Assessment on the Future Seismic Behaviour in Heritage Buildings In San Juan, Argentina

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SUMMARY:
San Juan city is situated in the mid-west of Argentina in South America. It is located at 350 km to the east of the line of convergence of the Nazca and South American plates.
In January 1944, there was a significant quake, IMM=IX, M=7.4; DH=14km at San Juan city, which destroyed most of the city and its cultural identity.
The analysis of most relevant aspects of Obras Sanitarias Sociedad del Estado building, an emblematic institutional building built after this earthquake, are presented in this research. This building suffered considerable damage during the November 1977 earthquake, IMM= VIII at San Juan city. It was necessary to retrofit it. This was done by placing resistant walls.
This research describes not only the current state of the building but also its possible behaviour if faced with a future earthquake. This is an important aspect to consider in cities with high seismic risk.

Keywords: Heritage Buildings Seismic Risk Structural Assessment

1. INTRODUCTION

At present, there is a global trend to reassess the cultural and historical heritage. Involves both preserve, improve the quality of urban life and protection, as the sense of citizens belonging to a place that has been adapted to meet their needs.

In seismic and arid areas as San Juan province, in the Argentina's center western region, architectural might be particularly damaged not only by climatic and human factors, but also by destructive earthquakes taking place in this area.

San Juan city, located in the country's most seismically active zone, was almost completely destroyed in 1944 by an earthquake[1] of I_{MM} = IX (M=7.4; DH =14 km).

That was an important time for the development of technology and subjects related to building in the country. The engineering and architecture were involved in a process of knowledge development that would allow reduce the vulnerability of buildings to the occurrence of future earthquakes.
The process of rebuilding the city was heavily influenced by the stigma of this earthquake.

Built over 50 years ago, these buildings that were designed in order to "rebuild" the city can be seen today as architectural heritage as they account an original fact of this style, taking into account their Architectural and Structural design as well as their surrounding conditions.

Since 1996, the Facultad de Arquitectura -Universidad Nacional de San Juan- has been developing research projects related to seismic risks in San Juan city in order to reach a comprehensive

[1] Hstorical Earthquakes - Instituto Nacional de Prevención Sísmica - INPRES - - Ministry of Federal Planning, Public Investment and Services - San Juan – Argentina.

understanding of the city and its meaning through its buildings. It also suggests the studies of different architectural construction since each of them show its own identity.

The analysis of most relevant aspects of Obras Sanitarias Sociedad del Estado -OSEE- building, an emblematic institutional building, are presented in this research.

2. QUALITATIVE SPECIFICATION OF OSEE-

2.1. Historical background

The OSSE building is located in the central area of San Juan city, at a main Avenue nearly of the city's central square. The building was designed by the Public Department of Sanitation Project in the Nation, as a contribution to the Urban Reconstruction Plan implemented from the year 1947. It was built on an area of of approximately two thousand square meters and an effective occupation of the land of forty percent floor

First time in San Juan, were used Le Corbusier Architecture Five Points. It is the most distinctive contribution to the Modern Movement handled.

The building is one of the most representatives of the Modern Movement in the city. First time in San Juan, were used Le Corbusier[2] Architecture Five Points.

- the house supporting it by pilotis – reinforced concrete stilts;
- the open plan;
- the free facade, meaning non-supporting walls that could be designed as the architect wished;
- the garden terrace;
- elongated window;

2.2. Cultural Value of the Building

It is important to determine the cultural value of the building. This was established by “The Burra Charter”(3). This value is determined through:

- Symbolic Value: This building is representative of the collective memorabilia. It was erected according to last for ever, as symbols of a civilization to be transmitted to future generations.
- Architectural Value: It’s one of the Modern buildings of the rebuilding’s process of the 20th century.
- Landscape Value: It’s situated in a privileged place in the historical core of the city.
- Esthetic Value: For its space originality, its configuration, its scale and its proportions stated in “The Burra Charter”.
- Historical Value: The heritage of these buildings, resides in the perpetuity of offering a specific historical and cultural identity.
- Social Value: It was a referent building for the citizen of San Juan city.

