A Comparative Study of the Seismic Design Codes used in Puerto Rico and the Dominican Republic

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Abstract *— A comparative study of the seismic analysis between the seismic codes used in Puerto Rico and the Dominican Republic was performed. This study shows a calculation, step by step, of the seismic lateral load for both seismic codes. Results indicates that Guide R001 generates 41.2% higher Base Shear and 10.8% higher story drift, in average, than ASCE 7. However, the Guide R001 requires a lower boundary limit (75% less) for the allowable story drift, which might results in a stiffer building design structures as opposite to the ASCE 7.*

Key Terms *— Acceleration Parameters, Design Spectral, Fundamental Period of Structure, Lateral Loads, Site Classification.*

INTRODUCTION

Dominican Republic (DR) and Puerto Rico (PR) are two of the Caribbean mayor islands. Although they are less than 200 kilometers apart and almost share the same tectonic plates, as shown in Figure 1, their seismic design codes are different. The Puerto Rico seismic design code is based on the code developed by the American Society of Civil Engineers (ASCE) and for the purpose of this study the ASCE 7-2010 [1] will be used. The Dominican Republic seismic design code is based on the "Reglamento para el Análisis y Diseño Sísmico de Estructuras", Guide R-001 [2].

The present study pursue to stablish the difference in a building base shear considering both, the process determination and the variations in the member's internal forces after the analysis is performed. For this purpose, a ten (10) stories hypothetical building will be located at Aguadilla, PR and Higüey, DR.

Figure 1
Caribbean Tectonic Plates

ASCE 7 [1] is a publication of American Society of Civil Engineer which became official under Section 49 CFR193.2013. It was considered legally upon all citizens of the United States of America and US Territories on 2002 as revision of ASCE 7-98. This standard provides requirements for dead, live, soil, flood, wind, snow, rain, ice and earthquake loads, and their combinations. The 2002 edition was followed by the 2005 and 2010. At present the 2016 edition is on development. The ASCE 7-2010 publication contents 31 chapters, 4 appendixes and several comments chapters. Chapters 11 through 23 are dedicated to define the criteria and parameters for the seismic analysis and design of building and other structures.

Department of Public Works and Communications of the Dominican Republic adopted the R001 document as the guidelines for the seismic analysis on year 2011. The regulations R001 was approved under Law No. 201-11 and established as a general guide for the seismic analysis and design of building and other structures. This regulation was established to ensure public safety by setting minimum requirements for the design and construction of any engineering work considering the geological and seismic situation in the region.

Guide R001 [2] became since its approval in a public document which is available to the society for free at any office of the Department of Public Works and Communications across the country; its sale is considered an illegal act.

The R001 Guide is divided into eight major titles described as follow:

- Title I - General Conditions
- Title II - Seismic Zoning
- Title III - Classification of Buildings
- Title IV - Seismic Analysis of Structures
- Title V - Structuring
- Title VI - Foundations
- Title VII - General Criteria for Seismic Design by Performance
- Title VIII – Sanctions

OBJECTIVE

The main objective of this study is to determine the differences in the evaluation method of the seismic load using the guides for two different countries, DR and PR. Comparison of the building base shear, inter-story drift, and member's internal forces among codes, will be the focus of the investigation. Study seeks to evaluate those differences in the behavior of a hypothetical 10-story reinforced concrete rectangular shape building.

STRUCTURAL MODEL

The structural model selected for this study was a ten story reinforced concrete rectangular building. The building will be placed at Aguadilla, PR and Higüey, DR. for analysis purposes. This locations were selected based on its proximity.

The structure will be considered as an Ordinary Reinforced Concrete Moment Frame System, as per ASCE 7-2010 Table 12.2-1 [1] and as an Ordinary Reinforce Concrete Frame type A-IV as per R001 code Chapter II, Article 23, Part A [2].

Figure 2 below shows the office-building typical structural floor considered in this study. The plan view has a rectangular dimensions of 62 ft times 82 ft, for a total construction area of 50,840 ft^2 over an overall height of 123 feet. The floor height is 12 feet for all floor except in the first floor where 15 feet is considered. Also, it can be seen a Shear Walls core elevator at the center of the building.

