Journal of Civil Engineering Research 2014, 4(2): 42-45
DOI: 10.5923/j.jce.20140402.03

Lateral and Base Shear Forces Acting on 20 Stories Building in Bujumbura City during the Seismic Activity

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Abstract For designing a high-rise building in Bujumbura city, it is very important to know that the city is located in the seismic zone and therefore take adequate conceptual measures. This study was inspired by a tendency to high-rise building in Bujumbura city while the designers of these buildings do not have sufficient data on the impact of seismic activity in the area lying in the extension of the Rift Valley. By referring to the International Building code (Berkeley 2003) and the ASCE7 data, it is easy to draw a response spectrum curve for Bujumbura city based on the short period ground motion range **(To)**, the characteristic period of ground motion **(Ts)** and the spectral response acceleration **Ss** and $\mathbf{S_1}$. By using the Extended Three Dimensional Analysis of Building Systems (ETABS) software for the 20 stories building, the seismic base shear forces **(V)** can reach -2000KN and the seismic stories lateral forces **(Fx)** can reach 230 KN.

Keywords High-rise building, Seismic base shear forces, Seismic stories lateral forces

1. Introduction

The earthquake is a natural disaster that has a detrimental effect on people's lives because it can destroy entire buildings and other social, economic, commercial and touristic infrastructures. In the countries where seismic activity is intense, many human and material damages were already registered. In some of these countries, measures of structural design of high-rise buildings were already taken.

As stated by Midzi V., the vulnerability of the East African populations to seismic events has been underscored by a study which advised that the region's capacity in earthquake preparedness and hazards mitigation need to be improved significantly. [1]

Burundi is located in the Rift Valley area where seismic activity is intense. Unfortunately the building designers do not consider this aspect or do not have reliable data on seismic impact especially as the current trend is the high-rise construction in Bujumbura city.

In the present study, base shear and lateral loading forces were calculated using the Extended Three Dimensional Analysis of Building Systems (ETABS) software. [2]

The Mapped 0.2 sec. Period Spectral Acceleration, **Ss** and the Mapped 1.0 sec. Period Spectral Acceleration, **S1** for Bujumbura city are known and are very important for designing a seismic structure [3]. According to the UFC3-310 01. (2005), Bujumbura city is the sixth city in Africa which has high values of Ss and S1after Algeria, Tunisia, Egypt, Djibouti and Bukavu. [4]

In this study, to determine the values of base shear and lateral forces for the 20 stories building in Bujumbura city, it was very important to calculate first the values of the short period ground motion range to and the characteristic period of ground motion Ts using the Spectral Response Acceleration SMS and SM1. These factors are necessary in tracing of the response spectrum curve.

2. Drawing a Curve of Spectral Response Acceleration for a Building in Bujumbura City

Before drawing the curve of spectral response acceleration for a building in Bujumbura city, we need to know first the values of **To** and **Ts**. These values are given by the following formula:

$$\text{To} = \frac{0.2\ \text{SD1}}{\text{SDS}} \quad \text{and} \quad \text{Ts} = \frac{\text{SD1}}{\text{SDS}} \quad [5]$$

Where: **To** = the short period ground motion range
Ts = the characteristic period of ground motion
SD1 and **SDS** = Design Spectral Response Acceleration [6]

SD1 = 2/3 SM1 and **SDS = 2/3SMS**

Where: **SM1** and **SMS** = Maximum Spectral Response Acceleration [7]

SM1 = F1*S1 and **SMS = Fa*SS**

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Published online at http://journal.sapub.org/jce
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where **F1** = Velocity-based Site Coefficient(Equal to 1 for Bujumbura site [8]
S1 = Mapped 1.0 sec. Period Spectral Acceleration (Equal to 0.26 for Bujumbura site) [9]
Fa = Acceleration-based Site Coefficient (Equal to 1 for Bujumbura site) [10]
SS = Mapped 0.2 sec. Period Spectral Acceleration (Equal to 0.66 for Bujumbura site) [11]