3. METHODOLOGY

The study of the building is approached from:

- Description of the surroundings
- Architectural Description
- Cultural Heritage Assessment of the building
- Description and structural analysis

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[2] Charles-Édouard Jeanneret, better known as Le Corbusier; October 6, 1887 – August 27, 1965,

4. ARCHITECTURAL DESCRIPTION OF THE BUILDING

The first thing that is the appearance of a regular pattern that extends throughout the plant. Each family of structural elements, cladding and internal partitioning is an isolated and independent whole. Each group has its own logic. Their relationship embodies a complex interior space.

The plant shows a condition strictly plastic, which would allow its reading as if it were a picture purist. The open plant has a paradigmatic form. Continuous concrete slabs supported by a grid of identical circular pillars that separate the volume of the soil to incorporate the landscape composition. An open floor plant is constructed using this structure, rhythmic and reticulated, it introduces the traditional elements

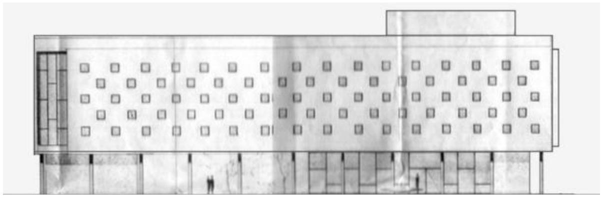

Figure 1 Main Façade - Facade North

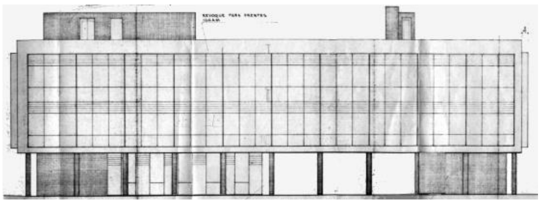

Figure 2 Facade South

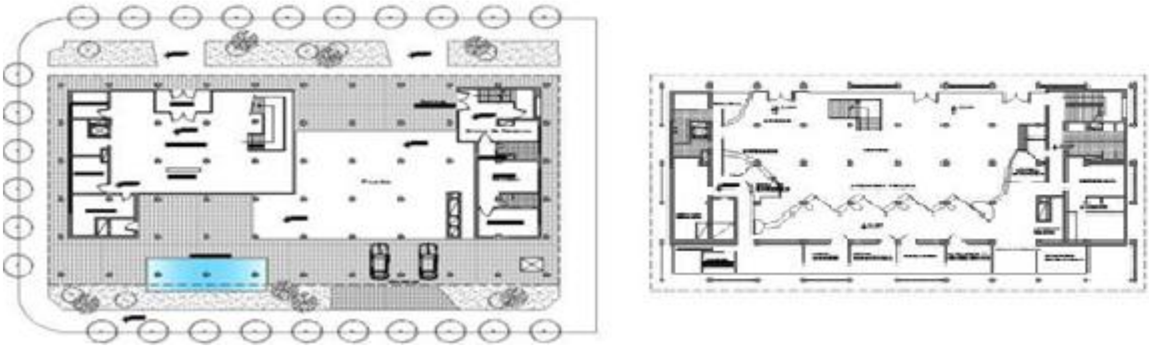

Figure 3 left, Old floor ground plant - right, Present floor ground plant

The figures 4 to 8 show the present facades of the building.