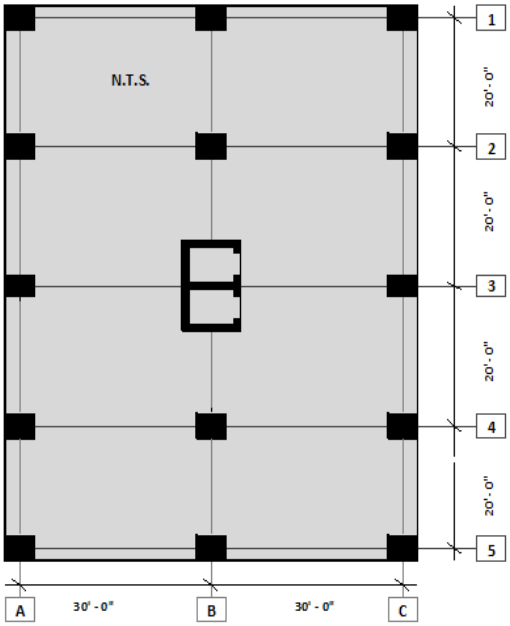

Figure 2
Building Plan View and Dimensions

All structural elements are reinforced concrete having columns sections of 24in x 24in, beam sections of 24in x 30in, and wall thickness of 8in. Both, gravity and lateral loads, will be sustained by a Frame System in both directions. The Site Class will be taken as D for both locations, as per ASCE 7-2010 Section 11.4.2 [1].

In both cases, the lateral loads will be distributed according to element stiffness. Thus, Base Shear and its distribution for each story was determined following the process stated in both guides and final Story Shears are showing in Table 1 and 2.

Figure 3 shows an elevation for a typical frame in the transversal direction with the corresponding coupled shear wall at the end. The shear wall integration with the frame was considered including its lateral stiffness, thought a rigid link in a 2-D structural analysis performed using FTOOL software [3].

SEISMIC LOAD DETERMINATION AS PER PR BUILDING CODE ASCE 7-2010

<u>Site Class Classification:</u> In accordance with Chapter 11 Section 11.4.2, where the soil properties are not known in sufficient detail to determine the site class, Site Class D shall be used [1].

<u>Mapped Acceleration Parameters Ss and S_1:</u> The parameters Ss and S_1 shall be determined from the 0.2 and 1.0 sec Spectral Response Acceleration as specified in Section 22. Thus, for project location this values are:

$$S_S = 1.35$$
$$S_1 = 0.50$$

<u>Adjustment Site Coefficients Fa and Fv</u>: This parameters are defined in Table 11.4.1 and 11.4.2 [1]. By interpolation:

$$Fa = 1.0$$
$$Fv = 1.5$$

<u>Spectral Response Acceleration Parameter SMS and SM1:</u> The SMS, for short periods (0.2 sec), and SM1, for long periods (1.0 sec), are adjusted for Site Class effects:

$$S_{MS} = Fa*Ss = 1.35 \quad (1)$$
$$S_{M1} = Fv*S_1 = 0.75 \quad (2)$$

<u>Design Spectral Acceleration Parameters, SDS and SD1:</u> These values shall be determine following equation 3 and 4.

$$S_{DS} = (2/3)*S_{MS} \quad (3)$$
$$S_{DS} = 0.90$$
$$S_{D1} = (2/3)*S_{M1} \quad (4)$$
$$S_{D1} = 0.5$$

<u>Fundamental Period of Structure, T:</u> The fundamental period of the structure, in the direction under consideration shall be established using the structural properties and deformation characteristics of the resisting elements in a properly substantiated analysis. The fundamental period, T, shall not exceed the product of the coefficient for upper limit on calculated period (Cu) from table 12.8-1 [1] and the approximate fundamental period, T_0, determined in accordance with section 12.8.2.1[1]. An alternative which is permitted is to use this approximate building period, T_0 as the natural building period directly.

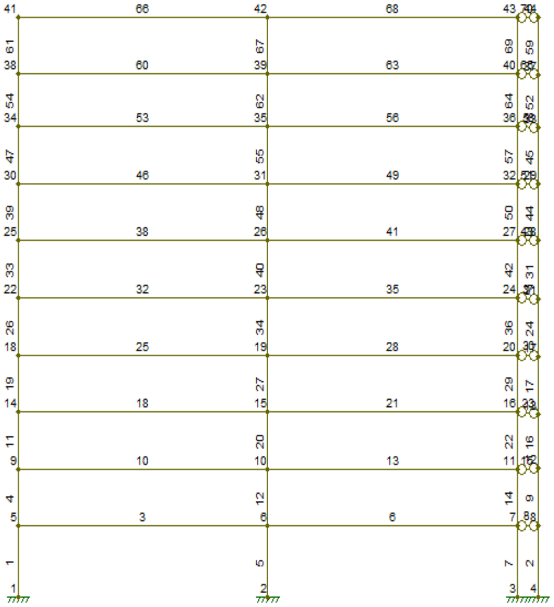

Figure 3
Typical Building Section along X-X Direction

<u>Approximate Fundamental Period, Ta:</u> The approximate fundamental period, Ta, in seconds, shall be determined from the following equation:

