INVESTIGATION OF EARTHQUAKE - RESISTANT DESIGN IN THE EGYPTIAN CODE

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ABSTRACT

Earthquake-resistant design provisions in the Egyptian Code are discussed and evaluated in this research. These provisions are also compared with the corresponding ones in U.S. codes; namely The Uniform Building Code (UBC) and The National Earthquake Hazards Reduction Program (NEHRP) provisions. Seismic forces as required by the adapted Egyptian Code; namely The Calculation of Loads and Forces Code, are determined. A comparison is made between the base shear ratios calculated by using seismic and wind forces for buildings having heights ranging from ten to a hundred meters located in the highest seismic zone of Egypt. Seismic forces as required by UBC and NEHRP are also calculated for buildings having the same range of heights considered before and located in zones having similar seismic activity as that of the highest seismic zone of Egypt. Then, a comparison is made between the base shear ratios calculated by using these foreign codes and those calculated by using the Egyptian code. Finally, the results of these analyses are examined on two buildings of regular configurations. Six-story and ten-story reinforced concrete buildings are designed according to the Egyptian Code. Their structural dynamic behaviors are evaluated. It has been found that the lower and upper bounds of the base shear ratios calculated by using seismic forces are less than that calculated by using wind forces. It has also been found that the base shear ratios calculated by using the Egyptian Code are 60% (in average) of those calculated by using the Uniform Building Code and The National Earthquake Hazards Reduction Program provisions. Therefore, it can be concluded that the design seismic force calculated by using the Egyptian Code is underestimated and needs to be enlarged. The analysis of the mathematical models shows that the maximum base shear ratio demand is somewhat independent on the natural period of the structure. It has been found that the drift ratio given by the Egyptian Code to insure elastic behavior for buildings during earthquake excitation is non-conservative. It is recommended that drift ratio limit should be reduced to value less than 0.003 with a reliable factor of safety. It is recommended that earthquake-resistant design provisions in the Egyptian Code should be modified to be similar to that of zone 2B of the Uniform Building Code since they have similar expected peak ground acceleration.

Keyword: Seismic analysis, Egyptian Code, Earthquake forces, Dynamic behavior.

INTRODUCTION

The provisions of earthquake-resistant design have been established in the Egyptian codes and now it is obligated to be considered in the design procedure especially after Cairo earthquake of 1992. The subject of the calculation of earthquake forces is covered in The Egyptian Code of Practice and Design for Reinforced Concrete Constructions (ECPD) of 1989 [1] and The Egyptian Code for Soil Mechanics and Foundation; Design and Execution (SFDE) of 1991 [2] to some extent. However, because of the distractive effect of Cairo earthquake of 1992 on the metropolitan area of Cairo, the Permanent Egyptian Committee for Construction Provisions assembled all loads that can be used in design procedure in what is called the Loads Code. In 1993, the first edition of the Egyptian Code for The Calculation of Loads and Forces (CLFC) [3] has been issued.

Three methods have been given by CLFC that can be used to include earthquake effects in the routine work of design. The equivalent static load method is the only detailed procedure given by CLFC. The other two methods; the response spectra and the complete dynamic analysis, are just mentioned and required to be used for buildings in which first method can not be used. Nevertheless, there are no response spectra curves neither earthquake characteristics given or suggested by the CLFC that can be used.

In this research, the design criteria of lateral force considerations given by the CLFC including earthquake force and wind load are evaluated. Some earthquake-resistant design provisions; namely the Uniform Building Code (UBC) [4] and the National Earthquake Hazards Reduction Program (NEHRP) [5], are also presented. A comparison is made for the base shear ratios for buildings having heights ranging from ten to a hundred meters calculated by using CLFC, UBC, and NEHRP. Two mathematical models are examined and their dynamic behaviors under earthquake forces are evaluated. The deficiency, as seen, in the determination of earthquake force in CLFC is highlighted and discussed. Recommendations have been proposed to modify earthquake provisions in the Egyptian Code (CLFC).

