COMPARATIVE ANALYSIS OF SEISMIC LOADING ON HIGH-RISE STEEL BUILDING STRUCTURES IN BUJUMBURA AND KIGALI CITIES

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ABSTRACT:

The seismic loading analysis is very important for designing high-rise buildings in the most seismic ground motions zone. The objective of this study was to compare some seismic loading forces on two similar high-rise building structures located in Bujumbura city (Capital of Burundi) and Kigali city (Capital of Rwanda); using ETABS software .These two cities are located in the Western side of the East African rift system; known as the African most seismic ground motions zone. In the present study, all the seismic design data were the same for the two buildings except their seismic site spectral response acceleration Ss and S1.The result of the study showed that the average of the seismic base shear forces and the seismic stories lateral forces on the building located in Bujumbura city is ranged between 2.3 and 2.4 times greater than the average of these seismic loading forces on the building located in Kigali city.

KEYWORDS: East African rift system, Ss and S1, high-rise steel building, seismic base shear forces, seismic stories lateral forces.

1. INTRODUCTION

The East African region is often shaken by the earthquake principally because of the presence of the rift valley. The earthquake in that region which covers about 5.5 million km^2 and holds more than 120 million people has been identified as the major threat.[1] .Thus, with major population growth and urbanization increasing , the vulnerability to the earthquake hazards has greatly increased. [2] **.**For facing simultaneously to the urbanization target and the earthquake threat, it is very important to construct the high-rise buildings with high seismic design consideration. 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.[3] In the present study the seismic base shear forces and the seismic stories lateral forces acting on each building structures (20 stories) were calculated and a comparison analysis of these forces was done for the two buildings.

As the seismic spectral response acceleration (Ss and S1) are known for the two building construction sites, the International Building Code [4] and other design references was helpful to determine the input data for the seismic loading design.

The Extended Three Dimensional Analysis of Building Systems (ETABS) software [5] was used to perform automatically the seismic loading design process. Bujumbura city which has high values of seismic spectral response acceleration than Kigali city is the sixth African city with high seismic spectral response acceleration Ss and S1after Alger (Algeria), Tunis (Tunisia), Djibouti (Djibouti), Bukavu (Congo Democratic) and Cairo (Egypt)[6].These factors are very decisive for seismic building design process on any given construction site. The result of the seismic loading comparison showed that the average of the seismic loading base shear forces and seismic stories lateral forces on building located in Bujumbura city is ranged between 2.3 and 2.4 times greater than the average of the seismic loading base shear forces and seismic stories lateral forces on building located in Kigali city .

Table 1 Seismic loading design data

Seismic design characteristics	Seismic design values	
	Bujumbura Building	Kigali Building
Occupancy Category and Seismic Use Group , SUG [7]	I	I
Seismic Importance Factor , I [8]	1	1
Seismic Site Class [9]	B	B
Mapped 0.2 sec. Period Spectral Acceleration , Ss [10]	0. 66	0. 28
Mapped 1.0 sec. Period Spectral Acceleration , S1 [11]	0. 26	0. 11
Acceleration-based Site Coefficient , Fa [12]	1	1
Velocity-based Site Coefficient , F1 [13]	1	1
Maximum Spectral Response Acceleration , SMS [14]	SMS =Fa x Ss = 0.66	SMS =Fa x Ss = 0. 28
Maximum Spectral Response Acceleration , SM1[15]	SM1=F1x S1= 0. 26	SM1=F1x S1=0.11
Design Spectral Response Acceleration , SDS [16]	SDS=2/3 SMS=0.44	SDS=2/3 SMS = 0.19
Design Spectral Response Acceleration , SD1[17]	SD1=2/3=SM1=0.17	SD1=2/3 SMS= 0. 07
Seismic Design Category , SDC [18]	SDC=C (SUG)= I	SDC = B (SUG= I)
Seismic Response Modifier , R [19]	R = 8	R = 8

2. DESIGN SPECTRAL RESPONSE ACCELERATION FOR THE TWO CITIES

On the Fig.1 below, the response times To and Ts needed for constructing response spectra curves for the two cities are calculated as follows:

$$T_o = \frac{0.2\ SD1}{SDS};\quad T_s = \frac{SD1}{SDS} \quad [20] \qquad (2.1)$$

where To is the short period ground motion range and Ts is the characteristic period of ground motion.

