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SEISMIC VULNERABILITY OF A REINFORCED CONCRETE BUILDING USING THE CAPACITY SPECTRUM METHODOLOGY

Álvaro Rafael Caballero Guerrero[1], Carlos Millán[2], Fernando Jove[3]

[1]*Department of Civil and Environmental Engineering, Universidad del Norte, Barranquilla, Colombia*
[2]*Department of Civil Engineering, Universidad de Sucre, Sincelejo, Sucre, Colombia*
[3]*Department of Civil Engineering, Universidad de Sucre, Sincelejo, Sucre, Colombia*

Abstract

The designs carried out, following the requirements of the Seismic Resistant Standards, should present low Vulnerability and be more reliable in the face of seismic threats different from that of the design; but recent seismic events have shown the opposite, so it is necessary to evaluate the Seismic Vulnerability of structures based on the control of the Dynamic response. In this study, the Seismic Vulnerability of a reinforced concrete framed building was determined against three levels of seismic threat (service, design and severe earthquakes), using the methodology proposed by ATC-40, or the Capacity Spectrum methodology through an analysis Pushover, which resulted in this building, has the capacity to withstand a severe earthquake (Aa =0.15g), although the first floor beams are in the range of collapse, so its reinforcement is recommended.

Keywords: Vulnerability, Seismic, Pushover, Capacity spectrum

1. INTRODUCTION

The question we ask ourselves today is whether the earth's seismic activity has increased? Given that it is very common to hear the news about the damage caused by earthquakes; but research on the subject shows that this is not the case. What is really happening is population growth, which is what really increases the loss of human and economic life over time, becoming incalculable. Therefore, it is necessary to know how vulnerable our buildings are to the seismic threat, especially those that, due to their use, concentrate a greater number of population (Boukri et al., 2018) and (Hassan et al., 2022). The present study of seismic vulnerability was carried out in a classroom building of the Universidad de Sucre - Colombia, and its objective was to find the degree of structural vulnerability of said building before three levels of seismic threat (service, design and severe), of according to the seismic hazard curve of the city of Sincelejo, using for this purpose the capacity spectrum methodology.

2. CAPACITY SPECTRUM

It consists of determining the point of performance of a structure when it is subjected to seismic movements of different intensity; that is, the ability to resist lateral forces is compared with the seismic demand, represented by means of a reduced response spectrum. The true behavior of the structure is evaluated with three levels of threat, service (0.065g), design (0.125g) and severe (0.150g), values that were defined from the seismic hazard curve of the city of Sincelejo.

It is worth mentioning that the Seismic Resistant Standard of Colombia (Garcia, 2014) has been prepared based on a large number of accelerograph records of seismic movements and all this has been possible thanks to the instrumentation of the National Network of Accelerographs, which operates Ingeominas in many towns of the country. Analyzing some of the recorded values of horizontal acceleration, it has been found that they are relatively low, compared to the values required by the Standard. For example, the maximum value of horizontal acceleration recorded in Villavicencio (120 km from the epicenter) for the Tauramena earthquake was 0.027g (2.7% of the acceleration due to gravity), while the Standard requires 0.30g, or ten times more. The same occurs for the city of Bogotá (140 km from the epicenter) with the same earthquake, the rock record was 0.017g (1.7% of the acceleration due to gravity), while the standard requires using 0.20g in the designs, of the order of ten times more. A similar situation occurs with the Calima-Darién earthquake: the maximum record was obtained in Trujillo, Valle (40 km from the epicenter) and was 0.048g (4.8% of the acceleration of gravity), and the Standard requires there 0.25g, five more times. The city of Pereira is located approximately 120 km from the epicenter, therefore, the acceleration must have been less than the value registered in Trujillo.

The foregoing simply indicates that the earthquakes that have been measured correspond to events that are far from the design earthquake provided for in the Standard, at least for the places where the records were obtained. The attenuation of the energy of the seismic waves makes it reduce appreciably as the distance that the waves have to travel is greater. However, significant damage occurred, even in new buildings, particularly in non-structural elements, with earthquakes whose accelerations in several cases may be of the order of ten or more times less than those determined by the Design Standard.

