Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Perception of stiffness trend in city residential buildings

To cite this article: G C Prada Botía *et al* 2019 *J. Phys.: Conf. Ser.* **1329** 012008

View the article online for updates and enhancements.

You may also like

- Characterization of the physical-mechanical and thermal behavior of a clay building unit designed with thermo-insulating attributes and a coffee cisco organic additive
M S Narváez-Ortega, J Sánchez-Molina and C X Díaz-Fuentes
- Optimal percentage of asphalt cement in MDC-19 for flexible pavements in the city of San José de Cúcuta, Colombia
O Hurtado-Figueroa, B E Eslava-Vila and J A Cárdenas-Gutiérrez
- 5th International Meeting for Researchers in Materials and Plasma Technology (5th IMRMPT)

This content was downloaded from IP address 190.8.208.80 on 18/11/2021 at 15:04

IOP Conf. Series: Journal of Physics: Conf. Series **1329** (2019) 012008 doi:10.1088/1742-6596/1329/1/012008

Perception of stiffness trend in city residential buildings

G C Prada Botía[1], J P Rojas Suárez[1], and M S Orjuela Abril[1]
[1] Universidad Francisco de Paula Santander, San José de Cúcuta, Colombia

E-mail: gaudycarolinapb@ufps.edu.co

Abstract. In this project, a descriptive research was carried out in order to analyze, evaluate and detail the behavior of buildings between 4 and 18 floors of residential use in the City of San José de Cúcuta, Colombia, at the moment they are subjected to forces produced by earthquakes. For this purpose, a sample of 40 buildings framed in the above-mentioned characteristics was used by means of the SAP 2000 software. The seismic analysis of each building was made and the displacements of these were obtained when they are submitted before an earthquake. With this information, it was possible to calculate the drifts and evaluate them based on the requirements that determine the stiffness conditions present in the buildings. Finally, a document was drawn up identifying those buildings that are susceptible to significant damage in the event of a seismic movement and recommendations, due to the fact that they represent a social risk.

1. Introduction

An earthquake is a sudden movement of the ground that is usually caused by slipping along fault lines that results in the sudden release of energy in the earth's crust, generating seismic waves and in turn, give their energy to the foundations and then to the structure [1]. As a result of these earthquakes, human lives are lost that are proportionally linked to the vulnerability of buildings in this natural event, increasing their mortality rate due to the number of people who live and work in buildings [2]. After the occurrence of an earthquake, the information collected from the collapsed building should be done in a timely manner to be used as an effective implementation guide at the time of the emergency rescue [3].

Falls of buildings cause almost 95% of the victims in this natural catastrophe, therefore, it is important to study the damage to buildings in earthquakes [4]. One of the reasons that affect the constructions at the moment of an earthquake are the inadequate materials used in the construction (mud, stone, briquette, blocks of soft stone, among others), either by their low quality or because they do not fulfill the standards against the seismic forces [5], besides the materials used it is the method of realization at the moment of constructing, being United States and Japan, one of the countries using base insulation, a passive structural control technology with the aim of reducing earthquake damage to structures by isolating the soil superstructure using flexible bearings (seismic isolation bearings), which have some stiffness and are inserted between the foundation and superstructure, thus separating the seismic energy in the structure [6].

In the city of San José de Cúcuta, Colombia, a tendency to the construction of buildings with a considerable number of floors has been evidenced, orienting the city to a vertical urban growth; In addition it is located in a region characterized by its a zone of high seismicity on the frontal fault of the eastern mountain range of Colombia, with an effective horizontal peak design acceleration of 0.30 g [7], which confirms because there was an earthquake in 1875; achieving this natural event a countless number of homeless people, causing a total halt of all economic activities for a long time, which in turn chained an increase in poverty indicators [8]. In this order of ideas one of the parameters of great

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

importance is the present rigidity in the buildings which contributes to the resistance of seism, limiting the displacement caused by the action of the forces applied on these, for such reason, a study is made on the tendency of rigidity that contain the buildings of residential use that possess between 4 and 18 floors.

2. Methodology

The sample is made up of all residential buildings between 4 and 18 floors in San José de Cúcuta, Colombia, in the time interval from 2008 to 2015; in this way 40 buildings were obtained that met these requirements. Information was collected through project [9] and [10], SAP 2000 software and curatorship's 1 and 2, the latter being acquired: name of the project, location, height of the building, number of floors, dimensions, structural system and date of issuance of license; in order to classify buildings that meet the standards required by the NSR-10 [11].