SM1 = 1*0.26 = 0.26
SMS =1*0.66 = 0.66
SD1 = 2/3*0.26 = 0.17
SDS = 2/3*0.66 = 0.44
To = (0.2*0.17) /0.44 = 0.08
Ts = 0.17/0.44 = 0.39

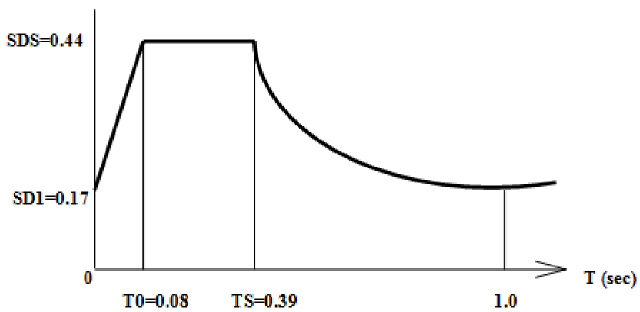

Figure 1. Response spectrum curves

3. Lateral Forces (F_x)

The lateral forces acting on the 20 stories is given by the following equation:

$$F_x = C_{vx} \times V \quad [12]$$

where: C_{vx} = the vertical distribution factor
V = the shear forces

$$C_{vx} = [W_x \; h_x^k] / \{\sum_{i=1}^{n} W_i (h_i)^k\} \quad [13]$$

where: W_i = portion of the total gravity load **W** assigned to the level **i**
W_x = portion of the total gravity load **W** assigned to the level **x**;
h_i = height from the base to level **i**
h_x = height from the base to level **x**;
k = the exponent related to the building period **T** and takes into account the whiplash effects in tall slender buildings.

$$T = C_t (h_x)^{3/4} \quad [14]$$

C_t = a period coefficient.

$$k = \frac{(2-1) \times (T-0.5)}{(2.5-0.5)} + 1 \quad \text{(for 0.5 sec < k < 2.5 sec)}$$

The value of k is equal to 1.75.

4. Base Shear Forces (V)

The base shear forces acting on 20 stories building is given by the following equation:

$$V = Cs \times W \quad [15]$$

where: **Cs =** the seismic design coefficient
W = the building reactive weight including cladding.

$$Cs = \frac{SDS}{(R/I)} \leq \frac{SD1}{(TR/I)} \geq 0.044 \; SDS \; x1 \quad [16]$$

Where:
T = the fundamental period (T is equal to 2)
R = the Seismic Response Modifier (R is equal to 8)
Cs = 0.044 x 0.44 x 1 = 0.01936.