Due to the above, it is important to clarify that, in the case of Sincelejo, the values of the hazard curves do not agree with the data recommended by the seismic-resistant standard for structural design, since for the design earthquake, the standard recommends a acceleration of 0.15g, while using the curve this value is 0.125g.

3. STRUCTURAL CHARACTERISTICS OF THE BUILDING

The building is made up of a three-story structure, with a lightened reinforced concrete slab. Typologically, it is made up of reinforced concrete porticos, as well as non-structural masonry walls. For the present study, the longitudinal direction was chosen since it is considered to be more unfavorable from the point of view of stiffness.

In the direction analyzed, the p2 portico was also chosen, which consists of 6 lights and 3 floors, the last floor has only 5 lights and a cantilever (See modeling in SAP2000).

Technical specifications:

Total weight of the building = 958.65 tons

Acceleration coefficient (Aa) = 0.15 (Intermediate seismic hazard zone)

Design shear = 79,089 tons

Reinforced concrete of 210 Kg/cm2

Main steel of 4200 Kg/cm2

Transversal steel of 2800 Kg/cm2

Block masonry or hollow brick with 50 Kg/cm2 mortar

All criteria subject to NSR-10 in Colombia

4. APPLICATION OF THE METHOD

To obtain the capacity curve of the structure, an analysis was carried out PUSHOVER using the SAP2000 program. The analysis requires knowing the sectional characteristics of the elements that constitute the main structure in the study direction. The same software, defines these with the data previously supplied and with the geometric characteristics of each element and also taking into account the reinforcement found in the structural plans (Dona and Shemin, 2016) and (Neethu and Saji, 2015).

5. PUSH-OVER ANALYSIS

The capacity curve was obtained based on the determined parameters, with the SAP2000 program and through a non-linear static analysis of the model, the capacity curve was obtained. The location of the plastic hinges is made based on the diagram of linear elastic bending moments, they were located at the foot and head of columns and at the ends of the beams.

A "displacement-controlled" analysis was carried out (2% of the height of the building, which is 11 m, that is, 22 cm), in which the monotonic horizontal load is applied until the collapse occurs, in which a curve that represents the basal shear with respect to the horizontal displacement of the rigid diaphragm corresponding to the first level. Figure 1 shows the capacity curve obtained for the structure.

6. PERFORMANCE POINT

Following the guidelines proposed in Chapter 8 of ATC 40, Figures 2, 3 and 5 represent the performance point of the building under study for the three threat levels: service, design and severe, respectively; It is observed that the building resists the seismic demand imposed by the elastic spectrum of the NSR-10 design, without total collapse of the structure. The results of the performance point for severe earthquakes appear in Table 1.

Table 1. Values obtained for the performance point with severe earthquake

Parameter	**Value**
Pseudo-displacement	1.329 cm
Pseudo-acceleration	0.375 g
Effective damping	5.0 %
Performance Point Period	0.378 seg.

