-historical buildings, the extensions known for their power in terms of quality and quantity or the harmonious bond between the old and the new. The atrium roof structure will be supported on the walls of existing building. Since the roof structure would be on the interior of the building footprint it is important to consider manageable erection process.

1. Introduction

The spirit of Central and Western Europe at the time, its culture, lifestyle and expressions of eclectic architecture and historicism slowly made its way into these regions as well. The period of Academicism¹

¹ Nedžad Kurto, «Arhitektura Bosne i Hercegovine: Razvoj bosanskog stila», Sarajevo Publishing, International Peace Centre, Sarajevo, 1998, p. 24



should also be mentioned, as it included transmission and adoption of conventional motifs found in historical styles and skills applied without innovative solutions.

It was in this period that numerous important buildings of both sacral and profane features were built in the architectural style based on the analogies of eclecticism by means of which the new order of the ruling Monarchy was striving for recognition. Neo-Renaissance was, as a matter of fact, the classical universal architectural style in almost all public buildings during the period of the Austro-Hungarian rule. These were premises for government bodies and the military, numerous publics, industrial and residential buildings, many of which are used even today (the Provincial Government building, the National Museum, the State Hospital, the Pension Fund Building, First Grammar High School, the tobacco factory, the carpet factory, the brewery, etc.). Sacral and church buildings were built in the NeoRomanic and Neo-Gothic style, whereas elements of Neo-Baroque and Neo-Renaissance may be found in residential and commercial buildings.

The Provincial Government building is legally protected by the Act of the City's Bureau for the Protection and Maintenance of Cultural Monuments of Sarajevo. This building is also listed in the Temporary list of national monuments comprising the "Ambience Unit of the City of Sarajevo". Since the building was proclaimed a national monument, the protective measures for such buildings are clearly. The main (ceremonial) entrance may be reached from the main road in the north, the staff entrance from the side road next to the building, and the entrance used for deliveries and other businesses from the south side of the park, which is by means of a passage connected to the inner courtyard. Next to the entrance halls on the ground floor and parts of the building used for horizontal and vertical communication, the hallways, restrooms and staircases are state management and administration offices, conference and reception halls, the porter's apartment, the archives, and other offices on different floors.¹ Today, civil servants' premises are located in this building. The height of the cellar is cca. 3.0 meters. The height of the ground floor and the first floor is cca. 5.0 meters, while the second and the third floor are cca. 4.0 meters in height. Some rooms, such as the reception hall are 10 meters high. The constructive elements of the building are massive bearing walls made of solid brick (25x15x7cm) bound by lime mortar the thickness of which varies (60-75 cm in the cellar; 60 cm on the ground floor, and 45cm-35 cm on the upper floors). The partition walls are 15 cm thick and lined with lime mortar on both sides of the wall so that they are approximately 20 cm thick in total. The foundations and the cellar walls are made of stone, i.e. the plinth is panelled with stone. The inter-floor structures between the cellar and ground floor, as well as between the ground floor and other floors, are made of metal traverses with low brick vaults arranged within a shorter range (the so-called Prussian ceiling), which was a usual ceiling found in buildings constructed during the Austro-Hungarian period.

2. Integrating a transparent roof structure above the centrally designed atrium

Considering that the inner atrium was not included in the restoration and was not treated functionally, aesthetically or in terms of energy efficiency, the aim of the present paper is to emphasize the importance of atrial and open spaces integrated into the volume of the building. These are the spaces that can be used to synthesize and functionally transform spaces into controlled and contextually selected forms, contemporary shapes and materials by applying functional creativity without endangering the ambience and historical values of the building. On the contrary, by closing the courtyard and atrial spaces, it would be possible to ensure a buffer zone between the interior and the exterior as well as to create a microclimate and eliminate processes that generally occur in façades facing such spaces. The structure used to support this roof is designed to maximize the amount of light entering the building, using optimal member's width.