3. Results

3.1. Calculation of the design spectrum

The elastic acceleration spectrum of each building in the project was calculated taking into account the following considerations: Zone of high seismic risk, corresponding to the city of San José de Cúcuta, Colombia, C soil profile, which are regulated by NSR-10 [11]; they are determined by the coefficient that represents the effective horizontal peak acceleration Aa, the coefficient that represents the effective horizontal peak velocity Av; according to these two standard coefficients of each capital city, the level of seismic threat AE and AD is determined; the coefficient of amplification that affects the acceleration in the zone of short periods, Fa, the coefficient of amplification that affects the acceleration in the zone of intermediate periods Fv and the coefficient of importance I. The coefficient of amplification that affects the acceleration in the zone of intermediate periods Fv is determined by the coefficient of amplification that affects the acceleration in the zone of intermediate periods Fv and the coefficient of importance I. It should be noted that there is a plateau of constant accelerations for short periods, less than Tc, for periods greater than Tc the value of acceleration decreases with the value of the vibration period T, up to TL and from here decreases with the value of the vibration period squared [11], Aa = 0.35; Av = 0.3; Ae = 0.25; Ad = 0.1; Fa = 1.05; Fv = 1.5; importance grade I = 1; Ct = 0.047; ά = 0.9; building height (h) = Variable of each; with the above values Ta, To, Tc, TL, Sa were obtained according to the equations shown in Figure 1.

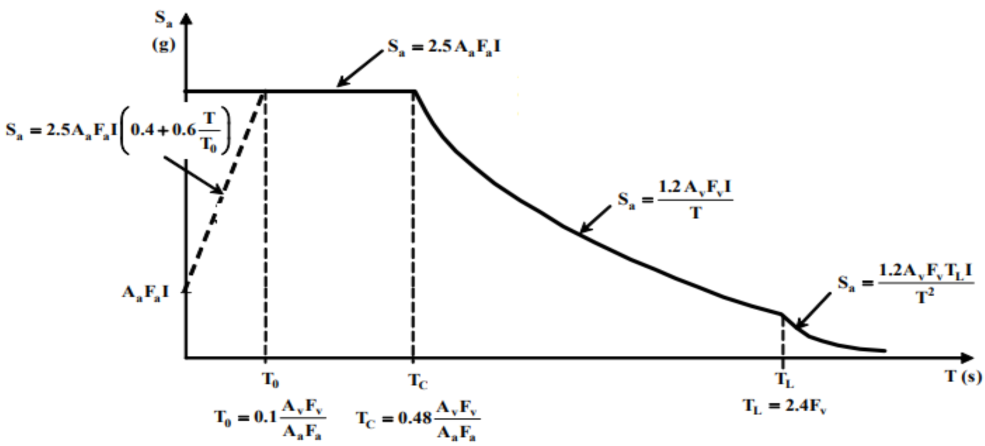

Figure 1. Elastic spectrum expressed as a fraction of gravity acceleration (g) [11].

The calculation process to determine the value of K (stiffness value) and Sa (value of the design acceleration spectrum for a given vibration period) is performed by means of the Ta value (characteristic periods of the spectrum) and the Equation (1), Equation (2) and Equation (3).

$$\text{Ta} < 0.5;\ \text{K} = 1 \tag{1}$$

$$0.5 < \text{Ta} < 2.5;\ \text{K} = 0.75 + 0.5 * \text{Ta} \tag{2}$$

$$\text{Ta} > 2.5;\ \text{K} = 2 \tag{3}$$

Table 1 shows the values of Sa and K of different buildings in the city of San José de Cúcuta, Colombia, that comply with the parameter of 4 and 18 floors, it being understood that the buildings do not have high values of Sa and K proportionally, as in the case of Barcelona Apartment that has the highest value of rigidity, its Sa is the lowest.

Table 1. Values of Sa and K.