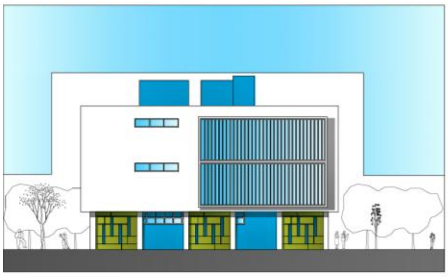

Figure 4 Facade East

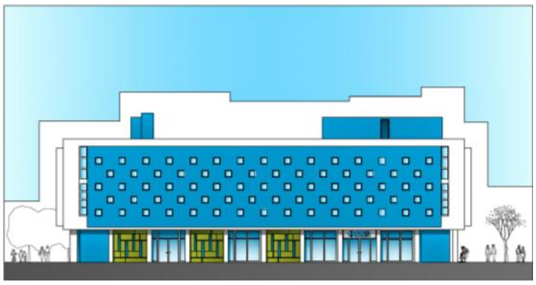

Figure 5 Main Façade - Facade North

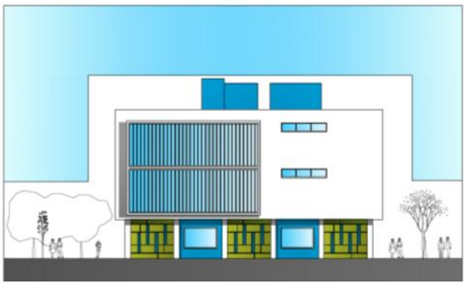

Figure 6 Facade West

Figure 7 Facade South

5. DESCRIPTION AND STRUCTURAL ANALYSIS

5.1. Methodology of Structural Analysis

The seismic-resistant capacity of the building has been evaluated bearing in mind the relation between its potential seismic capacity and the assumed seismic risk.

The potential seismic capacity has been calculated according to different parameters, such as structural typology, dimensions and irregularities of the building, strength and ultimate strength of the materials employed, etc. The assumed risk depends –among other causes– on the earthquake hazard –potential maximum seismic intensity– and the local features of the soil foundation.

This evaluation has demanded different tasks, as reviewing existing documents (historic records are essential to elaborate a diagnosis to preserve a monument), evaluating structural capacity according to documents, site inspections, the building's deterioration and environmental analyses.

The procedure applied for the study of each building allows the revision of Reinforced concrete buildings constructed in seismic zone.

The most important feature of this method is that it gives greater importance to the analysis of resistance than to the internal stresses that could eventually cause an earthquake in the elements of the structure. It can be said that for the application of the method it is not practically necessary to realize a detailed analysis of internal stresses. The method also confers great importance to the determination of collapse mechanisms and energy dissipation of the elements, which are classified into different groups according to their behavior and type of failure.

5.2. Overview of Structure

The building plant is rectangular; east-west ground floor has circular columns separate from axis to axis of 4.05 m and a height of 3.50 m; released from walls. The first and second floor is a compact volumetric structure that generates a contrast with the flexibility of the ground floor.

It has a structural typology of frames in the main directions: North-South, 11 frames of 5 continuous lengths, East-West, 6 frames of 10 continuous lengths.

We set a model of the building which, was designed as a block, made up of: basement, extended along the east half of the building; ground floor, first floor, second floor and roof accessible.

During the earthquake of November 1977[3] the building suffered considerable damage, which leads to decreased resistance capacity[4]. Manifested stress concentrations in the northwest corner of the building, still observed nowadays cracks caused by the earthquake in the wall of the west facade.

The damage, see Figure 13, was motivated by its structural design, concerning the tenets of modernism, with a flexible ground floor and compact upper floors that gave a rigidity not contemplated in these stories. Studies by specialists, determined the consolidation immediate. Joined the structural reinforced with 12 concrete walls, each formed by a pack of 5 columns, placed between the columns on the outer sides of the building, increasing floor stiffness. The location of those is shown in the graphic information, Figure 8. Each concrete wall has openings whose purpose is to maintain "if possible" the architectural style of the building.