$$Ta = Ct*H_n^x \quad (5)$$

Where:

Hn = building height in feet = 123 ft.

Ct and x are determined from Table 12.8-2 from ASCE 7 [1], which for a concrete moment-resisting frame are:

$$Ct = 0.016$$
$$x = 0.90$$

Then, replacing those values the approximate period will be equal to:

$$T = T_0 = 1.22 \text{ secs}$$

<u>Design Response Spectrum:</u> Figure 4 shows the design response spectrum as required by this standard. When site-specific ground motion procedures are not used, the design response

spectrum curve shall be developed as indicated in section 11.4.5 [1].

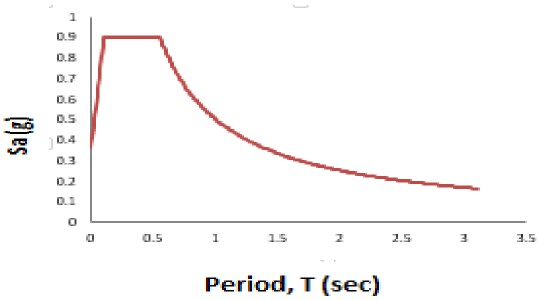

Figure 4
Design Response Spectrum

<u>Importance Factor, Ie:</u> An importance factor, Ie, shall be assigned to each structure in accordance with Table 1.5-2 [1]. Considering Risk Category II, the importance factor by Table 1.5-2 [1] for this building should be:

$$I_e = 1.0$$

<u>Seismic Design Category, S_{DC}:</u> Structure shall be assigned a Seismic Design Category in accordance with Table 11.6-1 and 11.6-2. The worst design category should be used in the analysis.

<u>Design Coefficients and Factors R, C_d, Ω:</u> This parameters are selected according to Table 12.2-1 [1] for the corresponding seismic force resisting system. In this case, for an Ordinary Reinforced Concrete Moment Resisting Frame the building Response Modification Factor, R, Over Strength Factor, Ω, and the Deflection Amplification Factor, C_d, can be obtained as:

$$R = 3.0$$
$$\Omega = 3.0$$
$$C_d = 2.5$$

<u>Redundancy factor, ρ</u>: The redundancy factor, for a Seismic Design Category D, E or F should be taken as ρ = 1.3, unless one of the following two conditions are met, in which case it is permitted to be taken a 1.0:

- Each story resisting more than 35 percent of the base shear in the direction of interest shall comply with Table 12.3-3 [1].
- Structures that are regular in plan at all levels provided that the seismic force-resisting systems consist of at least two bays of seismic force-resisting perimeter framing on each side of the structure in each orthogonal direction at each story resisting more than 35 percent of the base shear.

In this case, none of the above conditions are met, therefore the Redundancy factor of 1.3 can be used.

<u>Equivalent Lateral Forces Procedure:</u> This procedure is based in to determine and to distribute among floors the building Seismic Base Shear, V, which in any given direction, shall be determined in accordance with equation 12.8-1 [1], as:

$$V = C_S W \qquad (6)$$

Where:

C_S = the seismic response coefficient determined in accordance with Section 12.8.1.1 [1].

W = the effective seismic weight as indicated in Section 12.7.2 [1]

$$= 8439.9 \text{ kips}$$

<u>Seismic Response Coefficient, Cs:</u> The seismic response coefficient shall be determined in accordance with Eq. 12.8-2, 12.8-3, 12.8-4, and 12.8-5 as follow:

$$C_s^{min} \leq C_S = \frac{SDS}{\left(\frac{R}{Ie}\right)} \leq C_s^{max} \qquad (7)$$

Where:

$$Cs = \frac{0.9}{\left(\frac{3}{1.0}\right)} = 0.30$$

C_s^{min} = Cs minimum value.

$$= 0.044 S_{DS} Ie = 0.0396 \geq 0.001 \qquad (8)$$

C_s^{max} = Cs maximum value.

$$= C_s^{max} = \frac{SD1}{T\left(\frac{R}{Ie}\right)} = 0.137, \textit{ for } T \leq TL \qquad (9)$$

T_L = long-period transition period determined according to Section 11.4.5 [1], which for Puerto Rico

= 12 sec.