Project name	Sa	K	Project name	Sa	K
Santa Barbara Towers	0.456	1.340	Platinum Boshc Building	0.7170	1.126
Rio Tower Building	0.706	1.132	Versailles Balcony Closed Set	0.4390	1.365
Bary Torres Multifamily Complex	0.438	1.365	Montreal Building	0.9190	1.000
Los Libertadores Apartment Building	0.526	1.262	Fomanort	0.7220	1.124
Unicentro Tower	0.382	1.458	Royal Park Building	0.5930	1.205
Verona Building	0.872	1.060	Buenavista Building	0.6580	1.16
Tour Columbia Limited S.A.S.	0.918	1.030	Forest Towers	0.4540	1.344
Specialist Center Building	0.816	1.081	Parks of Bolívar 2	0.9190	1.000
Barcelona Apartment	0.300	1.648	Parks of Bolívar 1	0.9180	1.000
Hotel & Business Center	0.314	1.610	East Riviera	0.3560	1.509
Miro Building	0.651	1.164	Ceiba Real	0.3890	1.440
Viñedos	0.447	1.350	Edificio Torres de San Juan	0.6220	1.184
Portobello	0.482	1.310	Edificio Gaudy	0.6020	1.199
Nogal Country	0.459	1.340	Edificio Manhatan	0.5960	1.203
Versalles	0.333	1.560	Edificio Naziri	0.5570	1.234
Colibrí	0.919	1.000	Edificio Skarlata	0.5000	1.290
Nuvo	0.448	1.353	Edificio Manhatan Ii	0.6380	1.174
Ventura Reservado	0.378	1.463	Hotel Casa Blanca	0.7560	1.107
La Primavera	0.651	1.165	Torre de la Ceiba	0.9180	1.04
Santa Ines	0.653	1.164	Conjunto Residencial Portachuelo	0.9818	1.00

3.2. Basic data for structural models
The structural models developed for the seismic analysis by means of SAP 2000 software had the following data according to Table 2, where there are different variations in the measurements of floor heights, being the maximum among them of 4.36 m and plate height of 0.7 m, so that the building with more height in its floors and plate is "Fomanort" with 4.33 m and 0.7 m, respectively.

3.2.1. Areas of structural elements. According to the results obtained from the seismic analysis of the buildings in Table 3, it was perceived that 47.5% of the 40 buildings in the sample were constructed with the requirements stipulated in the Colombian norm of resistant seismic construction NSR-10 [11], which stipulates that the minimum area of the column is 0.5 m^2 and 33 m^2 for the structural wall area.

Table 2. Basic data.

Project name	H floor (m)	Dead load	Project name	H floor (m)	Dead load
Santa Barbara Towers	3.00	6	Platinum Boshc Building	4.36	6
Rio Tower Building	3.17	6	Versailles Balcony Closed Set	2.69	6
Bary Torres Multifamily Complex	3.42	6	Montreal Building	3.55	6
Los Libertadores Apartment Building	3.41	6	Fomanort	4.33	6
Unicentro Tower	3.66	6	Royal Park Building	2.99	6
Verona Building	2.51	6	Buenavista Building	2.40	6
Tour Columbia Limited S.A.S.	3.93	6	Forest Towers	2.59	6
Specialist Center Building	3.78	6	Parks of Bolívar 2	2.50	6
Barcelona Apartment	3.82	6	Parks of Bolívar 1	2.50	6
Hotel & Business Center	3.90	6	Rivera del Este	2.64	6
Miro Building	3.47	6	Ceiba Real	3.91	6
Viñedos	3.35	6	Torres de San Juan Building	3.19	6
Porthovello	3.76	6	Gaudí Building	3.31	6
Nogal Country	3.58	6	Manhatan Building	3.35	6
Versalles	3.20	6	Naziri Building	3.61	6
Colibri	3.10	6	Skarlata Building	3.62	6
Nuvo	3.07	6	Manhatan Ii Building	3.11	6
Ventura Reservado	3.41	6	Hotel Casa Blanca	3.43	6
La Primavera	1.87	6	La Ceiba Tower	3.23	6
Santa Ines	2.42	6	Portachuelo Residential Complex	3.25	6

Table 3. Areas of structural elements.

Project name	Column area (m^2)	Structural wall area (m^2)	Project name	Column area (m^2)	Structural wall area (m^2)
Los Libertadores Apartment Building	1.10	33.37	Platinum Boshc Building	2.50	4.87
Bary Torres Multifamily Complex	0.95	25.96	Versailles Balcony Closed Set	3.52	30.80
Rio Tower Building	6.56	9.40	Montreal Building	3.24	23.50
Santa Barbara Towers	17.5	10.61	Fomanort	6.46	2.69
Unicentro Tower	1.98	153.18	Royal Park Building	4.80	1.45
Verona Building	5.52	36.96	Buenavista Building	6.48	45.69
Tour Columbia Limited S.A.S.	14.7	9.94	Forest Towers	3.96	11.37
Specialist Center Building	4.35	3.27	Parks of Bolívar 2	1.56	16.35
Barcelona Apartment	7.84	9.92	Parks of Bolívar 1	10.39	9.29
Hotel & Business Center	2.10	21.81	Rivera del Este	1.89	25.94
Miro Building	5.44	3.56	Ceiba Real	8.74	3.13
Portachuelo Residential Complex	7.08	2.88	Torres de San Juan Building	5.145	1.48
Porthovello	2.30	14.49	Gaudí Building	5.60	12.28
Nogal Country	1.20	9.30	Manhatan Building	3.10	5.11
Versalles	12.6	4.15	Naziri Building	6.42	10.10
Colibri	2.80	19.09	Skarlata Building	5.46	4.53
Nuvo	7.6	15.21	Manhatan Ii Building	6.27	12.12
Ventura Reservado	3.15	20.45	Hotel Casa Blanca	3.33	7.95
La Primavera	0.2	9.372	La Ceiba Tower	4.32	31.5
Santa Ines	1.68	3.7	Viñedos	3.52	1.48

3.3. Evaluation of requirements
The determination of the drift is made by means of Table 4, which stipulates what is the maximum drift that the construction can have to be accepted by NSR-10 [11] as earthquake resistant.