For the building located in Bujumbura city: To = 0.08 ; Ts-B = 0.39 ; SD-B = 0.17; SDS-B = 0.44
For building located in Kigali city: To = 0.08 ; Ts-K = 0.37 ; SD1-K = 0.07 ; SDS-K = 0.19

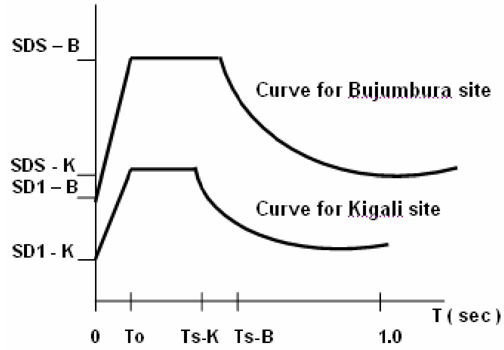

Fig.1 Response spectrum curves

3. SEISMIC BASE SHEAR FORCES (V)

The seismic base shear forces is given by the following equation:

$$V = Cs \times W \quad [21] \tag{3.1}$$

where Cs is the seismic design coefficient and W is the building reactive weight including cladding.

$$Cs = \frac{SDS}{(R/I)} \leq \frac{SD1}{(TR/I)} \geq 0.044\, SDS \times I \quad [22] \tag{3.2}$$

The fundamental period T and the Seismic Response Modifier R values are respectively equal to 2 and 8.
For building located in Bujumbura city, Cs = 0.044 x 0.44 x 1 = 0.01936.
For building located in Kigali city, Cs = 0.044 x 0.1 9 x 1 = 0.00836.

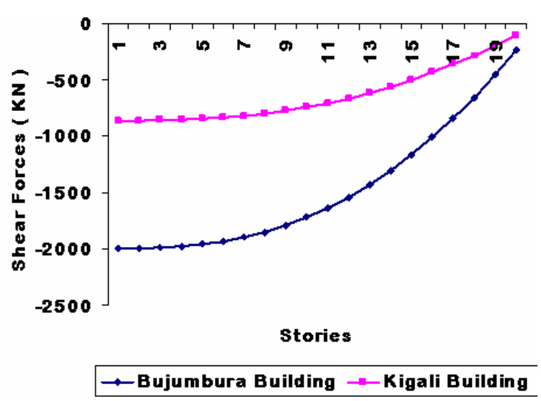

Fig. 2 Seismic Base Shear Forces Result

4. SEISMIC STORIES LATERAL FORCES (Fx)

The equation for the seismic stories lateral forces calculation is:

$$F_x = C_{vx} \times V \quad [23] \tag{4.1}$$

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

$$C_{vx} = [W_x (h_x{}^k)] / \{\sum_{i=1}^{n} W_i (h_i)^k\} \quad [24] \tag{4.2}$$

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

$$T = C_t (h_x)^{3/4} \quad [25] \tag{4.3}$$

where: h_x is the total height (in feet) of the building and C_t is a period coefficient.

$$k = \frac{(2-1) \times (T - 0.5)}{(2.5 - 0.5)} + 1 \quad (\text{for } 0.5 \text{ sec} < k < 2.5 \text{ sec}) \tag{4.4}$$

The value of k is equal to 1.75 for the two buildings.

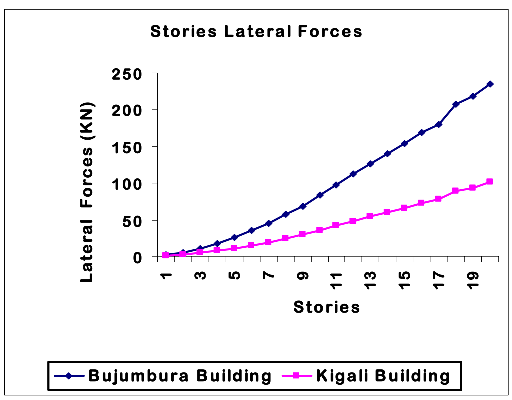

Fig. 3 Seismic Stories Lateral Forces Result

5. CONCLUSION

After analysis and calculation of the seismic base shear and the seismic stories lateral forces acting on the two buildings as illustrated on the figures 2 and 3, we realized that the average of these loading forces on building located in Bujumbura city is ranged between 2.3 and 2.4 times greater than the average of the same loading forces acting on the building located in Kigali city. The highest seismic loading forces for building located in Bujumbura city is given especially by the highest values of its site seismic spectral response acceleration Ss and S1 comparatively to Ss and S1 for building site located in Kigali city.

The earthquake shakes in the region had already caused humans and animals life losses and a lot of infrastructure injuries. Thus, 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 against the earthquake threat. The decision can be taken at three levels of commitment to implement mitigation and preparedness .These three levels of commitment are the development knowledge, public awareness raising and education, preparedness investments.

High-rise building construction can be a sustainable solution for development in the countries that are over-populated and the system can also create sufficient space in urban area for other development infrastructures. More researches are needed to enrich this study in order to contribute to the urban development without earthquake threat in East African rift system.

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