DESIGN CRITERIA

General

The purpose of any design criteria is to insure that the designed structural system is able to carry and to resist the design loads. Moreover, in earthquake-resistant design provisions, the design philosophy is that structural system should resist the average expected ground motion excitation without any destruction and should be able to response to sever earthquakes with partial damaged but without complete collapse. This criteria should be satisfied in the routine work of design. As required by the Egyptian codes, buildings should be designed to resist gravity loads as well as lateral load of earthquake and wind whichever is the greater.

The Earthquake Forces of CLFC

According to CLFC of 1993, Egypt is divided into three seismic zones. These zones are named as one, two, and three. They represent low, low to moderate, and moderate seismic activity zones respectively. The work presented in this research is focused on the highest seismic activity area of Egypt which is zone three. This zone includes all cities on the Mediterranean sea, red sea, Aswan, Elfayom, Elesmaeelia, and the south west part of the west desert.

Three methods are given by the CLFC [1] that can be used to calculate the lateral seismic forces. The first method is the equivalent static load procedure. This method can be used for regular buildings in which their heights are not more than a hundred meter and the ratio of the total building's height to its width in the direction of lateral force is not more than five. The second method is the response spectra procedure. This method can be used for regular buildings in which their heights are between a hundred and a hundred fifty. It can also be used for those in which the ratio of building's height to its width in the direction of seismic forces is more than five. The third method is to perform a complete dynamic analysis for the structure. This method should be used for irregular buildings in the elevation view or the plan view and for those in which their heights are greater than a hundred fifty.

In the first method, the base shear forces can be calculated as follows:

$$V = ZIKCSW \qquad (1)$$

In which Z, I, S, and K are defined as the zoning, the importance, the soil, and the structural system factors respectively. Values of these parameters are given in Appendix (1). C is defined as the construction system factor and can be calculated as follows:

$$C = 1/(15\sqrt{T}) \quad \leq 0.12 \qquad (2)$$

in which T can be calculated as:

$$\begin{aligned} T &= 0.1N && \textit{for moment resisting frame system} \\ T &= 0.09H/\sqrt{B} && \textit{for any other system} \end{aligned} \qquad (3)$$

where N is the number of story and H is the total height of the building measured from the foundation level. B is the width of the building in the direction under consideration.

Finally, W is the designed weight of the building and equals to the dead loads for buildings which designed for live load not more than 500 kg/m^2. It is also equal to the dead load plus half the live load for buildings designed for more than 500 kg/m^2 live load. As can be recognized, there is no a lower limit on the calculated seismic force but there is an upper limit for it since C can not be more than 0.12.

In the second method, a modal analysis is performed by using the response spectra procedure in determining earthquake forces. However, the required response spectrum curve is not specified. Therefore, this second method can not be practically used as required by CLFC. In the third method, a complete dynamic analysis is performed. However, the characteristics of earthquake excitation that should be used in the analysis is not specified. Therefore, this given third method can not also be used as specified by the CLFC since there is not enough information to perform this analysis. Then, practically the equivalent static lateral load method is the only procedure that can be used. Nevertheless, this method is the one evaluated in this research.

The Wind Forces of CLFC

According to CLFC of 1993, wind effect should be considered on the structural system (outer surface) and on the non structural elements. Wind loads can be calculated for the structural system by using the following equation:

$$P_e = C_e k q \qquad (kg/m^2) \tag{4}$$

where P_e is the design wind loads on the unit area of the outer surface of the building under consideration. q is the wind pressure which depending on the geography of the site. k is a factor depending on the height of the building measured from the ground level. C_e is the pressure or the suction factor depending on the outer shape of the building. By calculating the wind loads on the unit area from Eq. (4), the total lateral wind forces on the structural system can be determined. Values of these parameters in different wind zones are given in Appendix (1).

