

BASE ISOLATION IN ARCHITECTURE

Adriana Guisasola¹

¹ *Specialist in Prevention, Planning and Overall Handling of Disaster Prone Areas. Specialist in Higher-Education. At Present, attending the Doctorate in Architecture. Professor, Dep. Structures - Faculty of Architecture, Urban Planning And Design - University of Mendoza. Email: maguisasola@yahoo.com.ar, Web: www.adrianaguisasola.com.ar*

ABSTRACT

Mendoza is located on a highly seismic region of Argentina (South America), it is crucial to take into account such factor when initiating any architectural project in the area.

The main purpose of this research is to deepen the understanding of several matters dealing with prevention of natural disasters which is regarded, at present, as an essential strategy for 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 variables incorporation at the early stages of the creative process makes it easier and improves the final architectural results.

This research aims at contributing to the integration of architecture and engineering through the analysis of the architectural implications derived from the use of this technology. And it also endeavors to accumulate the knowledge necessary to develop a project using such technology from the very first stages. This study also attempts to prove that buildings can be more efficient, secure, functional and economical and that new seismic design alternatives can be achieved.

The interdependence existing between architectural design and its context is the starting point to determine the architectural implications arising from the use of base isolation. In such context architectural variables such as morphology, functionality, aesthetics, economics, resistance, structural behaviour, materials, construction techniques and space-time interact and buildings must provide a proper response to earthquakes.

KEYWORDS: architectural structural design, earthquake architecture, base isolation

INITIAL CONSIDERATIONS

The present research paper is a summary of a PhD Thesis in process. The Thesis director is José Antonio Inaudi, Ph.D. in Civil Engineering, and the Co-directors are Juan Carlos De La Llera, Ph.D. in Civil Engineering and Agustín Reboledo, Engineer. Daniel Moisset de Espanes and Juan Jose Marino are consulting architects.

It intends to be a sort of tip of an iceberg by triggering questions which, due to the complexity of the problem treated, must be approached by different sciences

It also constitutes the next step after the research on THE STRUCTURE'S OF ARCHITECTURE submitted to the 14th WCEE 2008 in Beijing. Through it many natural limiting factors were solved by providing proper architectural answers. Base seismic isolation technology allows developing more advanced, audacious, safe and modern designs complying with the requirements of sustainable architecture.

There exist a very close relationship between architecture and engineering and both of them must cooperate to transcend the bounds of architectural design in seismic regions.

1. INTRODUCTION

Among the several hazards that threaten man, natural disasters such as earthquakes are caused by uncontrollable factors. Consequently, earthquakes can not be avoided, but they surely can be prevented and their consequences diminished. Different preventing measures against earthquakes have been accounted for throughout history, although not all of them were equally effective in the light of present knowledge. Generally, they come up after a disaster of great proportions.

The global incidence of earthquakes turns architecture into an essential tool to provide appropriate answers to this problem and lessen both human and material damages.

Architecture and Earthquake Engineering share the building construction. Earthquake engineering provides with new seismic resistant elements which architecture must take into account to give better answers to this conditioning factor. This approach may then be defined as Earthquake Architecture. (Robert Reitherman 1985, Christopher Arnold 1996, Andrew Charlesson 2004).

2. ANTECEDENTS

Throughout the years, several attempts to withstand earthquakes' strength have been carried out but, the battle has been uneven since earthquakes' functioning mechanisms have been comprehended since the middle of the twentieth century and this fact has caused many victims and material damages.

For example, the Imperial Hotel of Tokyo, built by the architect Frank Lloyd Wright, used a device to withstand earthquakes: The hotel was built over a sand bed and when the 1923 earthquake battered Japan, it floated like a ship on this sand bed and resisted the movement.

Another example is given by the Olive View Hospital in California; the building was conceived with the more advanced structural design available at the end of the sixties; however the 1971 earthquake showed that there were still structural matters to be taken care of.

The case of the San Francisco City Hall in California is also worth-mentioning; it was built between 1904 and 1906. The 1906 earthquake damaged it considerably so it was demolished and built in another place making use of the more advanced knowledge of that time. The building resisted until it was seriously damaged by the Northridge earthquake. In order to preserve this monument, witness of the history of San Francisco, a structural rehabilitation was conducted using state-of-the-art knowledge: base isolation. The building is, at present, the largest isolated building on earth and the operational headquarters of the city in case of disasters.