Then, using Eq. 7 the value of Cs is found:

$$C_S = 0.137$$

In addition, for structures located where S_1 is equal to or greater than 0.6*g*, Cs shall not be less than

$$C_S = 0.5 * S_1/(R/I_e) \qquad (10)$$

However, this condition does not apply since, $S_1 = 0.50g$.

Vertical Distribution of Seismic Forces: The lateral seismic force, F_x (kip), induced at any level shall be determined from the following equations:

$$F_x = C_{vx} V \qquad (11)$$

$$C_{vx} = \frac{W_x * h_x^k}{\sum_{i=1}^{n} (W_i * h_i^k)} \qquad (12)$$

Where:

C_{vx} = vertical distribution factor.

V = total design lateral force or base shear of the structure (kip)

W_i and W_x = the portion of the total effective seismic weight of the structure (*W*) located or assigned to Level i or x.

h_i and h_x = the height (ft or m) from the base to level *i* or *x*.

k = an exponent related to the structure period which, is equal to one (1) for structures having a fundamental period of less than or equal to 0.5 sec. and equal to two (2) for structures having a period of 2.5 sec or more. If the structure has a fundamental period between 0.5 and 2.5 secs, then the k value shall be two (2) or shall be determine by linear interpolation among 1 and 2. For this study a liner interpolation is used resulting a values of k = 1.6.

Seismic Base Shear: After all parameter have been found, Eq. 6 can be used to determine the seismic base shear, *V*, in any given direction as follow:

$$V = C_S W \qquad (13)$$

$$V = 0.137 \text{ x } 8439.9$$

$$V = 1156.27 \text{ kips}$$

Table 1 summarize the results of the Seismic Load distribution per floor for an internal frame of the building under consideration.

MAXIMUM COMPUTED VS ALLOWABLE DRIFT PER STORIES

Story Drift is determined as per Section 12.8.6 [1] using the difference of deflection, δ_x, at the top and bottom of the story under consideration. Those deflections are evaluated using Eq. 14. The allowable Story Drift, Δa is listed on Table 12.12-1 [1]. Thus, for Risk Category II and Other Structure, Eq. 15 should be used.

$$\delta_x = \frac{C_d \delta_{xe}}{I_e} \qquad (14)$$

$$\Delta a = 0.020 * h \qquad (15)$$

A summary of the building story drift results can be found in Table 3. It can be seen that the design story drift do not exceeds the allowable drift of the ASCE 7-10 standards.

Table 1

Seismic Load Distribution for an Internal Frame on X-X Direction – ASCE 7

Story	Wi(kip)	Hi(ft)	K	Hi^k	V(kip)	$Wi*Hi^k$	Cvi	Fx(kip)	Fi(kip)
1	861.54	15	1.36	39.76	1156.27	34254.83	0.012139	14.04	3.51
2	848.04	27	1.36	88.44	1156.27	75000.66	0.026579	30.73	7.68
3	848.04	39	1.36	145.83	1156.27	123669.7	0.043826	50.67	12.67
4	848.04	51	1.36	210.04	1156.27	178122.3	0.063122	72.99	18.25
5	848.04	63	1.36	279.96	1156.27	237417.3	0.084135	97.28	24.32
6	848.04	75	1.36	354.88	1156.27	300952.4	0.106651	123.32	30.83
7	848.04	87	1.36	434.26	1156.27	368269.9	0.130506	150.90	37.73
8	848.04	99	1.36	517.68	1156.27	439013.3	0.155576	179.89	44.97
9	848.04	11	1.36	604.84	1156.27	512928.5	0.18177	210.18	52.54
10	794.04	123	1.36	695.46	1156.27	552223.1	0.195695	226.28	56.57
	8439.9					**2821852**	**1**	**1156.27**	**289.07**

SEISMIC LOAD DETERMINATION AS PER DOMINICAN REPUBLIC GUIDE R001-2011

Seismic Zone: Dominican Republic have been divided in two major seismic areas. These areas correspond to the Island levels of Spectral Acceleration, Ss, considering a returning recurrence period of 2,475 years with a probability of exceedance of 2% in fifty years.

