THE STRUCTURE'S ARCHITECTURE

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ABSTRACT

The present research work studies the architectural-structural approach applied to a high-mountain hotel project, the design of which enables it to resist not only seism but also other natural threats such as wind, snow and avalanches.

The Building was situated at Puente del Inca (2750 m above sea level). Such natural conditions modeled the architectural-structural and bioclimatic design. The appropriate architectural answers were given so as to solve such complex dimension.

In order to carry out this proposal, a survey on high buildings located at major seismic zones in the world, focusing on those located in Mendoza, was conducted.

Regarding the scope and complexity of current architecture, architects must incorporate the various scientific and technological advances and synthesize them in a creative, imaginative and pure manner through economics, sociology, aesthetics, engineering, planning and design.

As a result, a solution complying with state-of the-art safety standards and regulations in force was achieved. Thus, structures are conceived not only as mainstay of architecture but also as one of many creative alternatives architects must know and take advantage of.

KEYWORDS: architectural structural design, earthquake architecture, seismic design

1. INTRODUCTION

The province of Mendoza is situated on a highly seismic-prone region of Argentina, so it is essential to take into consideration such situation when designing an architectural project. The built environment is part of the physical elements exposed to natural threats, which must be taken into account when designing a building.

The identification and assessment of natural and antropic threats, the physical, social, economic and cultural vulnerability as well as the existing risk levels constitute the basic information necessary for drawing up the project and for preventing potential disasters

Although most natural threats are inevitable, their effects can be prevented or, at least, mitigated. The present research work attempts to prove that architecture provides solutions which can effectively control risks and foster sustainable development. This research also intends to account for the close relationship between architectural and structural design which allows architecture to find solutions to building in areas of high natural hazard risk areas.

The main purpose of the present research is to deepen the matters regarding disasters prevention which is, at present, an essential strategy for achieving sustainable development.

The secondary purpose of this study is to make known the variables that may be managed along the architectural design stages and affect the structural design. The incorporation of such variables at the early stages of the creative process simplifies it and improves the final architectural results.

2. DEVELOPMENT

Several factors including the spatial richness, the different shape patterns, the formal connection with the surrounding area, the fluency of the spaces and the exploitation of natural resources determined the choice of a high-mountain hotel project in the province of Mendoza.

The location, Puente del Inca - Las Heras - Mendoza – Argentina (2750 m above sea level), was chosen because of its impressive mountainous landscape, thermal waters and its bridge's natural formation which gives this spot unique colors and contrasts. It is the perfect setting to prove the research hypothesis. (Figure 1)

The site selection involved great challenges since many variables such as snow accumulation, seismic risk, winds effect and avalanches had to be considered.
Furthermore, the present research aims at revaluating Puente del Inca's historical heritage in view of the fact that in 1965 an avalanche destroyed a hotel that used to lie there.

Figure 1: **Impressive mountainous landscape**

The Project also contemplated the use of natural resources such as thermal waters for geothermic exploitation and solar energy for heating purposes. Such resources consideration was key to solve the problems regarding weather hardness.

2.1. Hotel Description

The building is an integral part of a tourist development formed by a Social Shopping Center, a Hotel and a Health and Recreation Center. (See Figure 2)

The building is composed of an access floor, a ground floor and seven stories for suites (60 suites) and a viewpoint located at the eighth story. The parking zone was placed in the west and east wings taking advantage of a difference in basement's floor level.