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[3] 7.4º magnitude on the Richter scale and intensity IX on the Modified Mercalli scale in the city of Caucete: and VII in the capital city
[4] Eng. Hugo Giuliani, Professor IDIA UNSJ

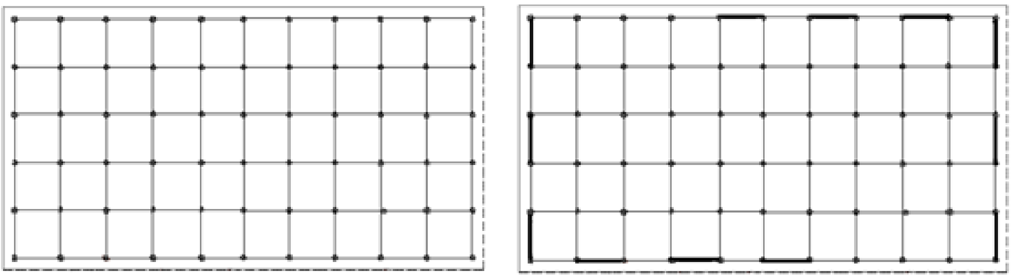


Figure 8 Schematic Plant Building.
Left, Old Structure in Plant - Right, New Structure in Plant, with Consolidation Walls

5.3. Building Capacity

The work carried out strengthened the structural symmetrical configuration in plant and elevation, a factor that lead to appropriate behavior to the seismic action.

There is a regrowth in resistance produced by the consolidation of the building, which contributes to higher earthquake-resistant capacity of the building.

There is not sign of structural damage after being consolidated, subsequent to the earthquake Caucete.

5.4. Seismic Demand - Seismicity of the Area

The sismicity studies of the location area were performed by the following isoseists.

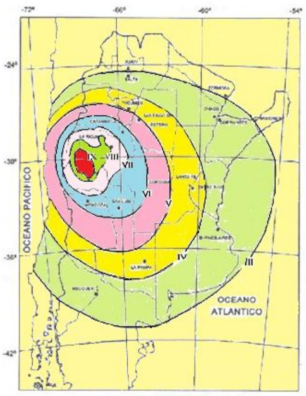


Figure 9 Isoseismics map of the earthquake[5] on October 27, 1894

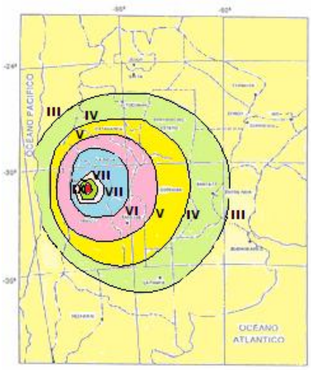


Figure 10 Isoseismics map of the earthquake on January 15, 1944

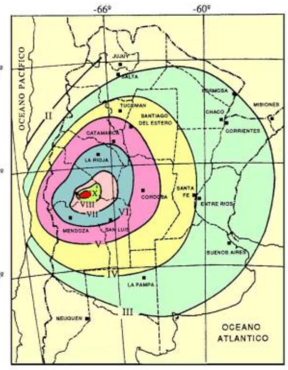


Figure 11 Distribution of intensities of the earthquake on November 23, 1977

Not only the city's seismic micro-zonation studies, but also its local ground features have been considered to estimate the assumed seismic risk. San Juan is situated in one of the most dangerous seismic areas of the country

In order to determine the seismic demand the following; seismicity studies, the occupation factor, the functionality and the heritage value of the building were taken into account. Resulting seismic demand is lower than the estimated capacity of the reinforced building.

The energy balance between the seismic capacity of the structure before and after consolidation, and the seismic demand, shows that the established design of the structure with a new structural type of

