Comparative Analysis of the Seismic Behavior in Latin American Countries using Response Spectra

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Abstract. This research compares the seismic behavior of a construction in five Latin America countries, considering the design spectrum for seismic excitation corresponding to each region. An 18-storey reinforced concrete structure was defined, in which a seismic spectral excitation was applied to get a bar graph showing structural damage data in the building elements for each country under study: Brazil, Colombia, El Salvador, Peru and Venezuela. Analyses and responses were worked using the SAP2000 v.20 computer program. All the seismic parameters required in each case were used in the modeling of the various design spectra. Design seismic spectra considering a rigid soil and an acceleration of 0.10g, 0,20g, 0,30g and 0,40g in all countries was tested. The results show potential structural damage scenarios for each beam and column element in the structure.

Keywords: seismic analysis, modal analysis, response spectrum, seismic codes, SAP2000 software.

1 Introduction

Regions of Latin America and the Caribbean have different levels of seismicity, as they are near some tectonic plates. The areas that are on the edge of these plates have high seismicity, as in some regions of Colombia, Peru and Venezuela. The regions within tectonic plates have low or almost no seismicity, as in Brazil. In this way, there is a difference in the need to use Seismic Codes. While some countries have had Codes for decades, as in El Salvador, others do not have any codes that cite the subject, as with Paraguay.

The seismic risk for each country under study is different. In Brazil, seismic zoning includes accelerations between 0.025g and 0.15g, and for regions with accelerations equal to 0.025g, seismic analysis is not required. In other countries, the Codes show seismicity between 0.05g and 0.50g and seismic analysis is mandatory in all regions of them.

This article defines the criteria used for the configuration of the project response spectra of each country and the equations used by each Code in its formulation. The minimum requirements to determine the use of response spectra are presented, as well as how to check if the results got are within what is acceptable defined by the Codes.

The Code used in Brazil is NBR 15421 [1], the Colombian Code is NSR-10: 2010 [2], the Peruvian Code is NTE.030: 2018 [3], the Venezuelan Code is COVENIN 1756-1:2001 [4] and the El Salvador Seismic Code [5].

Finally, the building to be evaluated with the help of SAP2000.v20 software is shown. This structure is used in Section 3 to analyze different design spectra.

2 Design Spectrum

The design spectra should provide the engineer with clear indications of the levels of acceleration that may occur at the site and the maximum acceleration and displacement demands that the structures can experience over their lifetime.

Studies carried out with the responses of complex structures to earthquakes have shown that the use of modal analysis is a consistent approach to the analysis of linear responses for this type of structures (NEHRP, 2003) [6].

The norms studied in this work describe the design spectrum for horizontal accelerations, as the elastic response spectrum for a damping rate equal to 5% of the critical damping. However, Peruvian NTE.030: 2018

Codes determine a parameter that allows adjusting the spectrum in situations where damping rates adopted differ from 5%.

Figure 1 shows the acceleration spectra of the studied seismic codes.

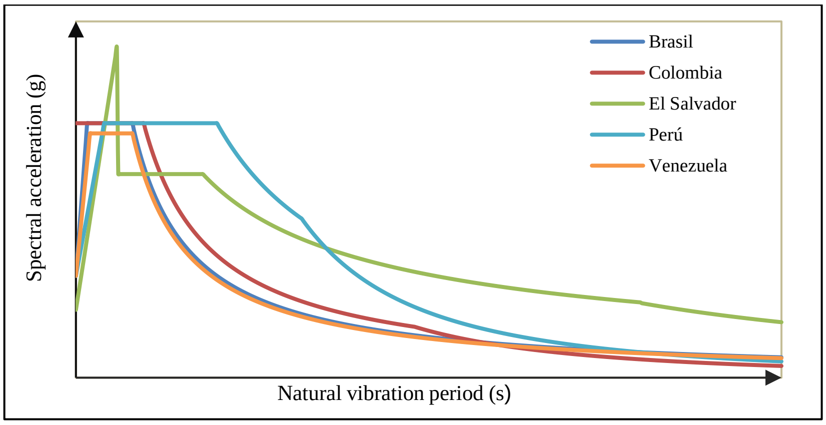


Figure 1. Design spectrum defined in the codes

3 Application Structure

To carry out analyzes using the six studied norms, an 18 floors building was adopted (includes the ground floor / parking, roof, engine room and water tank), with 14 standard floors, of reinforced concrete and according the project established by SANTOS et al. (2001) [7].