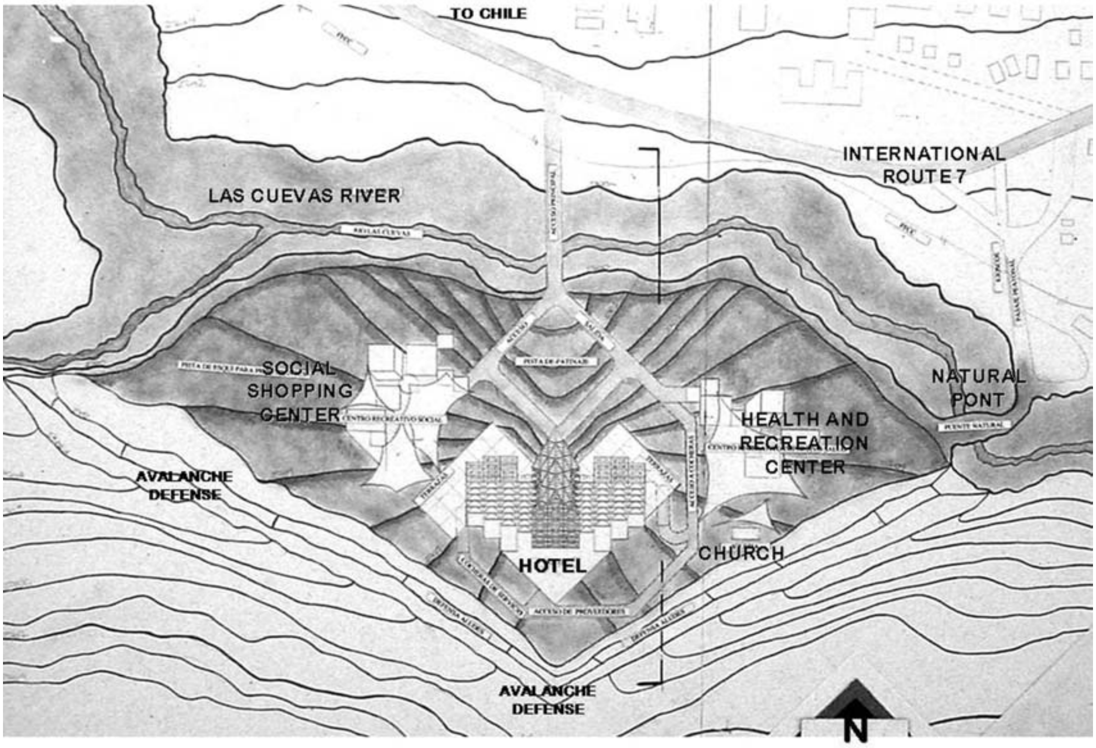

Figure 2: **Puente del Inca Architectural Complex**

To avoid architectural functioning disturbances, the building was provided with well defined areas arranged as follows: entrance – reception – hall – Green space (to contrast the natural environment) - on both sides there are living-rooms and the dinning room, the service-oriented area is located in the south part of the building to avoid obstructing or interfering with the hotel's main activities. In order to take advantage of the best views and the building's best orientation which is towards the north, the suites were sited on the eight upper floors.

According to the precedents studied, the building typology regarding high-mountain hotels includes small spaces, sloping ceilings and very few openings. This project intends to make the most of the impressive natural views by making the hotel more glass-like towards the north and less transparent towards the south.
In line with the main subject of this conference, this research will centre on the hardest to control natural threats such as earthquakes and avalanches as determining factors.

2.2. Architectural Response to the determining factor: Avalanches

Studies were conducted to determine what had happened with the pre-existing hotel and with the chapel.

The studies showed that the former hotel walls were not linked to each other, the structure was formed by independent walls. On the contrary, the chapel was composed of columns, buttresses and an apse that channeled the avalanches into that area. In the light of these facts, an embankment was built so as to divide and channel potential avalanches and landslides and to protect the whole complex. Another part of this passive protection system is, in fact, the outer shape of the building.

As shown in figure 3, the triangle shape of south side of the building, imitates the embankment's shape; the service-oriented area is made up of two levels built of reinforced concrete with very few openings. The reinforced concrete interior walls are the last mean of protection for the hotel guests and complete the avalanches and landslide defense system.

The dinning room and the living-room areas were protected by forming them into terraces and by adding them an iron and concrete structure of certain height in order to channel the material exceeding the defense into the areas designed for such purposes.