Table 4. Maximum derivatives as a percentage of floor height (h_{pi}) [11].

Structure of	Maximum drift
Reinforced concrete metal. Wood, masonry according to requirement	1.0% $(\Delta^{i}_{max} \leq 0.010\ h_{pi})$
Masonry according to requirement A.6.4.2.3	0.5% $(\Delta^{i}_{max} \leq 0.005\ h_{pi})$

In Table 5 and Table 6, it is shown that 27.5% of the buildings evaluated did not comply with the drift requirements in both directions (X,Y), as the maximum direction is 0.040 and 0.032 respectively, while 25% only met the drift requirements in one direction, exposing a great danger to an earthquake in the direction that has less rigidity with respect to the other, in addition to the fact that 20% of buildings with a floor height less than 3 m did not meet the necessary drift conditions; on the other hand, 63.33% of buildings with a height equal to or greater than 3 m were not fit to meet the derivatives.

Table 5. Buildings complying with NSR-10 [11] drifts.

Project name	Mezzanine floor height (m)	Δ Max X	Δ Max Y	% Drift	% Max Drift
Santa Barbara Towers	3.00	0.02712	0.01005	0.90%	0.34%
Rio Tower Building	3.17	0.02229	0.01714	0.70%	0.54%
Bary Torres Multifamily Complex	3.42	0.03429	0.01554	1.00%	0.45%
Los Libertadores Apartment Building	3.41	0.02685	0.03180	0.79%	0.93%
Tour Columbia Limited S.A.S.	3.93	0.02575	0.02039	0.66%	0.52%
Specialist Center Building	3.78	0.00457	0.02161	0.12%	0.57%
Barcelona Apartment	3.82	0.02404	0.03315	0.63%	0.87%
Viñedos	3.35	0.00318	0.01826	0.09%	0.54%
La Primavera	1.87	0.01337	0.01591	0.72%	0.85%
Santa Ines	2.42	0.00874	0.02099	0.36%	0.87%
Balcones de Versalles Closed Set	2.69	0.02220	0.02546	0.83%	0.95%
Royal Park Building	2.99	0.02650	0.02842	0.89%	0.95%
Buenavista Building	2.40	0.01718	0.01800	0.72%	0.75%
Parks of Bolívar 2	2.50	0.00504	0.00367	0.20%	0.15%
Parks of Bolívar 1	2.50	0.00520	0.00489	0.21%	0.20%
Rivera del Este	2.64	0.02824	0.01778	1.07%	0.67%
Ceiba Real	3.91	0.03273	0.04207	0.84%	1.08%
Torres de San Juan Building	3.19	0.00766	0.02102	0.24%	0.66%
Portachuelo Residential Complex	3.25	0.02944	0.01775	0.91%	0.55%

3.4. Recommendations
Earthquakes are unpredictable events that can occur very frequently, such as in Japan and Haiti, but they are usually infrequent in the vast majority of the world, causing disastrous consequences; although they cannot be controlled at the time of execution, the damages can be mitigated [12], by means of construction norms for buildings that each country presents, the differences between them will depend on the seismic level that can occur; in Colombia, NSR-10 [11] is applied, stipulating for each region the seismic level and its constants and/or values of the building structure. Between floors containing the building, the requirements are stricter, so it is recommended that future buildings with a greater number of 3 floors comply with the specifications of drift, direction of X,Y, height of the floor and plate, value of resistance and spectral elasticity; Since these buildings are visited daily by thousands of people in the area who may be in danger when a high impact earthquake occurs and the structures are not adequate to withstand it, risking their lives for lack of ethics by eliminating building materials or speeding up the project to start making profits.

Table 6. Buildings that do not comply with NSR-10 [11] drifts.