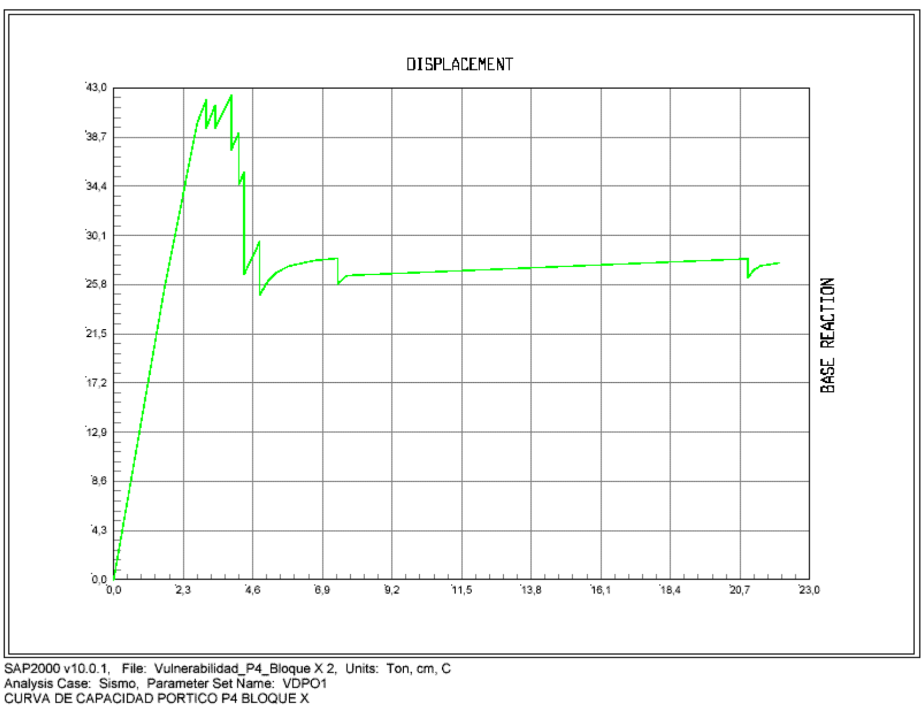

Figure 1. Capacity curve

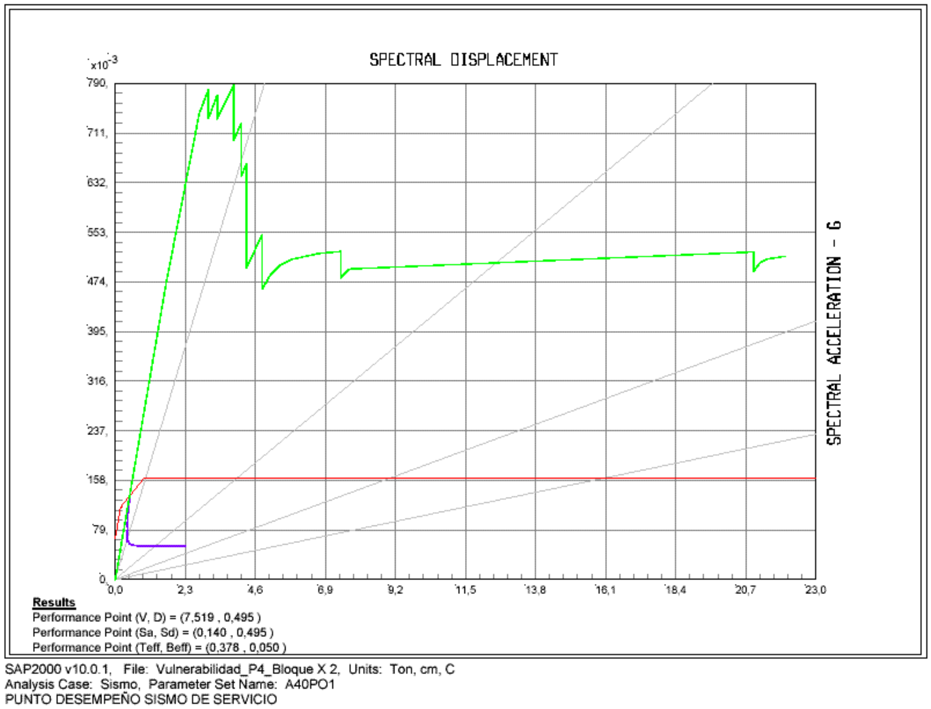

Figure 2. Capacity curve and performance point for service earthquake

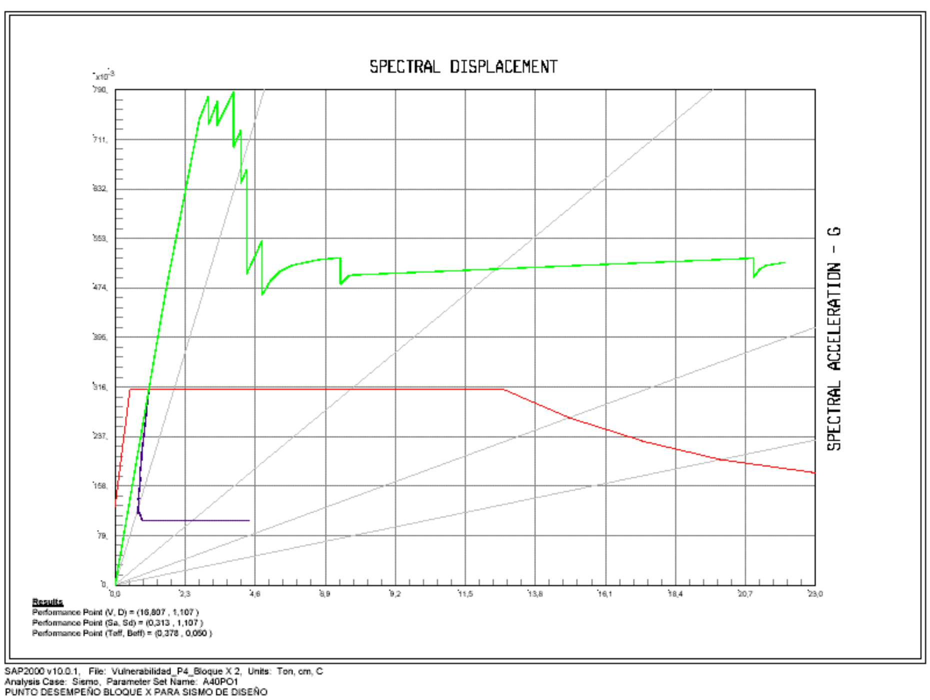

Figure 3. Capacity curve and performance point for design earthquake

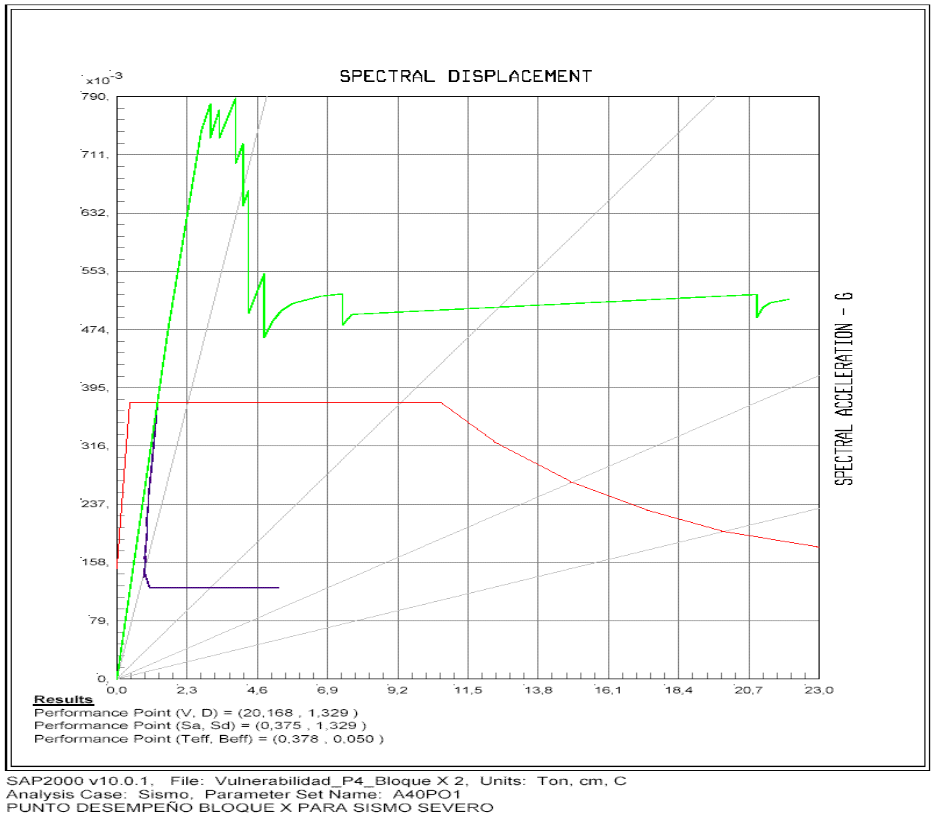

Figure 4. Capacity curve and performance point for severe earthquake