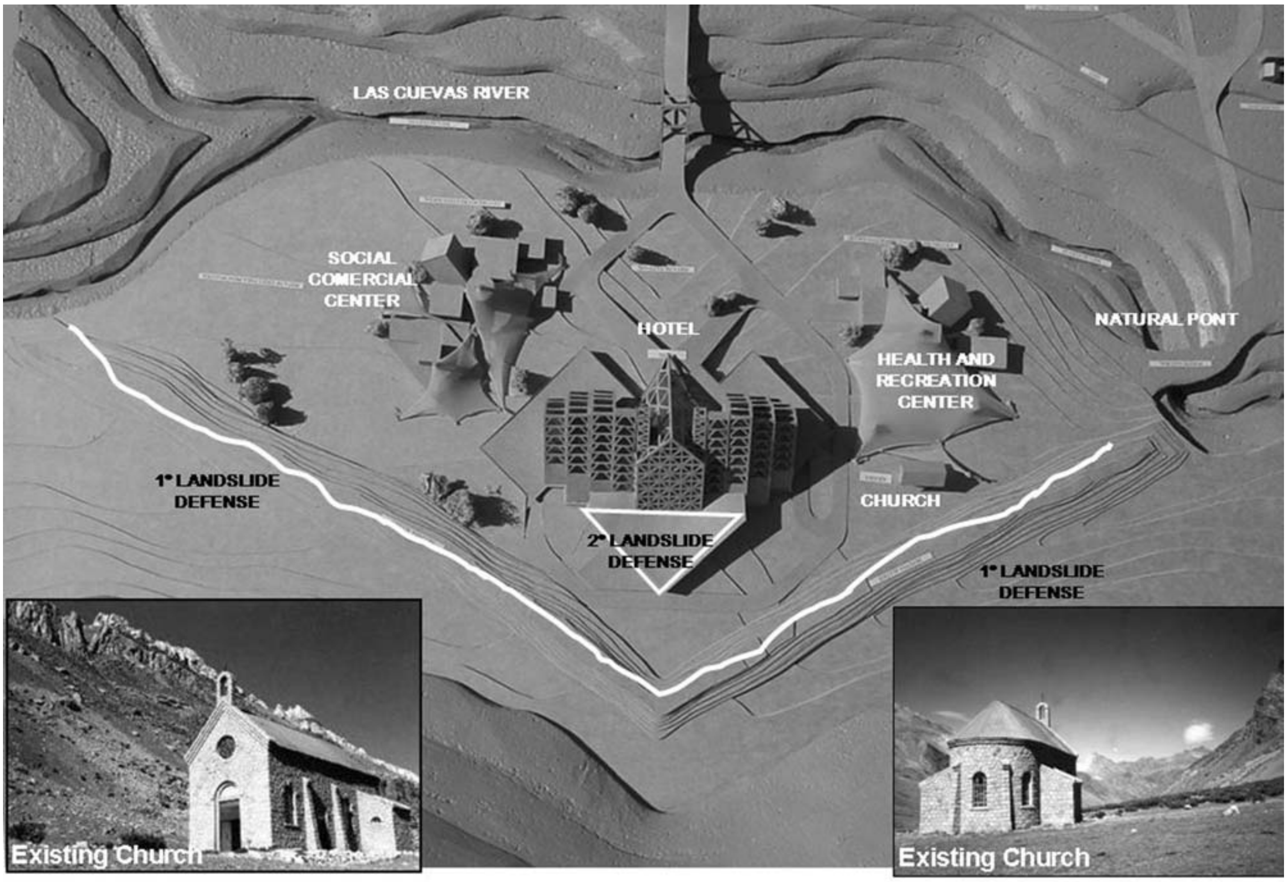

Figure 3: **Embankment and Outer Shape of The Building: Passive Defense Systems against Avalanches and Landslides**.

In order to avoid large snow accumulation, defenses on the upper mountainside will be placed as additional protection. Controlled explosions will also be carried out to reduce potential avalanche's size and sliding material.

2.3 Architectural Response to the Determining Factor: Earthquakes

The structural design was present from the very beginning of the project otherwise it would have been impossible to design these structure-based spaces.