The Uniform Building Code (UBC)

The Uniform Building Code (UBC) [4] is the building code most extensively used in the United States. Every three years there is a new issue of the UBC to modify or to insure the older edition. Regarding the seismic forces required by the UBC, five zones are defined and given the designated 1, 2A, 2B, 3, and 4. Of these zones, 2A and 2B are classified as moderate risk zones which can be compared with zone three of Egypt. The total base shear is given by the following formula:

$$V = (ZICW)/R_w \tag{5}$$

in which Z and I are the zoning and the importance factors respectively. C is a numerical coefficient which reflects the characteristics of the structure and the soil which is given as:

$$C = (1.25S)/T^{2/3} \qquad \leq 2.75 \tag{6}$$

in which S is the site coefficient depending on the characteristics of the soil. T is the natural period. R_w is a parameter representing the ability of the structure to dissipate the energy imparted by the earthquake through inelastic deformations. W is the total seismic dead load. Values for these parameters are given in Appendix (1).

The National Earthquake Hazards Reduction Program (NEHRP)

The National Earthquake Hazards Reduction Program (NEHRP) [5] is a recommended provisions for the development of seismic regulations for buildings in the United States. According to NEHRP, four seismicity index are given to the seismic zones. Seismicity index two and three are designated to moderate risk zones which are used in this work to be compared with the highest seismic zone of Egypt. The seismic forces are calculated as follows:

$$V = C_s W \tag{7}$$

where

$$C_s = (1.2A_v S)/(RT^{2/3}) \tag{8}$$

in which A_v is a coefficient representing effective

peak velocity-related acceleration.
S is a coefficient for the soil profile characteristics of the site and R is the response modification factor depending on the structural system. T is the fundamental period of the building and can be calculated as:

$$T = C_T\, h_n^{3/4} \qquad (9)$$

where
C_T equals 0.03 for concrete frames and h_n is the height in feet above the base to the highest level of the buildings. Values of these parameters are shown in Appendix (1)

METHOD OF ANALYSIS

In order to evaluate the seismic forces required by CLFC, two faces of study are performed. In the first one two different approaches are considered. In the first approach, a comparison is made between the base shear ratios calculated by using seismic force and those calculated by using wind load. Base shear ratio is defined as the ratio between the base shear force and the designed weight of the structure. This is done for structures built in the highest seismic zone of Egypt in which it is expected that seismic force should control the design lateral force to some extent. In the second approach, a comparison is made between the base shear ratios calculated by using the seismic force required by the CLFC and those calculated by using the seismic force required by UBC and NEHRP provisions for buildings in zones similar to that of zone three of Egypt.

In the second face of study, the outcome results of the first face of analysis are examined on two regular configuration buildings. Six- story and ten-story buildings are chosen to represent mid- and high-rise buildings respectively. Then, the structural behaviors of these buildings are studied and then evaluated.

In performing these analyses, firstly, buildings with regular configuration having a total height not more than a hundred meter are considered in this comparison in which the equivalent static load method can be used. This leads to calculate the base shear ratios for buildings having total heights ranging from ten meters to a hundred meter. This means that their natural periods ranging from 0.3 second to 3.3 second according to the two formulas of the natural period given by the CLFC [3]. The three types of soil conditions specified by CLFC are considered. Moment resisting frame (ductile and non-ductile) system and moment resisting frame-shear wall; dual system are the most common buildings in Egypt. Therefore, these are the two structural systems considered in this study. This leads to nine combinations in the calculations of the base shear ratios. However, the forces calculated for moment resisting ductile frames (MRF) on stiff soil and those calculated for dual system (DS) on soft soil set a lower and an upper bounds for the calculated base shear ratios respectively. On the other hand, in calculating the base shear ratios for these structural systems by using wind loads, the four wind zones lie in the third seismic zone are considered. Since wind force is independent on the structural system or soil conditions, this leads to only four combinations based on the wind zones. Therefore, zones where wind pressures (q) equal to 50 kg/m^2 and 90 kg/m^2 set a lower and an upper bounds for the base shear ratios calculated by using wind load respectively. Finally, the lower and the upper bounds of the base shear ratios calculated from seismic forces are compared with those calculated from wind loads.