On Title IV, Chapter II, Guide R-001 proposes five analysis methods; selecting the appropriate analysis method depend on the structure type, occupancy use and the number of stories [2].

These methods are better known as:

- Simplified Method
- Quasi-Static Method
- Dynamic Method
- Modal Method
- Nonlinear Static Method (Push Over)

International System (SI) is used as the only system of units. The use of certain parameters will depend of the selected method that applies to the particular case of study.

Mapped Acceleration Parameters Ss and S_1: Title II, Chapter 1 [2] defines the Island Seismic Zoning. The building used in this study is located at Higüey, which is a region classified as Zone I. Zone I can be used for all areas where $S \geq 0.95g$ and Zone II for a median seismicity activity area, where $Ss < 0.95g$. Thus, from Title II, Article 9, and Table 1 the mapped acceleration parameters can be selected:

$$S_S = 1.55$$
$$S_1 = 0.75$$

Site Class Classification: The Site Classification need to be selected from Table 3, Article 12, Title II [2]. For comparison purposes, a soil type D is been selected which correspond to Rigid Soil for 15 < N < 50, where N is parameter for SPT.

Adjustment Site Coefficients Fa and Fv: This parameters are defined in Article 21, Table 4 and 5 [2], and considering a soil type D with the corresponding mapped acceleration for the region:

$$Fa = 1.2$$
$$Fv = 1.5$$

The structural analysis have to be carry out according to the corresponding method of analysis selected. From Chapter 2, Article 32 a “Quasi-Static Method" is selected [2], which applies for building with a maximum of 10 stories. Additional seismic parameters for this method can be obtained in the Chapter 3, Article 34 [2], which are presented in the following sections.

Design Spectral Acceleration Parameters, SDs and SD_1: These values shall be determined using Equations (16) and (17).

$$SDs = (2/3)Fa*Ss = 1.2462 \qquad (16)$$

$$SD_1 = (2/3)Fv*S_1 = 0.754 \qquad (17)$$

Fundamental Period of Structure, T: The structure’s fundamental period should be the smaller value of Equations (18) and (19):

$$T = C_T H^x \qquad (18)$$

$$T = K_0 H/\sqrt{Ds} \qquad (19)$$

Where:

H = building height in metes = 37.80 m.

Ds = horizontal dimension in the direction of analysis = 18.29 m

K_0 = coefficient from Table 8 [2] depending on the structural system = 0.13

Ct and x are determined from Table 9 [2], which for a concrete moment-resisting frame are:

$$C_T = 0.046$$
$$x = 0.9$$

Replacing the corresponding parameters into Equations (19) and (20) the structure fundamental period can be found:

$$T \leq \begin{cases} T_{Eq.19} = 1.21\ secs \\ T_{Eq.20} = 1.15\ secs \end{cases}$$

Hence, the structure’s period is T = 1.15 secs.

Design Response Spectrum: Figure 5 shows the design response spectrum as per Chapter III, Article 34 [2], for the applicable seismic analysis method. The spectrum was constructed for a damping ratio of 5%, and contain the Design Spectral Accelerations (Sa) accordingly with one degree of freedom oscillator.

Design Spectral Acceleration (Sa): Figure 5 shows the spectral accelerations with three zones, where the boundaries limits are the corresponding periods defined as T_0 and T_S.

$$T_0 = 0.2\frac{SD1}{SDs} = 0.121 \text{ secs} \qquad (20)$$

$$T_s = 5T_0 = 0.61 \text{ secs} \qquad (21)$$

Since the building structure is located near a geological fault line and its fundamental period, T, is larger than Ts, the spectral acceleration should be evaluated using the following Eq. (22).

$$Sa = Fv*S_1/T = 0.978 \text{ g} \qquad (22)$$

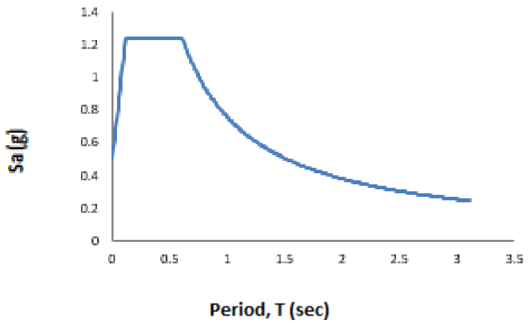

Figure 5
Design Response Spectrum

Seismic Base Shear: The seismic base shear, *V*, in any given direction should be determine using Eq. (23).

$$V = C_bW \qquad (23)$$

Where Cb is a base shear coefficient defined in Equation (24).

$$C_b = U * Sa/Rd \geq 0.03 \qquad (24)$$

Considering a structure appropriate to Group IV with a structural system Type A-IV, parameters U and Rd can be determine from Tables 7 and 8 [2] respectively.