As time goes by, man seem to root architectural works deeper and deeper in the ground. Nowadays, there are two options available: to accept the potential damages level, or else to avoid damages by not laying the building's foundation on solid ground but rather separating them through a transition structure. The buildings that take advantage of new technologies have applications which add a new dimension to architectural design.

It is important that new buildings, located at earthquake-prone zones, are designed with state-of-the-art technology such as Base Isolation so as to solve the problems they face.

Earthquake protection systems are used to reduce risks and preserve people, their property and other factors non-calculable in economic terms. This new technology influences the buildings features: the structures are not very slender; their proportions are not very large, etc.

Architectural design and other interdisciplinary approaches will be taken into account in the present research. New technologies will provide ingenious solutions according to present context needs.

3. DEVELOPMENT

Base isolation is a step forward in earthquake engineering which reduces earthquakes effects on architectural works. However, architects do not deeply know the alternatives that this technology offers. It will not be possible to design using this technology from the very first stages of the architectural design until architecture and engineering begin working cooperatively.

Architects must know these major advances in depth and include them as designing tools of a life-protecting system against earthquakes effects on their architectural works.

This work attempts to identify the limits and possibilities imposed by architecture to the concept of base seismic isolation. It also aims at finding out how architecture interacts and deals with the limiting factors characteristic of seismic isolation. By the same token, it assesses the potential of new and less seismic-conditioned projects.

3.1. Contextualizing the Problem

The use of seismic base isolation reduces building damages considerably. This technology was first developed in Japan and New Zealand, and then spread to the United States, China, Russia, Italy, Chile and other countries. In the Province of Mendoza there is a student's dormitory built based on this technology.

Architecture has incorporated this new damage reducing technology into its design stages. See Figure 1 and 2

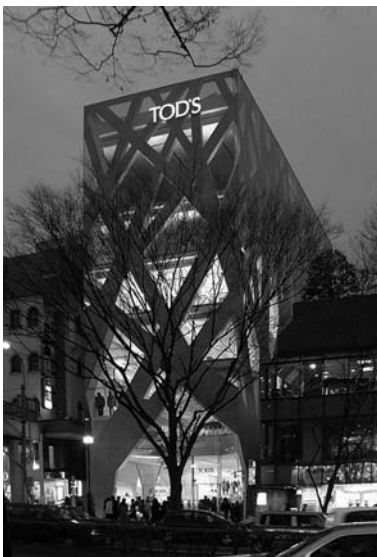


Figure 1: Tod's Otomesando, Japan



Figure 2: Shanghai Circuit, China

Most buildings having base isolation have been rehabilitated, that is, they were subjected to this seismic protection method for preservation purposes. The results achieved have been positive.

However, the consideration of base seismic isolation at the project's design conception would optimize not only the architectural design, but also the seismic protection systems and would open up new design possibilities for earthquake prone regions. Baha'i Temple in Chile serves as an example of this. See Figure 3.

Therefore, architecture must incorporate these new technological alternatives into its design strategies in order to protect people and buildings from potential earthquakes.

3.2. Conceptual framework

The principles of seismic resistant structural design are fully developed and there is general consent about its importance among practitioners and the scientific and academic community.



Figure 3: Baha'i Temple in Chile (in progress)

New technology-based seismic protection methods are very recent. The original idea was conceived a long time ago, but, in those days, it was impossible to perform it. Nowadays, thanks to new materials and technologies, buildings can be provided with base isolation which separates the building from the ground movement and absorbs earthquake energy. Thus, the structure that lies on the isolators avoids severe damages. An earthquake measuring 8 on the Richter scale can be perceived as 5.5. The damage level caused by one or the other is drastically different.

This new approach involves a conceptual and attitudinal evolution as well as a change in the decisions to be taken for solving the problem. On the one hand, the emphasis is put on controlling the damages by designing them, but not on eliminating them. On the other hand, the stress is laid on achieving a major damage reduction by using new mechanisms. The solution is rather different and requires adaptation to the changes that brings new considerations for the concept of reducing earthquake-caused damages on buildings.