Secondly, seismic forces as required by UBC and NEHRP provisions are calculated for the same two structural systems considered firstly. Then, the base shear ratios of the considered systems are calculated. Since the reinforced concrete structures are the only type considered in the CLFC, base shear ratios are calculated for reinforced concrete buildings in the moderate risk zones of these codes; namely zones 2A and 2B of the UBC and zones with seismic index 2 and 3 of NEHRP. Soil conditions are also considered. This leads to eight combinations for each zone of the UBC and three combinations for each zone of the NEHRP provisions. However, a lower and an upper bounds are set for moment resisting frame (MRF) on stiff soil and dual system (DS) on soft soil respectively for each zone of UBC and NEHRP. Then comparisons are made for the calculated base shear ratios of the UBC and the NEHRP with those calculated by using the CLFC.

Thirdly, the behaviors of the two designed buildings which their mathematical models are presented after are examined. Seismic force required by CLFC, UBC, as well as NEHRP provisions are calculated for each building. Wind load as required by CLFC is also calculated. lateral loads are applied on the two buildings individually and monotonically increased until failure in which a complete non-linear analysis is performed. Then, the structural behavior of each building is evaluated.

Mathematical Models

Two buildings of regular configurations are designed and used in this analysis. The first building is a six-story one-bay frame representing mid-rise structures. The second building is a ten-story one-bay frame representing high-rise structures. These two buildings are shown in Figure (1). They are chosen as six meter width and the repetitive floor height is three meters except the height of the ground floor is chosen as four meters. The repetitive space is five meters. These structures are chosen as moment resisting ductile frames in which they represent the lower bound of the base shear ratios calculated by using the seismic force of CLFC. Gravity loads and lateral loads are considered according to the ECPD provisions [1]. Load calculations show that the designed lateral loads are controlled by the wind forces even in the worst case of soil condition (S = 1.3). Table (1) show the calculated base shear ratios for the two buildings using seismic and wind loads of the CLFC for S equals 1 and q equals 80 kg/m_2 (Alexandria area). It also shows those calculated by using UBC and NEHRP for same soil condition considered in the CLFC. Cross sections of beams and columns are designed and chosen according to the ECPD provisions.

Table 1. Base Shear Ratios for Six- and Ten-Story Buildings.

Height	CLFC S=1	CLFC q=80	UBC S=1	NEHRP S=1
Six-St.	0.029W	0.068W	0.045W	0.047W
Ten-St.	0.013W	0.061W	0.021W	0.023W

A mathematical two dimensional model is constructed for each building [8]. Joint size is ignored but shear deformation of all members is considered. Beam-column element is considered in modeling the members. In calculating the yield surface for columns, the interaction of moment and axial force is considered. While in calculating the yield surface of the beams, axial force is ignored. Yielding considered to take place and plastic hinges form when the calculated internal forces lie on or outside the designated yield surface. In studying the inelastic behavior of these two buildings, the initial stiffness of the members are considered as half of the calculated stiffness. This is done because cracks take place as the structure responses inelastically and its cross sections deteriorate until collapse. This assumption was made based on previous experimental results [13]. The mass of each structure is considered lumped at the nodes.