U = 1.0
Rd = 5.5

Thus,

$$C_b = 0.178$$

W, in Eq. (23) is the structure seismic weight to be considered in the seismic analysis, and define by the following Eq.:

$$W = \sum_i^N Wi \qquad (25)$$

Where:
N = number of stories
Wi = total dead load, plus a percentage of the live load, corresponding to story "*i*".

$$Wmi + W'vi \qquad (26)$$

Wmi = considered dead weight at floor "*i*".

$$W'vi = (\phi i * \phi ri)Wvi \qquad (27)$$

W'vi = structure live load at floor "*i*"
Wvi = percentage of the live load to be considered part of the seismic weight on floor "*i*"
ϕi = live load reduction coefficient according to structure occupancy category found in Table A-2 [2].

$$\phi i = 0.2$$

ϕri = live load reduction coefficient according to the slab loaded area dimensions.

$= 0.30 + 3.13/\sqrt{Ae} = 0.72$ for a slab loaded area of $Ae = 55.76 \text{ m}^2$.

Therefore, replacing previous parameters in Eq. (23) and Eq. (25), the structure seismic weight and the Base Shear can be obtained:

W = 9172.00 kip
V = 1632.62 kip

Then, the Base Shear, can be distributed through floors to obtain the corresponding shear force per floor, Fi, according to Eq. (28):

$$Fi = \frac{(V-Ft)*Wi*hi}{\sum_{i=1}^{N} Wi*hi} \qquad (28)$$

Where Ft is an additional force at the top of the building evaluated using Eq. (29) if T ≥ 0.7 secs:

Table 2

Seismic Load Distribution for an Internal Frame on X-X Direction-Guide R001

Story	Wi(kip)	hi(ft)	V(kip)	Ft(kip)	V-Ft	ϕ*Wi*hi	Fx(kip)	Fi(kip)
1	934.75	15	1632.62	131.45	1501.19	14021.25	33.45	8.36
2	921.25	27	1632.62	131.45	1501.19	24873.75	59.34	14.84
3	921.25	39	1632.62	131.45	1501.19	35928.75	85.72	21.42
4	921.25	51	1632.62	131.45	1501.19	46983.75	112.09	28.02
5	921.25	63	1632.62	131.45	1501.19	58038.75	138.47	34.62
6	921.25	75	1632.62	131.45	1501.19	69.93.75	164.84	41.21
7	921.25	87	1632.62	131.45	1501.19	80148.75	191.22	47.80
8	921.25	99	1632.62	131.45	1501.19	91203.75	217.59	54.40
9	921.25	111	1632.62	131.45	1501.19	102258.8	243.97	60.99
10	867.25	123	1632.62	131.45	1501.19	106671.8	385.92	96.48
	9172					**618700.5**	**1632.62**	**408.16**

$$Ft = 0.07*T*V \leq 0.25V \qquad (29)$$

$$Ft = 131.45 \text{ kip}$$

Table 2 summarize the results of the Seismic Load distribution at each floor for an internal frame of the building considered in this study.

MAXIMUM COMPUTED VS ALLOWABLE DRIFT PER STORIES

Story Drifts are determined as per Chapter 7, Article 72 and 73 [2], using the difference of the relative deflection between two consecutives floors. The allowable Story Drift, Δa, is stablished according to the structure group category. For a Group IV building, Eq. (30) should be used, with the story height, h, in meters.

$$\Delta a = 0.005*h \qquad (30)$$

A summary of the building story drift results are presented in Table 3. It can be notice that the allowable drift of the Guide R001 are exceeded in all stories of the building.