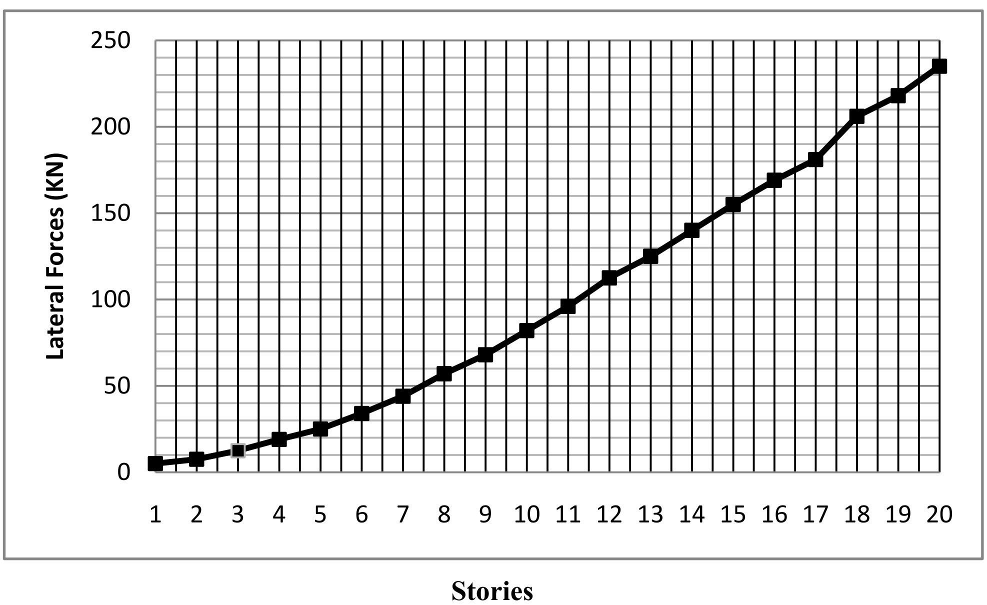

Figure 2. Seismic Stories Lateral Forces Result

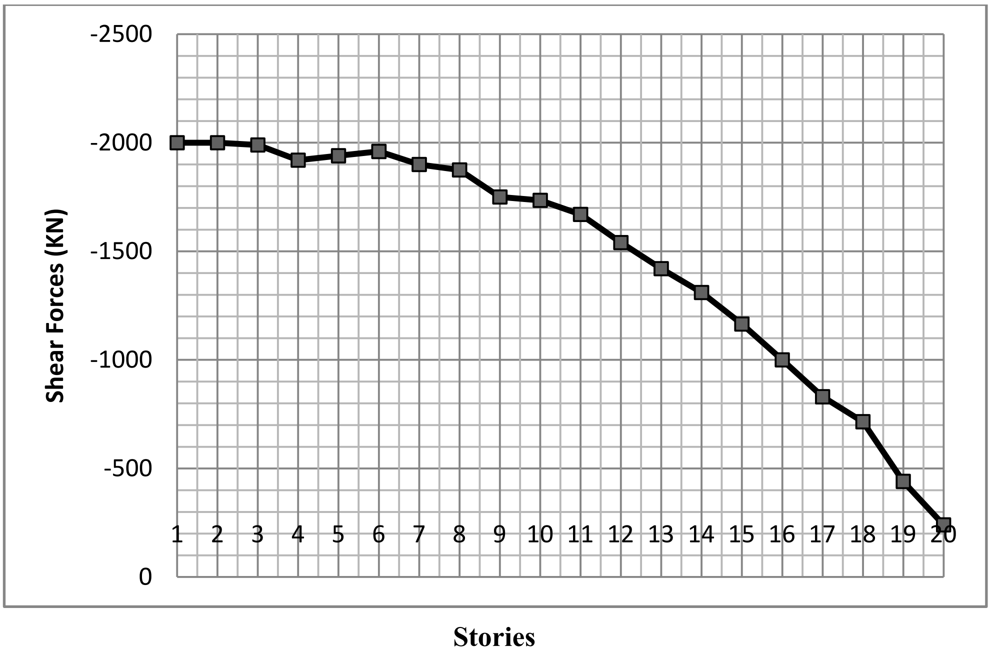

Figure 3. Seismic Base Shear Forces Result

5. Conclusions

The high-rise building system in one of possible solutions operationalize the urban system, especially in urban cities with large population. Bujumbura city is atypical cases where the government and other stakeholders in the field should take measures that promote high-rise building instead of leaving the city extend into agricultural areas known for their fertility. Designers and builders should be aware that the Bujumbura site is located the rift valley known for its seismic vulnerability because in some areas, the earthquake has caused human and material damage. In our study, we used the seismic data for Bujumbura site to analyze the behavior of 20 levels building. We find that the seismic shear forces and lateral forces can reach 2000 KN and 230KN respectively.

These forces are enormous and dangerous for high-rise building especially the designers of buildings does not take into account the seismic aspect in calculation of structures.

To prevent the earthquake threat, the decision makers in matters of political policies, engineering and planning professionals need to understand the nature of the hazardous phenomena and take all preventive measures. The decision can be taken at three levels of commitment to implement mitigation and preparedness including the development knowledge, public awareness raising and education, preparedness investments.

ACKNOWLEDGEMENTS

The author would like to thank all those who contributed to prepare this work.

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