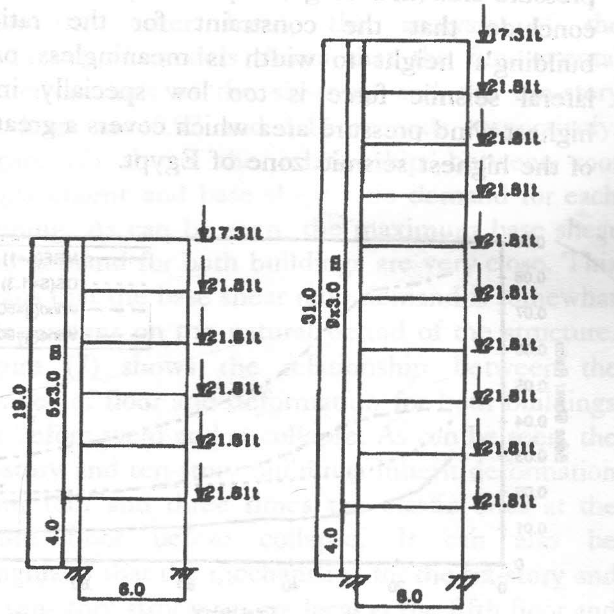

Figure 1. Six-Story and Ten-Story Buildings.

RESULTS OF ANALYSIS

Figure (2) shows the upper and the lower bounds for the relationship between building's height in meters and the base shear ratios calculated by using seismic and wind forces as required by CLFC when the ratio of the height to the width of buildings equals five. It can be concluded that the lower and the upper bounds of the base shear ratios calculated by using seismic forces are less than that calculated by using wind forces. However, for dual system buildings with heights more than 80 meters on soft soil, the base shear ratios calculated by using seismic forces are greater than those calculated by using wind loads in the wind area of q = 50 kg/m^2. This is true where the ratio of the building's height to width is equal to five. By keeping the space between the structural system constant, the designed weight changes relatively to the change in span. Based on that, seismic forces start to be biased as the ratio of the height of the building to its width reaches 2.2 and 4.5 for MRF and DS in the lowest wind pressure area (in average) respectively. On the other hand, seismic forces start to be biased as the ratio of the height of the building to its width reaches 1.2 and 2.3 for MRF and DS in the highest wind pressure area (in average) respectively. These results conclude that the constraint for the ratio of building's height to width is meaningless or the lateral seismic force is too low specially in the highest wind pressure area which covers a great part of the highest seismic zone of Egypt.

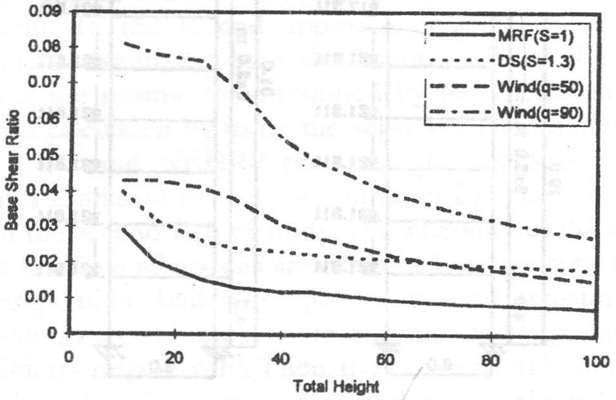

Figure 2. Height of Buildings versus Base Shear Ratios (CLFC Requirements).

Figures (3) shows the lower and the upper bounds of the base shear ratios calculated by using the UBC for zones 2A and 2B for buildings with a range of heights vary from ten to a hundred meters. By comparing the base shear ratios calculated by using UBC with those calculated by using the CLFC, it is found that the lower bound of the base shear ratios calculated by using the UBC in zones 2A and 2B are 1.14 and 1.52 (in average) greater than those calculated by using the CLFC, respectively. It is also found that the upper bound of the base shear ratios calculated by using the UBC in zones 2A and 2B are 1.32 and 1.76 (in average) greater than those calculated by using the CLFC, respectively.