Architecture must get involved with technologies that control earthquake damages. And it must also play a major role in design, as well as in the architectural possibilities that may contribute to the integration of this method as a solution to the seismic problem.

Architectural design based on new technologies has not been fully developed yet. Regulations refer to it only as construction details. It is then necessary to study how these new technologies affect the design and the ways to express them through architecture.

This is a new concept of architecture, a new order, or perhaps, a different concept that describes the use of new elements and keeps pace with knowledge advances.

3.3. The Architectural Design

The architectural design brings many solutions to different problems architects have to deal with when creating an architectural work. Earthquakes are one of such problems. The earthquake resistant architectural design variable is then crucial and must be a part of the design's conception.

This paper will deal with the importance of knowing what constitutive elements of architecture change or suffer transformations when designing with new technologies. Such modifications or transformations are the implications and they will be approached by the structural dimension. For example, the use of reinforced concrete which revolutionized the building techniques of those days and helped reaching unexpected design development, buildings' possibilities and heights, and longer clear spans.

The case of study will be approached similarly, since through new base seismic isolation technology for high earthquake hazard risk regions, it will be possible to modify previous models for the structure located over the seismic devices, and it will also permit to explore new architectural design possibilities. By exceeding the limits

imposed by traditional building structure design, it will be possible to study new architectural design alternatives more appropriate for the seismic limiting factor.

The use of seismic base isolation has been widely accepted and embraced by the international scientific community. It has been employed throughout the seismic world mainly in buildings of great importance such as hospitals, temples, nuclear centrals, museums, airports, high complexity laboratories, valuable heritage buildings, houses, etc. Especial safety measures have to be taken to protect the content of such buildings in case of earthquake.

Why do architects influence the building's seismic response? and why are they a source of different interests for engineers? "Because architects conceive and control the building configuration." (Arnold and Reitherman, 1987).

3.4. Hypothesis Statement

Hypothesis 1: The use of base seismic isolation technology from the architectural project's conception gives rise to new possibilities which allow architects to overcome certain limitations that the seismic structural design imposes on architectural design.

Hypothesis 2: Designs including the use of base seismic isolation since the project's conception, improve the architectural performance of buildings using such technology.

4. RESEARCH ADVANCES

The combined use of variables entails interdependency between them in the architectural design in order to improve and fit in with the response of a given architectural work. When the work is set in a context and it is affected by external actions such as earthquakes, it must respond through its internal actions (architectural performance). The architectural performance can be defined as the functioning regarding the application of the criteria formed by the work's architectural variables.

4.1. Architectural Implications

The interdependence between the architectural design and its context will be the starting point to establish the architectural implications derived from the use of seismic isolation.

All the architectural variables involved in the present research will interact in this context and the building will provide the appropriate responses in the event of earthquakes. Such variables are: morphology, functionality, aesthetics, economy, safety, structural behaviour, materials, construction techniques, psychological aspects and space time.

At present, the author of this research is developing the morphology variable and structural behaviour in her Doctoral Thesis.

4.1.2. Morphology Variable

The aspects affecting architectures' structural behaviour and subjected to the morphological decisions taken by the designer will be analyzed.

4.1.2.1. Resistant systems

The behaviour of traditionally and base-isolated designed structural frames, structural partitions and diaphragms will be analyzed and compared.

4.1.2.2. Architectural Configuration

Dimensions, as well as Horizontal and Vertical Composition will be analyzed. (See figure 4)

An analysis of common configuration experimenting problems in earthquakes related to the architectonic program such as soft story will be conducted. (See figure 5)