COMPARISON OF ANALYSIS METHOD ASCE 7-2010 AND GUIDE R001-2011

After performed the procedures to determine the lateral seismic load for both methodologies, it is found that both procedures have some similitudes. However, some parameter shows differences which are presented in the following paragraphs. First of all, the Guide R001 produce a structure fundamental period lower than the ASCE-7, which could indicate that the structure analyze with R001 guide is more rigid. However, a structural modal analysis for this cases indicates a fundamental period T = 1.497. This indicates that both, the Guide R001 and the ASCE-7, induce an error of 23.18% and 18.5% respectively in the fundamental period determination. Second of all, to determine the effective seismic weight, the Guide R001, includes a portion of the live load which the ASCE-7 does not consider. Because of this, the Guide R001 generate a Seismic Weight 8.67% higher than the one obtained using ASCE-7.

Thus, the R001 Base Shear result 41.2% higher than the ASCE-7 Base Shear. Furthermore, the Base Shear distribution through floors has mayor differences, being the most noticeable of all, the fact that Guide R001 requires to apply an additional forces, Ft, at the top of the building, for structures having a Period T ≥ 0.7 secs, as stated before. This, in addition to the R001 higher seismic weight, will generate a story shear distributions with larger values than the distribution generated by the ASCE-7, as can be seen in Figure 6. Table 4 shows a comparison of the seismic parameters required for both codes.

A consequence of having higher story shear distribution is directly reflected in the story drift. Figure 7 shows a comparison of the story drift obtained from both codes. Notice that, the analysis performed with Guide R001 produces higher story drift than the ASCE 7 code. Both codes amplify the corresponding story displacement by the displacement amplification factor, Cd. Even though, the ASCE-7's Cd factor is 1.25 times higher than the R001's Cd factor, and, the ASCE-7 displacement have to be divided by the Importance Factor (Ie), the R001 story drift, remains higher than the ASCE-7 story drift. However, the allowable story drift limit in the ASCE-7 code is four times higher than the same limit in Guide R001.

Table 3

Drift Comparison per Stories Guide R001-2011 vs. US ASCE 7-2010

		Results for Dom. Rep. – GUIDE R001		**Results for PR – ASCE 7 2010**	
Story	Point	Computed Drift (inch)	Allowable Drift (inch), 0.005*h	Computed Drift (inch)	Allowable Drift (inch), 0.020*h
0	1	0	0	0	0
1	5	1.32	0.9	1.22	3.6
2	9	2.34	0.72	2.07	2.88
3	14	2.68	0.72	2.43	2.88
4	18	3.00	0.72	2.72	2.88
5	22	2.58	0.72	2.79	2.88
6	25	2.88	0.72	2.53	2.88
7	30	2.48	0.72	2.28	2.88
8	34	2.20	0.72	1.93	2.88
9	38	1.72	0.72	1.54	2.88
10	41	1.66	0.72	1.50	2.88

Table 4

Comparison of Seismic Parameters between ASCE 7-2010 and R-001 Codes

Description	**Parameter**	**ASCE 7-10**	**R-001**
Mapped Acel. Parameter – Short Period	S_s	1.35	1.55
Mapped Acel. Parameter – 1 Second	S_1	0.50	0.75
Adjustment Site Coefc. – Short Period	**Fa**	1.0	1.2
Adjustment Site Coefc. – Long Period	**Fv**	1.50	1.5
Spectral Resp. Acel. – Short Period	S_{MS}	1.35	
Spectral Resp. Acel. – Long Peirod	S_{M1}	0.75	
Design Spectral Acel. – Short P	S_{DS}	0.90	1.2462
Design Spectral Acceleration	**Sa**		0.6283
Design Spectral Acel. – Long. P	S_{D1}	0.5	0.754
Seismic Category Design	**Site Class**	D	D
Total Building Height	**H**	123 ft	37.80 m
Approximate Fundamental Period	**Ta (sec)**	1.22	1.15
Building Period Coefficient	**Ct**	0.016	0.046
Coefficent related to Ta	K_0		0.13
Coefficient related to Ta	**X**	0.90	0.90
Importance Factor	**Ie**	1.0	
Live Load Reduction Area Factor	**ϕri**		0.72
Live Load Reduction Occupancy Factor	**ϕi**		0.20
Response Modification Coefficient	**R**	3	
Design Coef. Seismic Resistant Struct.	**Rd**		5.5
Over Strength Factor	**Ω**	3	
Deflection Amplification Factor	**Cd**	2.5	2.0
Redundancy Factor	**P**	1.3	
Seismic Response Coefficient	**Cs**	0.137	
Base Shear Coefficent	**Cb**		0.178
Building Plan Area	**Ds (m)**		18.29
Mapped Acel. Parameter – Short Period	S_s	1.35	1.55
Mapped Acel. Parameter – 1 Second	S_1	0.50	0.75
Adjustment Site Coefc. – Short Period	**Fa**	1.0	1.2
Adjustment Site Coefc. – Long Period	**Fv**	1.50	1.5
Spectral Resp. Acel. – Short Period	S_{MS}	1.35	