¹ http://old.kons.gov.ba/main.php?id_struct=6&lang=1&action=view&id=3034

3. Functional transformation of the Presidency Building

As the condition of the courtyard façades, as well as atria-oriented façades, is unfavourable, it is necessary to rehabilitate and refurbish them. The function of the free, open-air spaces has been neglected and forgotten. The added annex within the courtyard, especially the last two floors, degrades the value of this historical building and the south-oriented spaces, i.e. spaces oriented towards the central courtyard. If they were torn down and if green spaces, fountains and other functional parts were to be added in this part of the courtyard (suitable for exhibitions, etc.) and if they were to be covered by a transparent roof structure, the result would amount to a functional transformation of the building. The basic design of the open-air roof structure is founded on a latticed "structure", a diagonal concept of laminated boards that would support a transparent envelope made of insulating glass. The view towards the sky through a diagonal lattice would present an association to the "lattice window" or "mušebak", an architectural element found in the Oriental type urban houses in Bosnia-Herzegovina whose structure favourably contributes to the values of creating a comfortable micro-climate (figure 9).

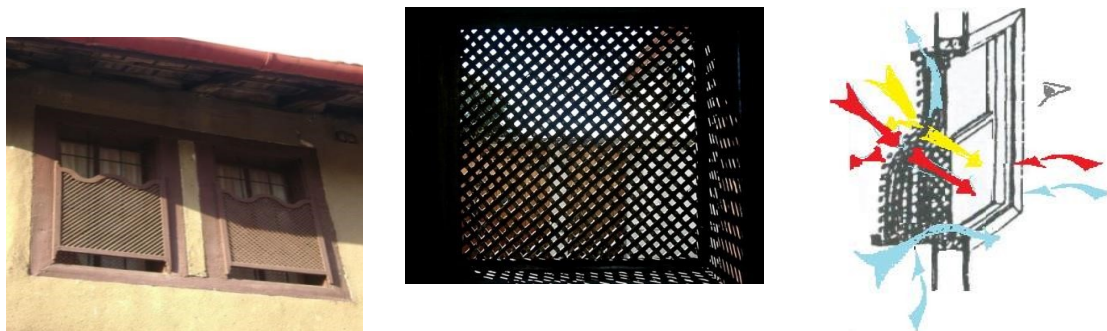


Figure 1. A lattice window (mušebak) from the Ottoman period, Sarajevo, Bosnia Herzegovina



Figure 2. A "sky-oriented window" - transparent roof structure integrated above the atrial space of the Presidency Building

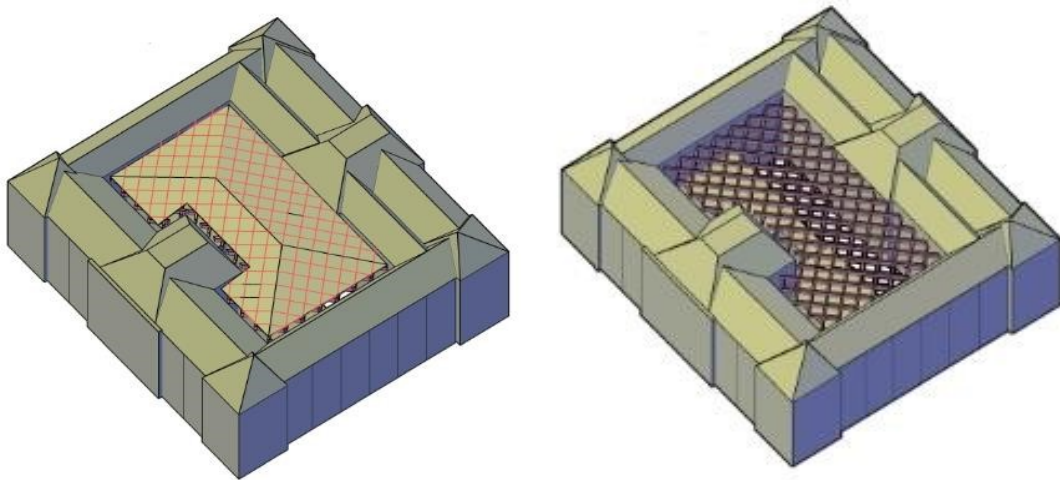


Figure 3. Atrium Roof Consist of Stainless-Steel Structure with Glass Skylight Frame 3D model