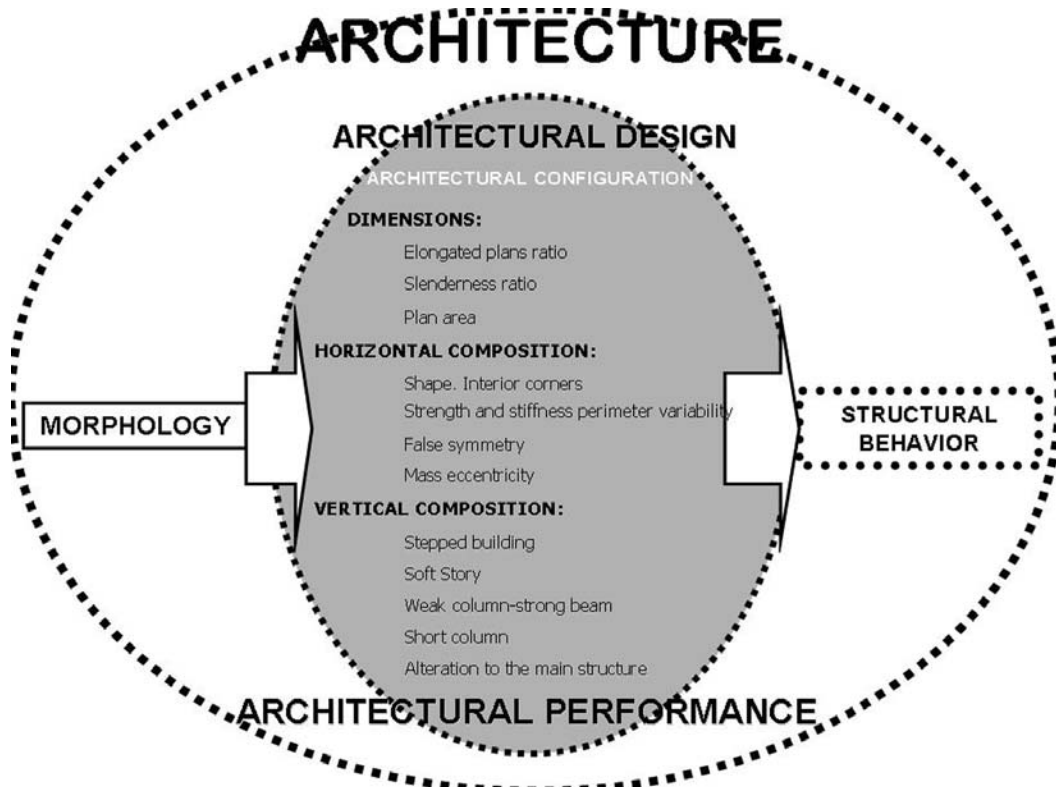


Figure 4: Morphology Variable Elements to be analyzed






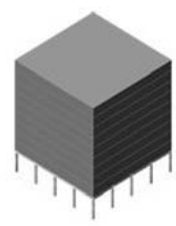
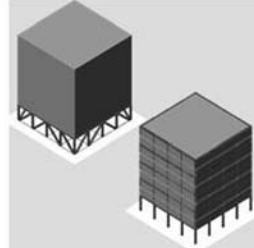
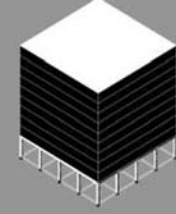



ARCHITECTURE+ EARTHQUAKES	EARTHQUAKE ARCHITECTURE			EXAMPLES OF BASE ISOLATED BUILDINGS
	INADEQUATE CONFIGURATION	ADEQUATE CONFIGURATION	ADECUATE CONFIGURATION WITH BASE ISOLATION	
 Taiwan 1999				 California
 India 2001	3- VERTICAL COMPOSITION: Soft Story			 California
 Kobe 1995				 India
 China 2008	It causes sudden stiffness change at the discontinuity point	Add triangulations, columns. Use mega-structures	¿Is it convenient to design buildings with soft story?	 New Zealand
	Open indoor spaces, commercial facilities on ground floor or open indoor spaces at any story are part of the architectonic program	There appear interferences: resistant structures are necessary where plans with less structural elements are required	¿Is it possible to design plans using less resistant structural elements with less interferences in the architectonic space?	