Architectural and structural designs were developed jointly. Thus, the structure fulfils a double function: as support of the structure and as part of the formal plastic language of the architectural design, without adding unnecessary elements. (See Figure 4)

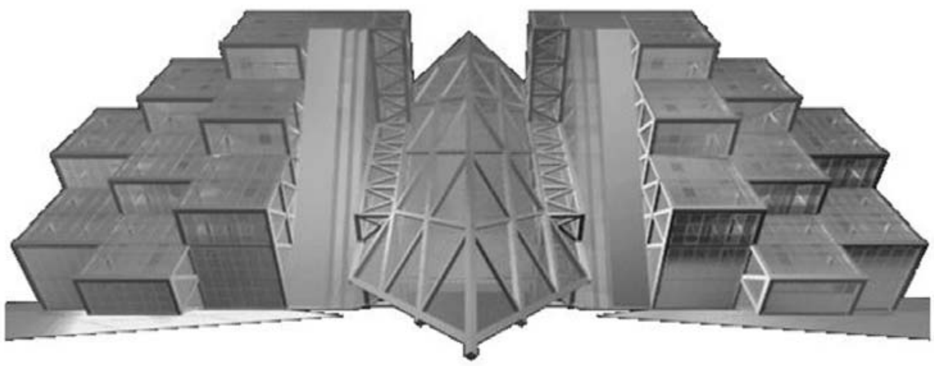

Figure 4 : **Building's north frontage view**

The building is divided by seismic joints into smaller and more regular buildings: east wing, west wing, main hall and the service-oriented area. The hotel is formed by repetitive units (the suites). (See Figure 5)

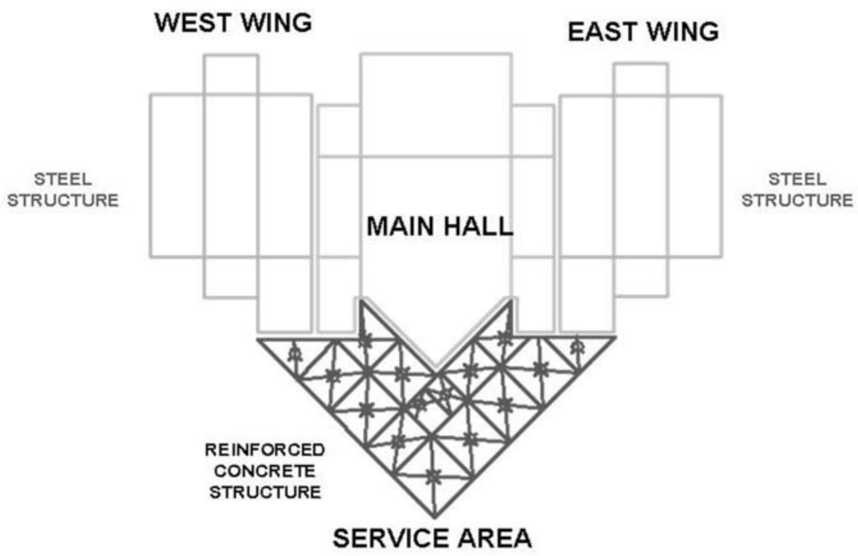

Figure 5: **Complex configuration**

The structure of each wing is formed by four large resistant triangle-shaped planes placed in a north-south direction crossed by other east-north oriented sloping planes and by mezzanines. The resulting structure is a seismic resistant spatial system that far from obstructing or interfering with the hotel's different activities it provides existence, richness and spatiality. For example, the structures do not interfere with the views of the suites since they were displaced towards the corridors, where they constitute them structurally, functionally and plastically.