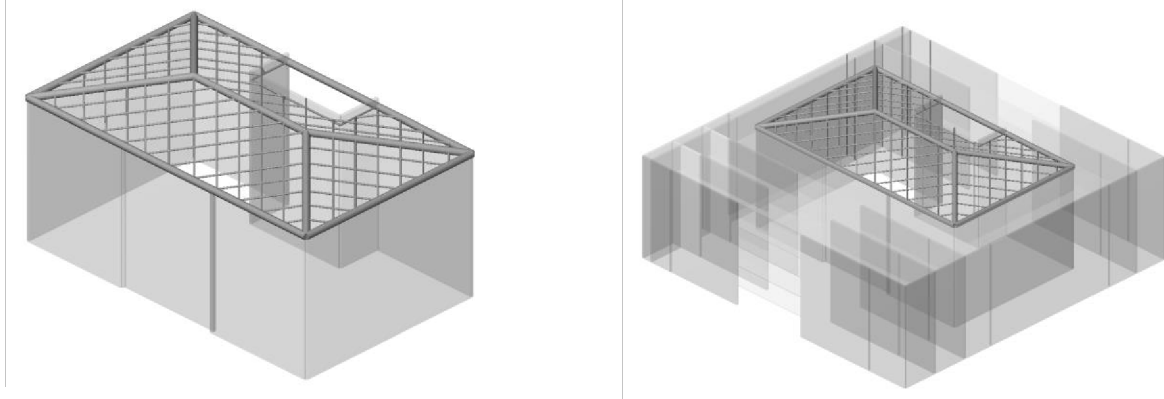


Figure 4. Tower 7 3d model - Static model of roof structure with and without main building's walls. To accurately model, analyse, render, and ultimately construct the roof structure, geometric parameters needed to be established that resemble the roof form

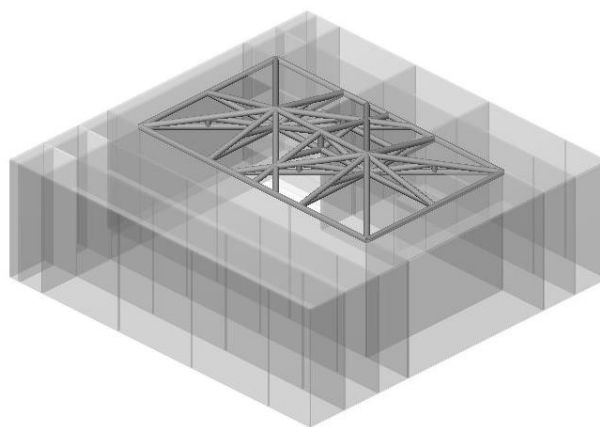


Figure 5. Tower 7 3D model - Static model of roof structure with main building's walls / considered variant