Figure 5: Soft story

4.1.2.3. Analysis of soft story's structural behaviour

The structural behaviours of the superstructure with inadequate configurations for seismic regions, adequate configuration for seismic regions and with adequate configurations for seismic regions with base isolation were analyzed. (See figure 6)

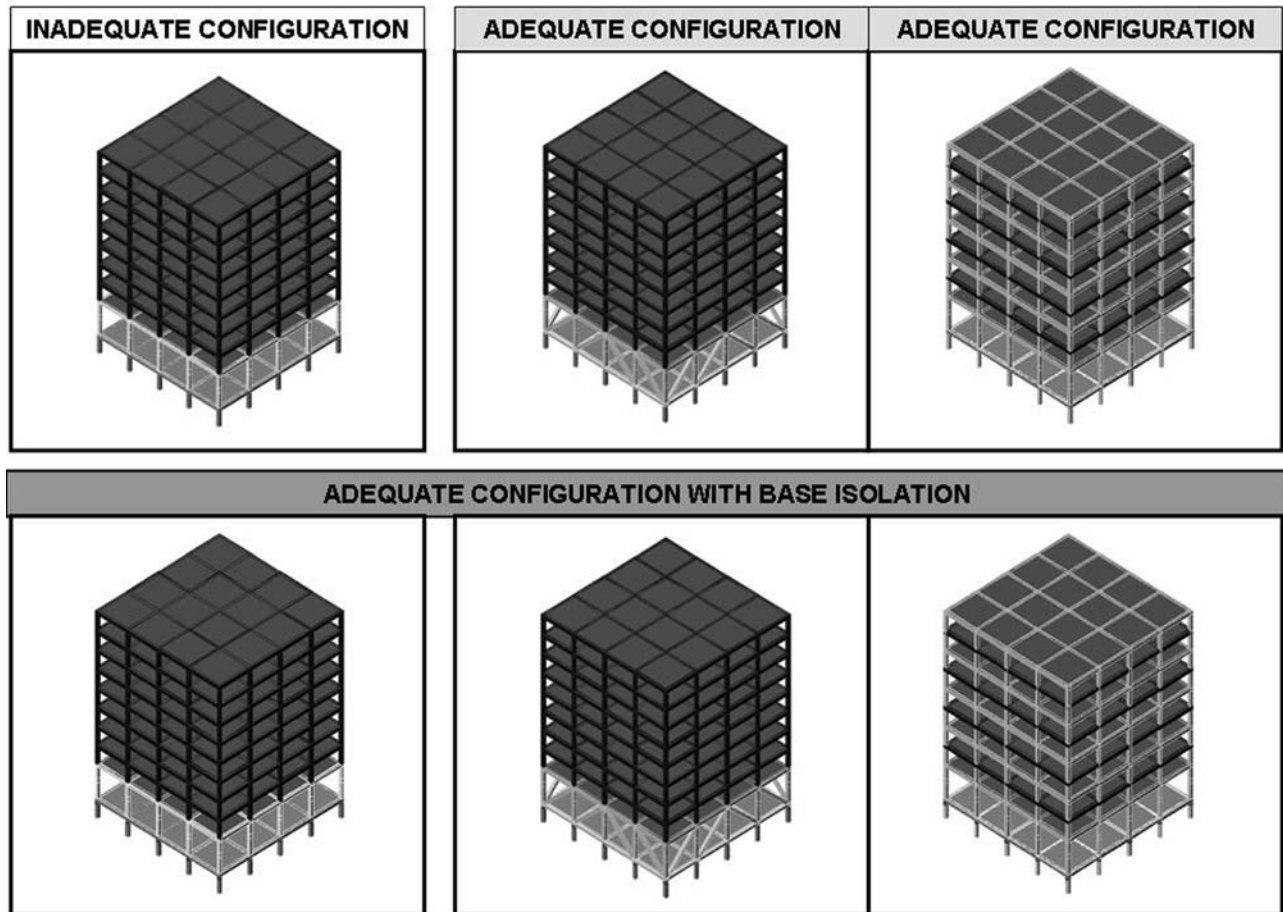


Figure 6: Comparison between adequate, inadequate configuration and adequate configuration with base isolation.

4.1.2.4. Partial Conclusion

The results obtained from the structural behaviours will be useful to answer the architectural questions necessary to achieve adequate designs including seismic isolation as a protection tool.

5. CONCLUSIONS

Architecture must provide a passive protection mean against seismic hazards. Architects must also know and include such advances and use them as life-saving design tools intended to reduce damages caused by earthquakes.

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 forms.

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.

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

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