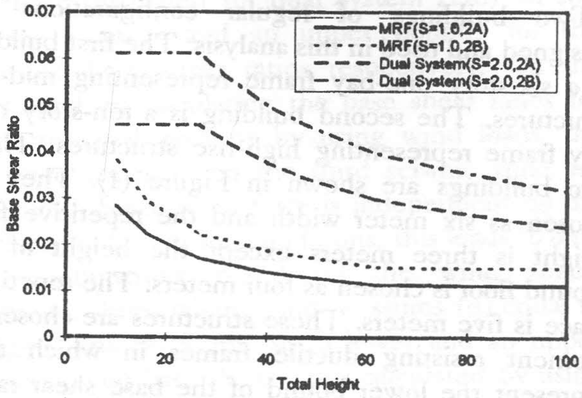

Figure 3. Height of Buildings versus Base Shear Ratios (UBC Requirements).

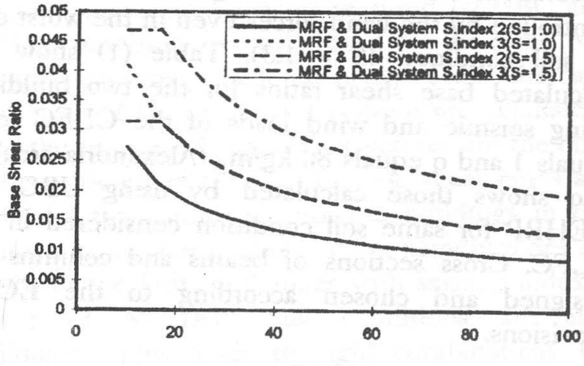

Figure 4. Height of Buildings versus Base Shear Ratios (NEHRP Requirements).

Figures (4) shows the lower and the upper bounds of the base shear ratios calculated by using the NEHRP for zones with seismic index 2 and 3 for buildings with a range of heights varies from ten to a hundred meters. By comparing the base shear ratios calculated by using the NEHRP with those calculated by using the CLFC, it is found that the lower bound of the base shear ratios calculated by using the NEHRP in zones with seismic index 2 and 3 are 1.14 and 1.70 (in average) greater than those calculated by using the CLFC, respectively. It is also found that the upper bound of the base shear ratios calculated by using the NEHRP in zones with seismic index 2 and 3 are 1.26 and 1.89 (in average) greater than those calculated by using the CLFC, respectively. Therefore, from Figures (2), (3), and (4), it can be concluded that the lateral seismic force required by CLFC is too small compared with that of UBC and NEHRP.

Although zones 2A and 2B of the UBC and those with seismic index 2 and 3 of the NEHRP are classified as moderate seismic activity zones, the classification is based on the effective peak ground acceleration (PGA) [4]. Zones 2A of the UBC and that with seismic index 2 of the NEHRP have expected PGA equal to 0.1g. In zones 2B of the UBC and in that with seismic index 3, the expected PGA is 0.15g. Based on previous researches [9], the expected PGA in the highest seismic zone in Egypt is 0.15g. Therefore, it is reasonable to compare the base shear ratios calculated by using the CLFC with those calculated by using UBC and NEHRP in zones 2B and that with seismic index 3 respectively. Figure (5) shows this comparisons. From this figure, it can be concluded that the base shear ratios calculated by using the CLFC are 60% and 56% (in average) of those calculated by using the UBC and NEHRP respectively. Therefore, it can be concluded that the design seismic force calculated by using CLFC are underestimated and needs to be enlarged. Although the seismic design provisions of the CLFC are initiated from the UBC, the CLFC did not develop its provisions as the UBC did. As mentioned earlier, the UBC improves its version every three years based on continues research works, the new registered earthquake records, and the developed structural materials. Seismicity in the recent version of the UBC is expressed in terms of zone maps which take into account both the intensity of ground motion and the frequency of earthquake occurrence. Therefore, it is recommended that the CLFC should modify its earthquake-resistant design provisions to mach that of zone 2B of the UBC.