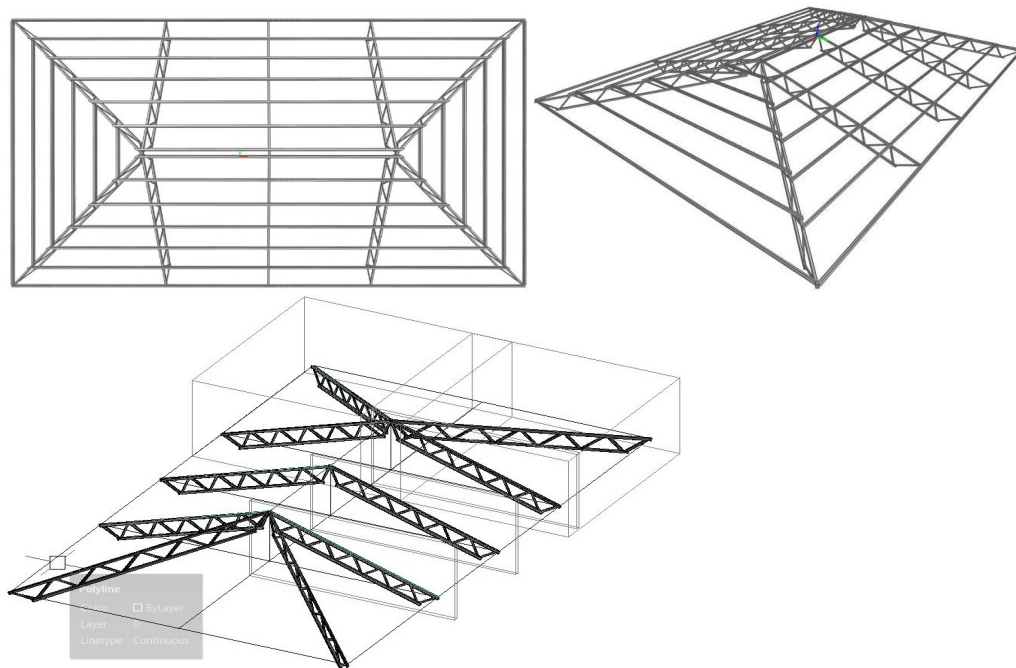


Figure 6. Advance Steel-Layout- Static model of the main roof structure final

4. The design and construction of long-span roof structures

Long span roof structures are usually defined as those exceeding 12.0m in span. The design and construction of long-span roof structures requires large range of skills from the structural engineer not usually required in usual building types where the redirection of forces is affected by form design and characteristic form stability.

Forces come into play, including material shrinkage, support settlement, temperature effects and sequence of erection that can normally be ignored in many building types but can have a dramatic effect on long-span structures.

The structure must be bearing its own weight; just to span the required distance a structure must support significant dead load and protects the building and its contents from the effects of weather. The complexity of long-span design increases when snow load, wind load, seismic load, deflection, serviceability, and the dead weight of roof system are all factored in different materialisation in timber or steel. Both structural timber and steel are graded with special designations depending on the region of the production. Factors that are impaction on our decision are as follows: the dimension of required horizontal clear span, special needs for geometric form, the form and the layout of the supports, penetrations of the roof for vents, elevators, skylights, and so on.

5. Surface active systems

Systems of flexible or rigid planes able to resist tension, compression or shear, in which the redirection of forces is affected by mobilization of sectional forces. The analyses conducted, as well as the modern design of the roof structure and the form of the building's base, resulted in choosing a constructive solution to the roof structure materialized by means of steel-latticed joists adapted to the shape of the building's structure in accordance with its height and width.

The circular (CHS – circular hollow section) and rectangular (RHS – rectangular hollow

section) hollow steel grid bearings have priority in contemporary civil engineering and construction over the commonly used grid bearings made of hot finished sections due to a range of advantages: less heavy, the anti-corrosive protection is cheaper, the O/A relation is lower, the aero-dynamical shape is better, there are greater possibilities for constructive and architectural shaping, and so on. They are made of CHS or RHS. All the filling elements are welded. The angled welds are 4.0 mm thick along the whole contour of the joining structures.