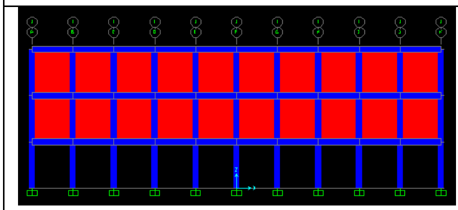
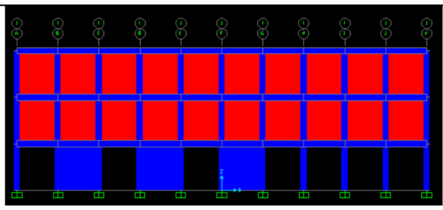
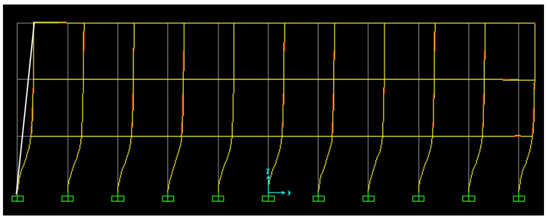
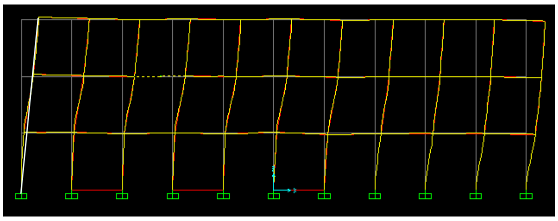
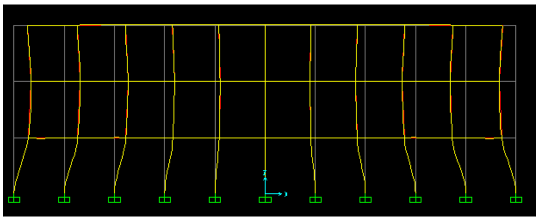
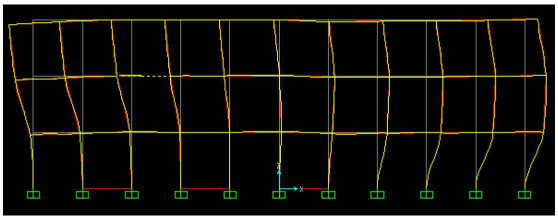
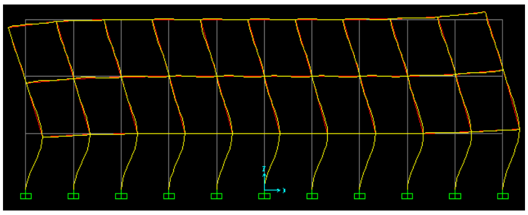
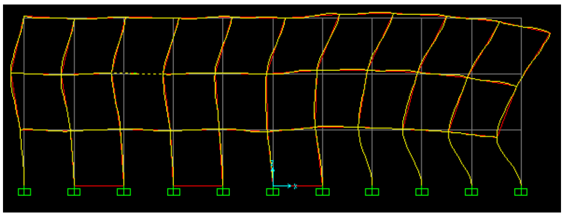
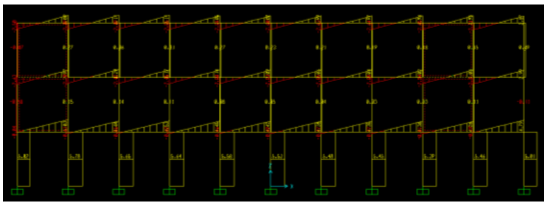
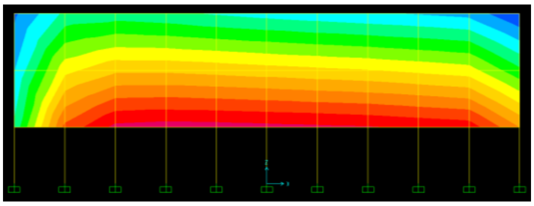
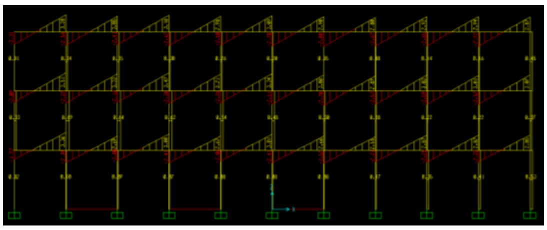
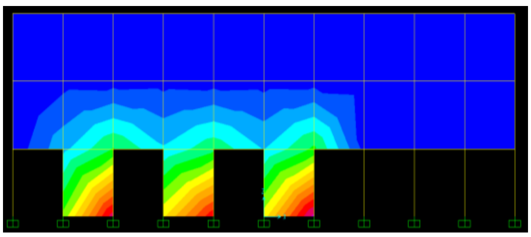
[5] History of isoseismals of earthquakes that struck the area of interest, San Juan - Argentina.
Laura Perucca, Angel Perez y Carlos Navarro – Inpres 2006