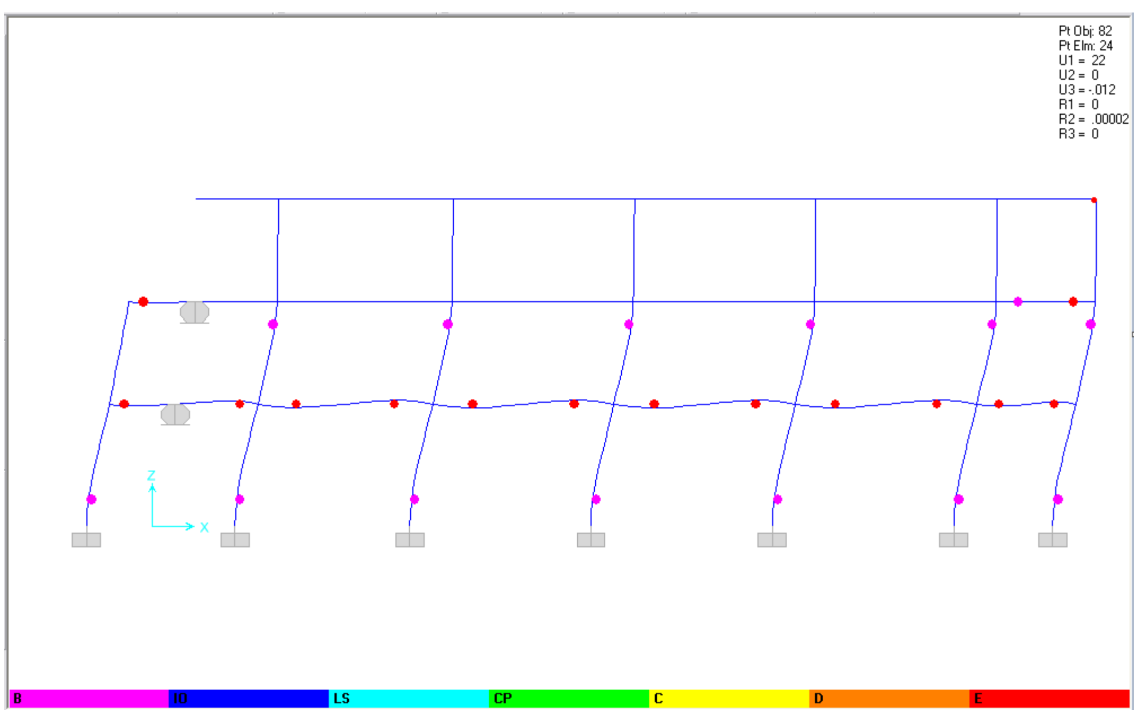

Figure 5. Labeling of the structure for the proposed conditions and severe earthquake

7. CONCLUSIONS AND RECOMMENDATIONS

As can be seen in figures 2, 3 and 4, the building has the capacity to resist a severe earthquake, that is, the building of the classroom block of the Universidad de Sucre, has structural capacity to resist the requirements of the demand spectrum of the NSR-10 for the severe earthquake. But when analyzing figure 5, it can be seen that there is labeling on the columns that do not cause collapse and, even, guarantee life safety; but the beams of the first floor fall into the range of collapse, therefore it is recommended to reinforce such beams.

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