The structure's behavior is not excessively out of balance due to the south frontage, the internal sloping planes and the mezzanines. Likewise, since the torsions were moderate, the eccentric truss' distribution was chosen, which is ductile and reduces deformations. (See figure 6)

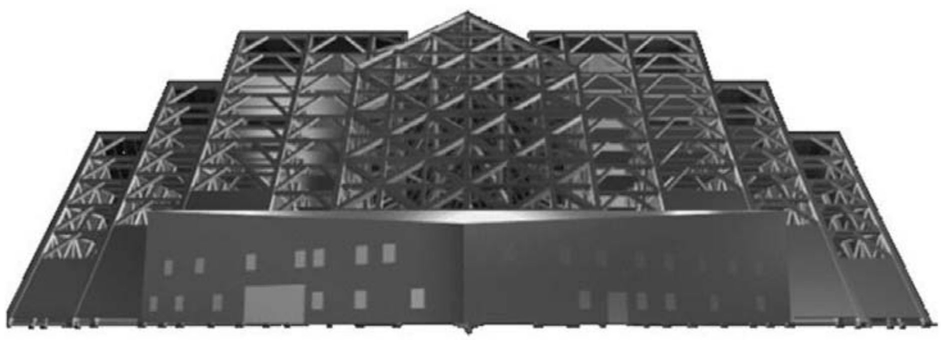

Figure 6: **Building's south frontage view**

It was decided to place the structure at specific areas of the corridors instead of placing it in the front side of the building this led to a torsion reduction and caused no interference with the landscape view. However, a certain degree of torsion deformation had to be admitted.

The longitudinal and transverse displacements as well as the structure's deformation were very low. The maximum deformation (along the whole height) was 0,12 % in direction x and of 0,088 % in direction z. (See Figure 7 and 8)

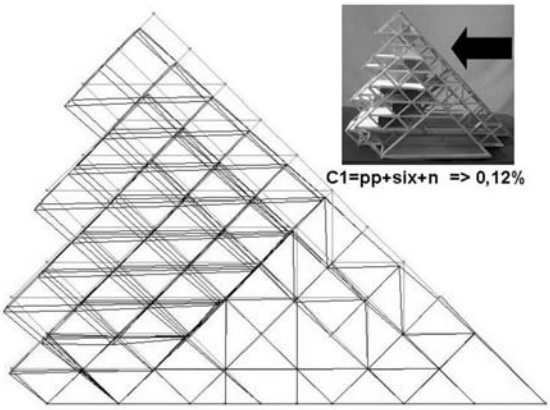

Figure 7: **Maximum deformation in direction x**

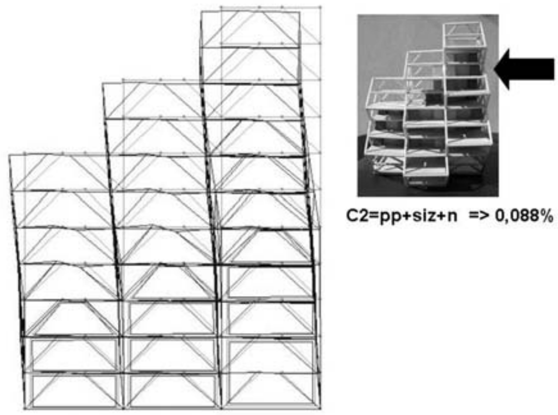

Figure 8: **Maximum deformation in direction z**

In case it had been necessary to reduce the resulting torsion by aesthetic and functional reasons we would have had two options:

a. provide the north frontage with resistant planes stiffened in their central part (33 % of eccentric triangulations) in this way, eccentricity is reduced causing a torsion reduction. This reduction in the deformation values affects those suite's views.

b. provide the north frontage with resistant planes having stiffened lateral (67 % of eccentric triangulations) in this way, eccentricity is reduced even more causing a significant torsion reduction. This reduction in the deformation values would affect those suites' mountains view even more.

The original idea was that the hotel resembled some huge rock crystals emerging from the mountain; the triangulations did not make this possible so it was decided to replace them by a reasonable structural design. (Figure 9)