frames and concrete walls conforms to the requirements of the zone site

5.5. Other Studies Carried Out: Modal Eigenvalue Analysis

Completing the study we set models with the building structure in both directions getting the following comparative table.

TABLA 1.1

Model Unconsolidated	**Consolidated Model with Concrete Walls**
	
 Modal 1 T=0.258602 Eigenvector [0.18465; 0.17777; 0.15624]	 Modal 1 T=0.097700 Eigenvector [0.23401; 0.16226; 0.03453]
 Modal 2 T=0.048111	 Modal 2 T=0.045156
 Modal 3 T=0.047549	 Modal 3 T=0.037510
Shear Stresses in Frames and Concrete Walls and Masonry Walls	
	
Model Unconsolidated	
	
Consolidated Model with Concrete Walls	

• It is noted that the consolidated model best fits the pseudo-static analysis performed to calculate the seismic capacity by standards applicable in the city of San Juan, see the white line drawn on the mode shape of the first mode.

• On the other hand and observing the spectrum of the seismic standard, the demand will be higher for the unconsolidated model, since due to the structure stiffening the demand for the standard will be lower. See design spectrum of the standard Figure 12

• As for the shear stresses, we see that are concentrated in the first floor columns in the flexible model, while the shear stresses are absorbed by the walls in the structural retrofitting model.

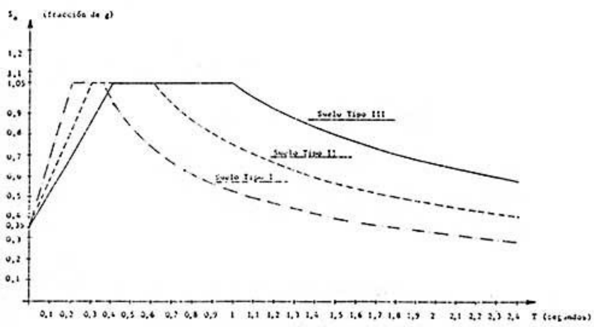


Figure 12 Pseudo elastic spectrum for seismic zone 4 ξ= 5 %

Everything seen in these modeling reaffirms the results obtained using the methodology of research.

6. CONCLUSION

From studies in this research shows that it is expected satisfactory performance of the "new structure" to the expected seismic loads to current standards.

In conclusion, to assure the preservation of this building treasured as an architectural and historical heritage, the following criteria should be considered:

- Respecting the building's original configuration, i.e. avoiding the addition or removal of structural and non-structural elements that may modify it in plant or in height.
- Respecting typical structural technologies proper of each construction, as the basic principle of preservation.
- Regarding the environment, it is necessary to determine *Historical Protection Areas*, since the conservation of the surroundings contributes to the preservation of the building.

Furthermore, and as a reflection of the team, it was found that every work of architecture is marked by his individuality, which means a new challenge to study, therefore able to obtain a record of the behavior of strategic buildings in the city is a desirable goal in areas of high seismic risk.

7. GRAPHIC INFORMATION

Figure 13 Northwest corner

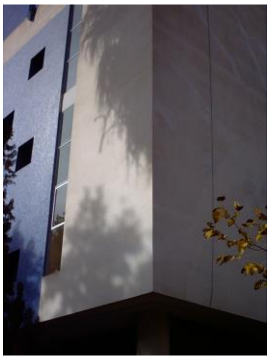


Figure 14 Southwest corner.

Figure 15 Main Entrance.

Figure 15 Free columns

ACKNOWLEDGEMENTS
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