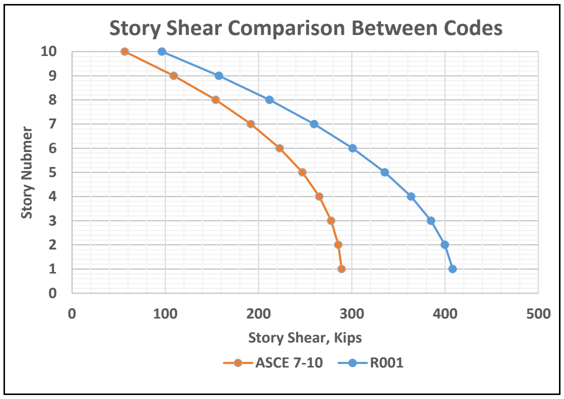

Figure 6
Storey Shear Distribution

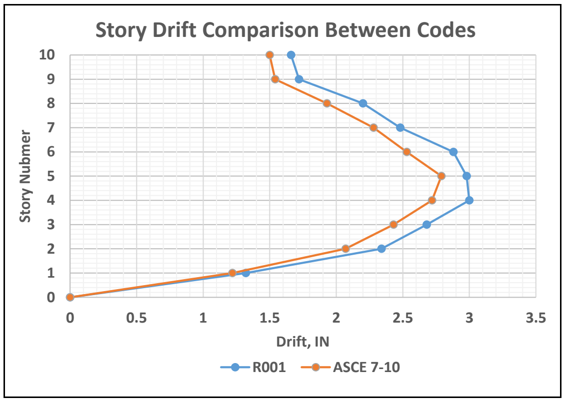

Figure 7
Distribution

CONCLUSIONS

The ASCE 7-2010 and Guide R001-2011 were used to compare their corresponding procedures to determine the lateral seismic load for a 10-story reinforced concrete building. After performing the analysis the following conclusions can be stablish.

The Guide R001 generates a structural fundamental period lower than ASCE 7. Comparing the values with a structural modal analysis, it can be determine that the R001 Guide reports a higher error than ASCE-7 code. R001 yielded a 23.18% error, meanwhile, the ASCE 7 generated an 18.5%.

The main different among the codes is that Guide R001 include a percentage of the live load in the calculation of the effective seismic weight, which the ASCE-7 does not consider, for this type of building occupancy. Thus, this represent an increase of 41.2% in the base shear when using the R001. Also, Guide R001 requires to apply and additional lateral force at top of the building, Ft, which is not required by ASCE-7. This will generate both, higher story drift and higher story shear. However, the deflection needed to determine the story drift, as per ASCE-7, are requires to be divided by the importance factor, Ie, which in this study made no difference, but it could, if the building occupancy changes.

The story drift limits are 4 times higher in the ASCE-7. In this study, the building did not complied with the Guide R001 drift limits, which is an indicative that under this guide the building requires the strengthening of its elements or a change on the lateral force resisting system, but this is beyond the scope of this study.

FUTURE WORKS

A two dimensional analysis was performed in this study. A further step could be to determine how seismic behavior change with a full 3-D analysis, considering the effect of accidental torsion. Also, a complete design of the structural members is recommended to determine how sections elements are affected by the drift limits imposed by design codes.

REFERENCES

[1] *Minimum Design Loads for Buildings and Other Structures*, ASCE 7-10, Ch. 11, pp 72-108, Ch. 12, pp. 72-108, Ch. 20, pp. 203-205, Ch. 21, pp. 207-209 and Ch. 22, pp. 219-227.

[2] *Reglamento para el Análisis y Diseño Sísmico de Estructuras*, “R001-2011” MOPC and DGRS, Ch. 1, 3, 4 and 7, pp. 6-42.

[3] *FTool Software 2012 Educational Version*, by PUC – Rio University, Brazil.