Columns have been defined with sections of 25 x 65cm^2, 25 x 90cm^2, 25 x 140cm^2, 25 x 160cm^2, 25 x 285cm^2 and 35 x 65cm^2 and beams with sections of 15 x 40cm^2, 30 x 60cm^2 and 40 x 60cm^2, all with fck = 27.6MPa, according to the model presented by the SAP2000.v20 program. The permanent loads adopted were: 3.5kN for the water tank cover slab; 4kN for the roof slabs; 4.75kN for the bottom slab of the water tank; 5kN for the slabs of the stairway, machinery box and the floor of the standard pavement; and 5.5kN for standard floor slabs. Regarding accidental loads, the minimum required by each code was adopted.

In Fig. 2, the deformed structure for the first three modes of natural vibration of the building is presented, as well as the structure in its initial configuration.

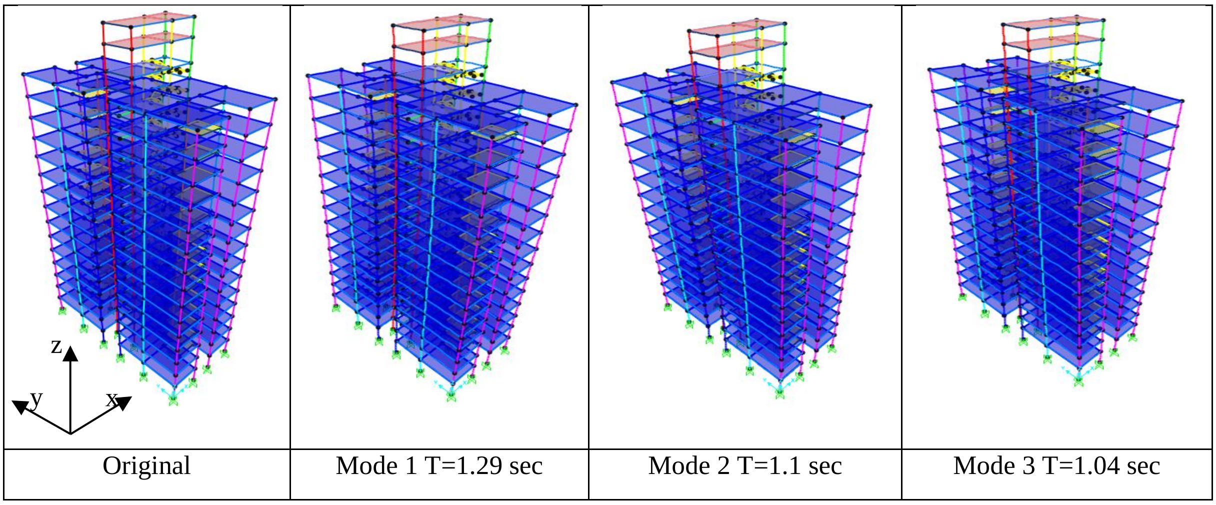


Figure 2. Vibration modes

4 Results

4.1 Case 1: Rigid soil and acceleration of 0.10g

In Case 1, an acceleration of 0.10g was determined for all countries, except El Salvador, because an acceleration of 0.30g is the smallest possible according to the Salvadoran code: NTDS 1997. Figure 3 presents the results got for design spectra and the bar graph showing structural damage for each beam and column element in different countries.

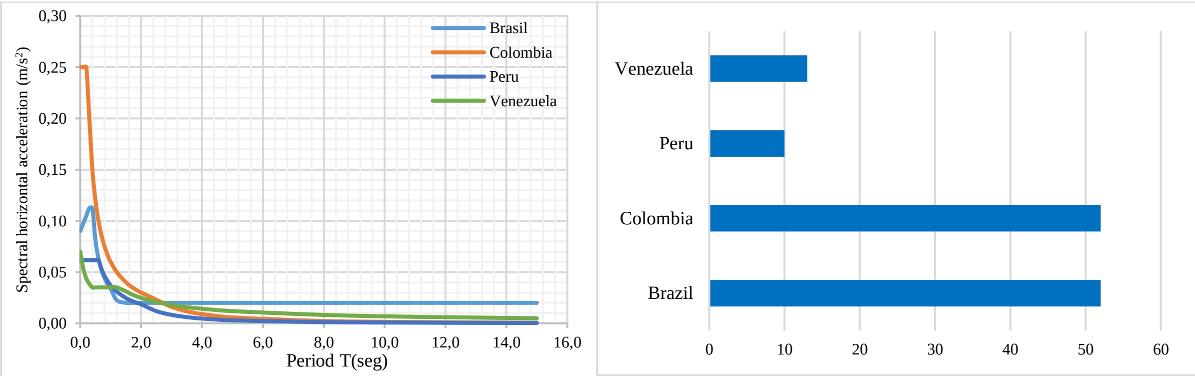


Figure 3. Spectrum comparison and bar graph indicating structural damage - acceleration 0.10g

When the Colombian code is used there is a greater number of elements requiring verification, while for the Peruvian code the percentage of structural elements for verification is low.