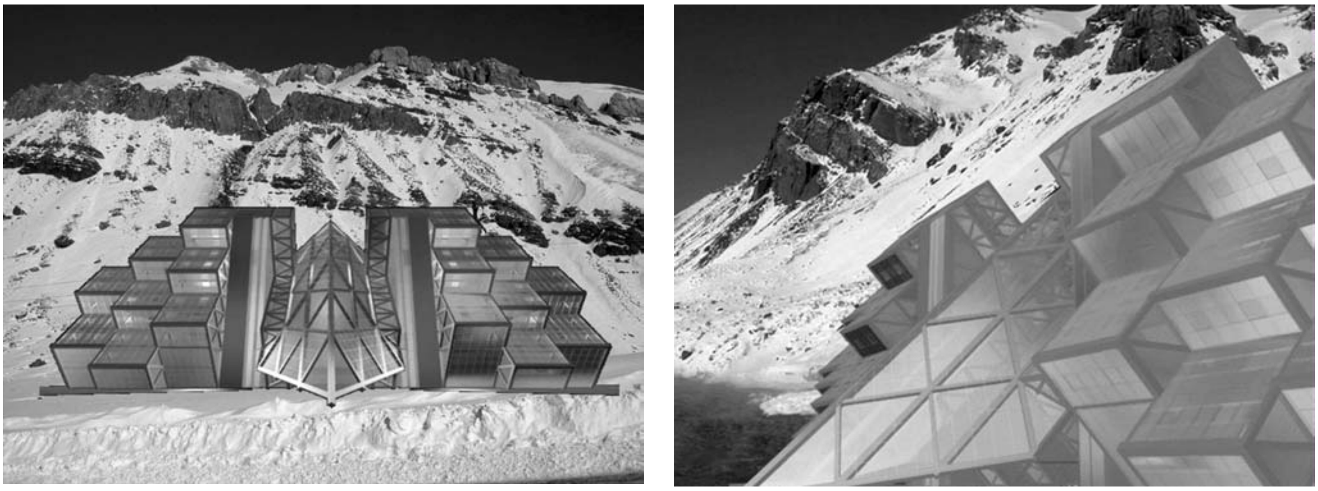

Figure 9: **Hotel resembled some huge rock crystals emerging from the mountain**

2.4. Integration with the surroundings

The integration with the surroundings is given by the building's triangular shape which resembles a mountain emerging, in the form of rock crystals, from the depths of the Cordon del Plata (Silver Chain of mountains). This architectural alteration imitates the rocks outcrops arising at different heights. The ocher color, inspired by thermal waters that stain the foot of the mountain, blends in perfectly. (See figure 10)

Figure 10: **Side view of the surroundings**

2.5. Strategies for reducing energy consumption.

Geothermic exploitation was the key to solve the energy dilemma. First, cold water is injected to get hot and minerals free water which is then pumped to all the suites and rooms for heating and energy generation purposes. Solar energy is used as combined system.

In order to preserve such energy and to minimize the heat loss, the hotel's glazing was built of double hollow-chambered tempered laminated glass. Solar energy of the north frontage was used as alternative energy.

3. CONCLUSION

All the efforts to bring architecture and art together will be unfruitful as long as technology continues to be left aside in the creative process of the architectural design. To know the relationship between structures and technological knowledge is essential to understand the world of architectural shapes.

It is important to consider design as a method for integrating functional, structural, social, psychological and economic needs relating to the architectural design. In this context, earthquakes and their consequences, as well as the energy dilemma represent additional difficulties and forced this dynamic being to produce its own energy.

Beyond its main role as support of architecture, structure offers various creative possibilities that architects must know and apply. Structure and architecture must be developed jointly and approached from a global perspective since it is through structures that it is possible to design safer and more rational and economic new projects.

It is also fundamental to consider the influence of the site's culture, weather and geography and to find design-based solutions for seismic and energy related problems. It is also important to acknowledge that architecture, engineering and other sciences are jointly responsible for the design.

Solar and geothermic energy constitute not only valid alternatives in view of the exhaustion of natural resources but also a major contribution to overcome energy problems.

We attempt to find the best design solution for solving efficiency and economy-related problems and providing the building with a functional combination of great plastic expression. In this way, the building will become an icon of the region and it will also function as a hazard control mean preventing potential disasters in that area.

The purpose of this work is to prove that it possible to design using nature as an ally instead of dominating it. Designing an architectural work which, far from damaging the environment or making it more vulnerable, preserves it, it make us believe that is possible to coexist with our planet and to find a path to a more promising future.

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