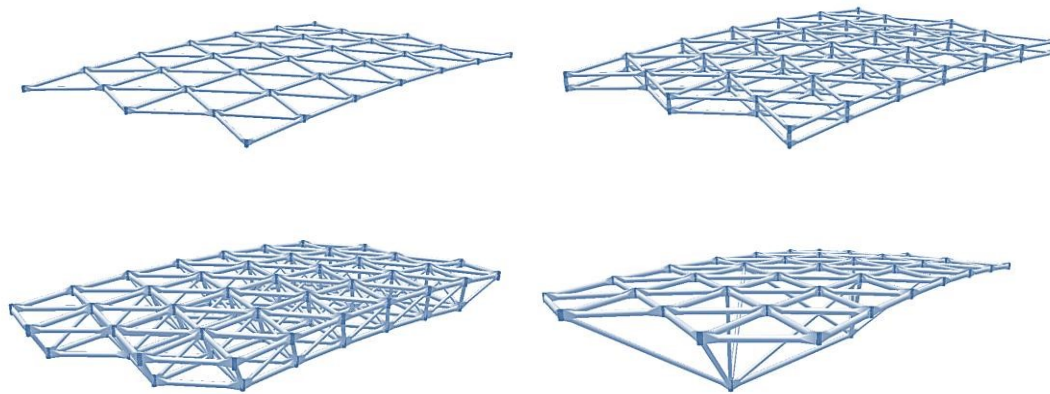


Figure 7. Systems of flexible or rigid planes

Structural members that span the distance between main elements, hold insulation, cladding, lighting and ventilation, moreover they constitute three-dimensional stiffness. Basic structural elements that compose a roof structure are rafter, purlin, strut, diagonal, collar, siding, tension beam and cladding board.

6. Advantages of glued laminated timber

Compared to the cut timber material as well as other construction materials glued laminated timber offers numerous advantages. First and foremost, possibility to overcome large spans, i.e. the possibility of producing large lengths of members, resulting in large span reaching up to 100 m. There are numerous possibilities of making different shapes that allows us greater flexibility and freedom in design. Also, worth to mention is high fire resistance and possibility to create envelope of burnt part of the wood that protects the core of the structural members, the durability that applies to glued laminated timber whose natural moisture dissipation and absorption is reduced to a minimum as well as resistance to aggressive chemical substances and ecological acceptability.

7. Advantages of steel roof structure

The strength and ductility of structural cold-formed steel, along with the holding power of connections, make it the ideal material for construction in high wind speed and seismic zones. Characteristics such as non-combustibility, termite resistance, and dimensional stability can decrease construction costs.

Member connections are designed based on designed capacity of members and future loads. Several members are checked for their capacity to carry the loads with hand calculations. Steel framing can lower construction costs. Price and stability of supply have driven many builders to adopt roof steel structure. To safely erect the atrium roof steel structure, along with facilitating roof glazing, sprinkler piping, painting, and electrical work, we have anticipated to build a temporary work platform just below the roof structure. The scaffold for this platform extended some 30 meters down through the atrium or

openings below and should be a significant structure in and of itself. It also proved to be an invaluable beneath to provide access for inspections of the structure.

The atrium roof structure was modelled and analysed using Tower 7 software and Advance Steel. Load cases and load combinations were defined according to Eurocode 3 design of steel structures. Load cases included dead, live, snow, wind, seismic, and temperature. Unbalanced snow and wind loads were given careful consideration. Basic loads were applied as line loads to the secondary members. Design relate to the technical and professional nature, tempered by a humanistic scale and environmental design that expresses its location. The main architectural statement expressed by the roof's rhythm of lattice window, arcing over the buildings and dipping towards the space. Long span roof is needed to cover a very large area.