4.2 Case 2: Rigid soil and acceleration of 0.20g

In case 2, the acceleration 0.20g was adopted in all countries, except for Brazil, where 0.15g was adopted for being the maximum allowed acceleration. Figure 4 presents the results got for design spectra and the bar graph showing structural damage for each beam and column element in different countries.

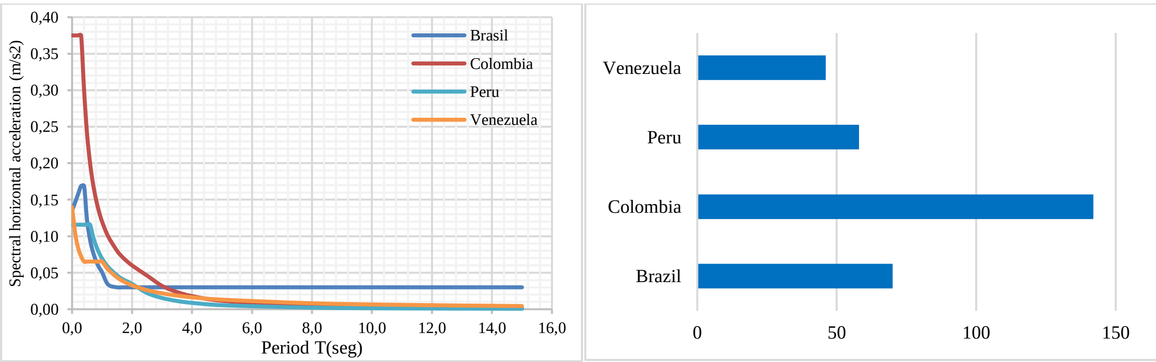


Figure 4. Spectrum comparison and bar graph indicating structural damage - acceleration 0.20g

When applying the spectra, it is noted that when the Colombian code is used there is a greater number of elements requiring verification, while for the Venezuela code the percentage of structural elements for verification is low.

4.3 Case 3: Rigid soil and acceleration of 0.30g

In case 3, the acceleration 0.30g was adopted. Figure 5 presents the results got for design spectra and the bar graph showing structural damage for each beam and column element in different countries.

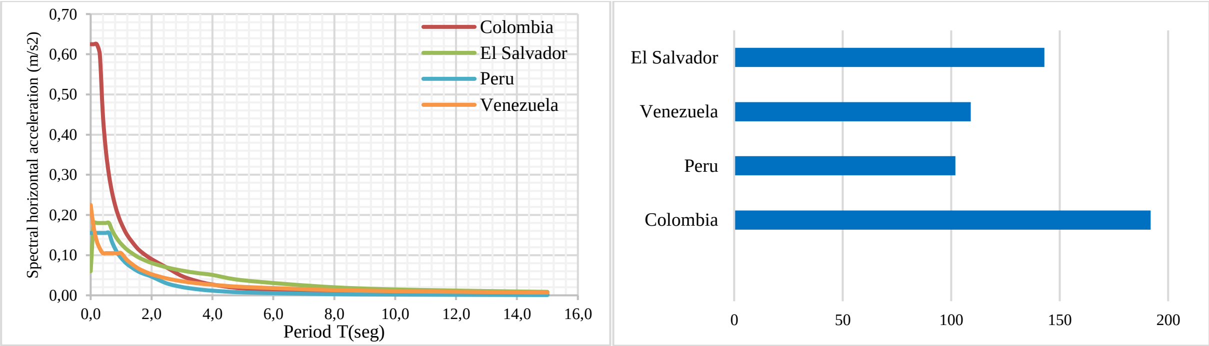


Figure 5. Spectrum comparison and bar graph indicating structural damage - acceleration 0.30g

In this case, when applying the spectra, it is noted that when the Colombian code is used there is a greater number of elements requiring verification, while for the Peruvian code the percentage of structural elements for verification is low.

4.4 Case 4: Rigid soil and acceleration of 0.40g

In case 4, the acceleration 0.40g was adopted. The Fig. 6 presents the results got for design spectra and the bar graph showing structural damage for each beam and column element in different countries.