Project name	Mezzanine floor height (m)	Δ Max X	Δ Max Y	% Drift	% Max Drift
Unicentro Tower	3.66	0.09946	0.02723	2.72%	0.74%
Verona Building	2.51	0.08730	0.21558	3.48%	8.60%
Hotel & Business Center	3.90	0.07408	0.07116	1.90%	1.82%
Miro Building	3.47	0.02098	0.04983	0.61%	1.44%
Porthovello	3.76	0.05249	0.03783	1.39%	1.00%
Nogal Country	3.58	0.05502	0.04767	1.54%	1.33%
Versalles	3.20	0.08013	0.10022	2.50%	3.13%
Colibri	3.10	0.03983	0.02405	1.28%	0.78%
Nuvo	3.07	0.53738	0.25484	17.51%	8.31%
Ventura Reservado	3.41	0.04001	0.04100	1.17%	1.20%
Platinum Boshc Building	4.36	0.02315	0.10962	0.53%	2.51%
Montreal Building	3.55	0.01715	0.05228	0.48%	1.47%
Fomanort	4.33	0.02547	0.06644	0.59%	1.53%
Torres del Bosque	2.59	0.04264	0.04248	1.65%	1.64%
Gaudí Building	3.31	0.02942	0.08226	0.89%	2.48%
Manhatan Building	3.35	0.11481	0.29107	3.43%	8.69%
Naziri Building	3.61	0.02548	0.08249	0.71%	2.29%
Skarlata Building	3.62	0.03128	0.10060	0.86%	2.78%
Manhatan Ii Building	3.11	0.04180	0.08172	1.35%	2.63%
Hotel Casa Blanca	3.43	0.06936	0.06714	2.03%	1.96%
La Ceiba Tower	3.23	0.01818	0.04553	0.56%	1.41%

4. Conclusions

Within the net evaluated buildings, 16 were constructed before 2010, implying that their structural design was carried out with the requirements of the old Colombian norm for constructions earthquake resistant according to law 400, 1997, even so, 12 did not comply with the requirements demanded as regards drifts of the norm currently in force, while the buildings constructed from 2010 onwards have an indicator of 50% that do not comply with the requirement regarding drifts established by the Colombian regulation for constructions earthquake-resistant. The seismic analysis carried out for the 40 buildings resulted in the following: buildings with 4 floors 50%, 5 floors 50%, 6 and 7 floors 100%, 8 floors 80%, 9 floors 50%, 10 floors 33.33%, 11 floors 25%, 12 floors 100%, 13 floors 50%, 14 floors 66.67% and 16 floors 100% inefficient according to Colombian regulation established for constructions earthquake resistant; in summary, 65.22% of buildings with less than 10 floors and 47.06% with more than 10 floors do not comply with the standards of the Colombian seismic resistant construction regulations. Therefore, policy makers should adopt anti-seismic construction strategies, mainly in areas of high seismic risk.

References

[1] Patil R, Naringe A and Kalyana J 2018 *IOP Conf. Ser. Mater. Sci. Eng*. **330** 012126
[2] Rusydy I et al. 2017 *IOP Conf. Ser. Earth Environ. Sci*. **56** 012006
[3] Zhai W and Zeng W 2017 *IOP Conf. Ser. Earth Environ. Sci.* **57** 012018
[4] Usta P, Morova N, Evci A and Ergún S 2018 *IOP Conf. Ser. Mater. Sci. Eng.* **300** 012062
[5] Güney D, Aydin E and Öztürk B 2015 *J. Phys. Conf. Ser.* **628** 012066
[6] Nguyen N V, Nguyen C H, Hoang H P and Huong K T 2018 *IOP Conf. Ser. Earth Environ. Sci.* **143** 012048
[7] Flórez C, Medrano C, Sarmiento M and Lozano C 2005 *Respuestas* **2** 31
[8] León G and Morales L 2017 *Cúcuta y Norte de Santander: Configuración histórica de una comunidad imaginada* (Colombia: Pontificia Universidad Javeriana)
[9] Asociación Nacional de Poliestireno Expandido (ANAPE) 1996 *Manual de aligeramiento de estructuras* (España: Asociación Nacional de Poliestireno Expandido)
[10] Blanco K and Becerra D 2014 *Percepción de la tendencia de rigidez en edificios típicos de uso residencial entre 4 y 18 pisos en la ciudad de San José de Cúcuta entre los años 2008 y 2015* (Colombia: Universidad Francisco de Paula Santander)

[11] Ministerio del Medio Ambiente Viviendo y Desarrollo Territorial 1997 *Requisitos generales de diseño y construcción sismo resistente* (Colombia: Ministerio del Medio Ambiente Viviendo y Desarrollo Territorial)
[12] McRae C, McClure J, Henrich L, Leah C and Charleson A 2018 *Int. J. Disaster Risk Reduct.* **28** 465