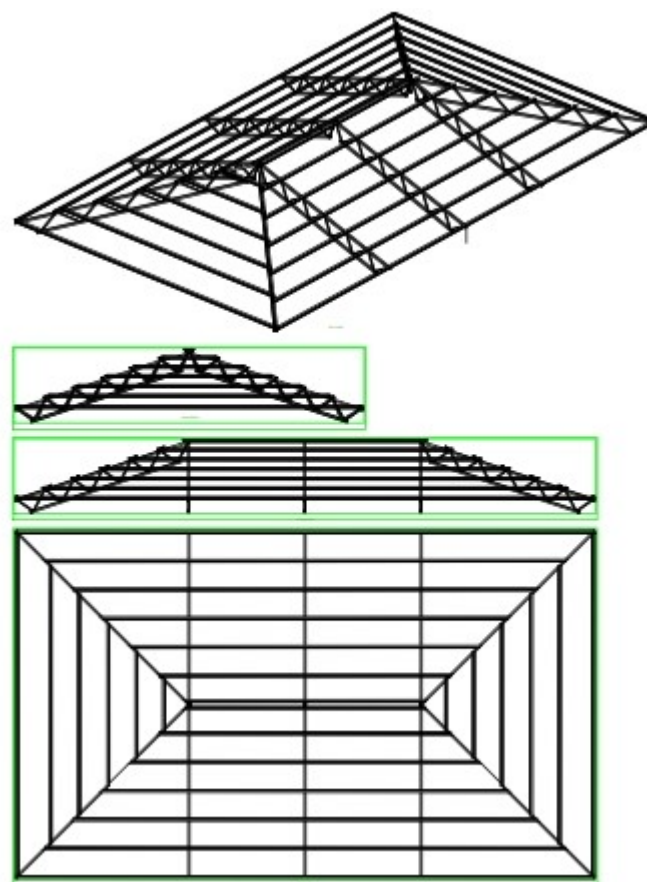


Figure 8. Advance Steel-Layout of main bearing structure

Several factors were considered making sure that the roof construction suit it purposes as a long span roof such as material, design and features, element of the roof, method of construction, connection and jointing and load to be carry. Material chosen, mostly steel is preferable to be use compare to timber because of it flexibility for construction of long span roof with high strength and intensity but light weight. Few design and features for a long span roof depending to the uses and type of the building. Roof members are pre-made or prefabricated in the factory before being erected at site. Erection on site needed skilled labour and lifting up plant and machinery. Members of trusses can be joined by riveting, bolting or welding. Design of the roof structure must be able to carry loads that are imposed to it to

prevent failure to its function. A glass-and-steel-encased atrium meets the goals of less structure and more openness.

Coating should be spray painting; galvanization and powder coated. Structure is durable for 50 years. High anti-rust performance is demanded. Structure is supposed to be waterproof, UV resistant, with heat insulation, antiaging and easy to install self-cleaning.

Long term maintenance costs are reduced because steel is resistant to rot, mold, termite and insect infestation. Thermal characteristics of glazing a transparent roof, i.e. the thermal transmission coefficient proposed in the analysis is 1,2 W/m² K. In this case, the annual expenditure on energy required for heating up the building is cca. 60.03 kWh/m². The greenhouse effect has been taken into consideration when conducting the analysis on thermal gains, i.e. losses and gains (in terms of transmission and ventilation) through the non-heated atrial space. The reduction in thermal losses has been verified as well as the enhancement of thermal gains in relation to the results of the thermal balance of the existing structure. In other words, by integrating the transparent roof structure and utilizing the greenhouse effect, and by reducing transmission and infiltration losses, it is possible to save 542 MWh, or more than 20,026 BAM per year. In this way, annual expenditure on energy would be reduced for cca. 12% taking the current energy price (0.037 KM/kWh) into consideration.

8. Conclusion

Heritage management is founded on safeguarding the values heritage structures represent by promoting involved participation from the moment of their protection. The reconstruction of heritage properties is dictated by need, use, and available resources. Several people with a range of specializations must be involved, in particular: The investor or occupant/beneficiary, Architects and town planners, Civil engineers from various specialist backgrounds, primarily construction and geomechanics, surveyors, geologists, conservers and restorers, Archaeologists and Art historians. Recognizing the value of cultural heritage monuments is a key step towards ensuring their proper maintenance and protection. The best way to preserve valuable historical buildings is to raise awareness of their value, to gain the necessary knowledge on ways of their maintenance. It is also important that the building is going to be utilized in a way that respects its historic value.

By adhering to construction principles, principles of sustainable construction and EE principles in the process of rehabilitating cultural-historical buildings, a functional and quality-based transformation of a building can be attained by means of creatively joining the old and the new. By integrating transparent roof structures of special constructive creativity, it is possible to express a significant contrast against the solid and massive quality of the existing structure as well as dynamics and balance. Such interventions leave recognizable traces in the history of architecture and improve the building's longevity. The atrium roof was a project in which the structural designer was able to take an active role in developing roof architectural design in terms of efficiency, economy, and elegance in the atrium roof structure.

The potential of the proposed concept, aside from preservation and active protection of the cultural historical building, is also found in the possibility to meet the requirements of contemporary environment by means of a positive dialogue with the natural surroundings.

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