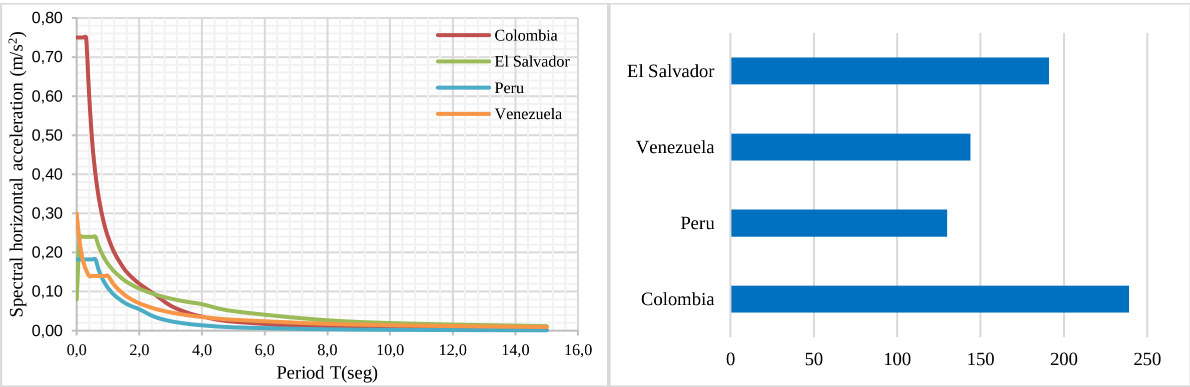
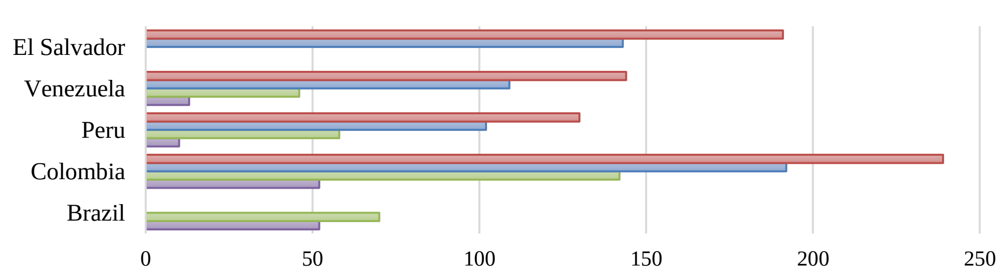


Figure 6. Spectrum comparison and bar graph indicating structural damage - acceleration 0.40g

When applying the spectra, it is noted that when the Colombian code is used there is a greater number of elements requiring verification, while for the Peruvian code the percentage of structural elements for verification is low.

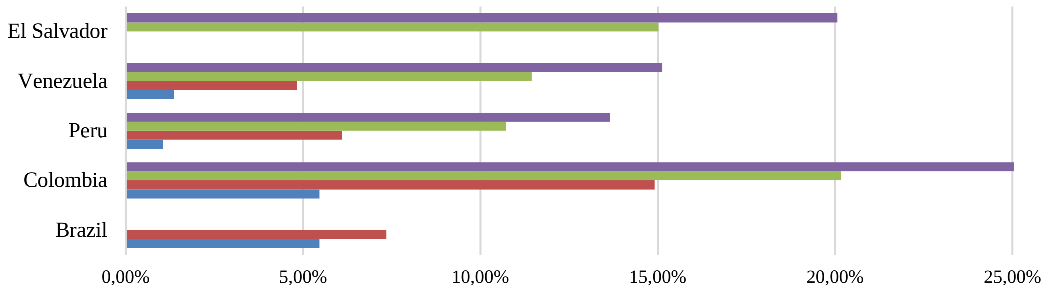
Figure 7 indicates the structural damage for each beam and column element in different countries and for different acceleration considered.



	Brazil	Colombia	Peru	Venezuela	El Salvador
0.4g	0	239	130	144	191
0.3g	0	192	102	109	143
0.2g	70	142	58	46	0
0.1g	52	52	10	13	0

Figure 7. Bar graph indicating structural damage.

Figure 8 shows structural damage percentage in different countries and for different acceleration considered.



	Brazil	Colombia	Peru	Venezuela	El Salvador
0.4	0,00%	25,11%	13,66%	15,13%	20,06%
0.3	0,00%	20,17%	10,71%	11,45%	15,02%
0.2	7,35%	14,92%	6,09%	4,83%	0,00%
0.1	5,46%	5,46%	1,05%	1,37%	0,00%

Figure 8. Bar graph indicating damage percentage.

When comparing the results, we can see that the percentage of damage in structural elements for 0.10g is small in all cases, for 0.20g there are intermediate damages in Colombia, for 0.30g and 0.40g the structures in all cases can present considerable damage.

5 Closing Remarks

Each country has its specific factors to get the design spectrum, as well as local micro-zoning and soil considerations. By applying different design spectra, for different accelerations, it is possible to get considerable damage for the structural elements. Therefore, it might be convenient to consider the regulations of each country to adjust the dimensions of the elements or improve the quality of the materials used (Fig. 7).

For countries with project spectrum having the same spectral acceleration for a large range of natural periods (plateau), it could be interpreted that the structural project would be more conservative than in the other countries (Fig. 1).

In this comparative study, rigid soil was used in all cases. It is recommended for future work to carry out analyzes considering different types of soils (intermediate soils, soft soils and others).

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