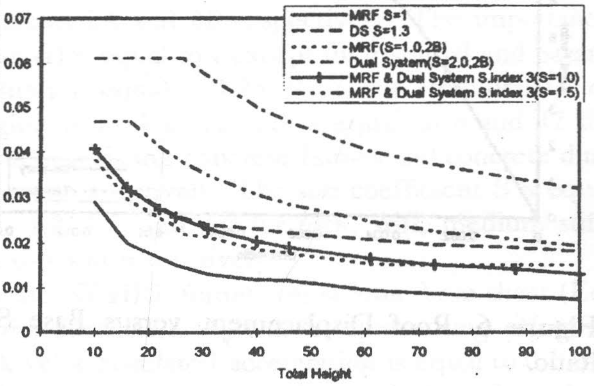

Figure 5. Comparisons Between The Base Shear Ratios as Required by CLFC, UBC, and NEHRP for Building's Height Vary from Ten to A Hundred Meters.

On the other hand, the analysis of the mathematical models shows that the fundamental natural periods of the six-story and the ten-story buildings are 0.92 and 1.16 seconds respectively. Figure (6) shows the relationship between roof displacement and base shear ratio demand for each building. As can be seen, the maximum base shear ratio demand for both buildings are very close. This means that the base shear ratio demand is somewhat independent on the natural period of the structure. Figure (7) shows the relationship between the number of floor and deformation for both buildings just before yield and at collapse. As can be seen, the six-story and ten-story buildings inherit deformation about four and three times the elastic ones at the failure floor before collapse. It can also be recognized that the mechanisms for the six-story and the ten-story structures are local at the fifth floor and at the seventh floor respectively. These results conclude that although these buildings are designed according to the CLFC, failure patterns for both buildings were locally. Therefore if some provisions are given in the ECPD to insure global failure, the supplied base shear ratio may increase significantly compared with that of the local mechanism [14].

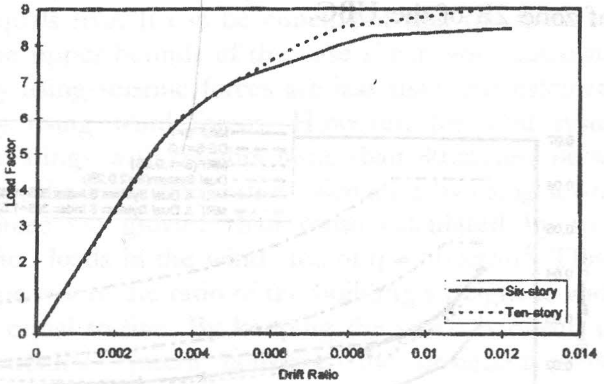

Figure 6. Roof Displacement versus Base Shear Ratio.

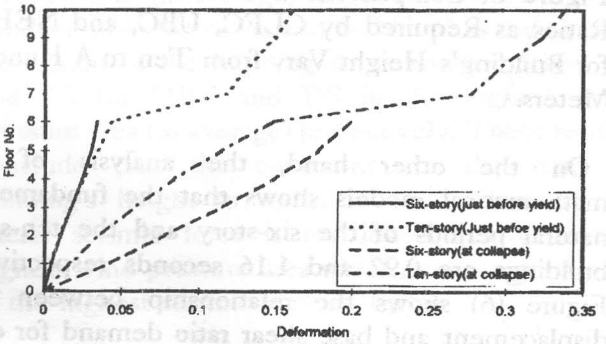

Figure 7. Deformation versus Floor Number

Figure (8) shows the relationship between the drift ratio and the load factor which is the ratio between the applied lateral force to the seismic force specified by the CLFC for both buildings. The drift ratio is defined as the difference in the lateral displacement between the top and the bottom of a story divided by its height. The Figure shows this relationship for the stories where the mechanism of each building is initiated. As can be seen, the structural behavior for both buildings are non-linear before the 0.005 ratio required by the CLFC to insure elastic deformation. However, it can be recognized that for both buildings, structural behaviors are elastic until drift ratio equals about 0.003. Therefore, the drift ratio required by the CLFC is non-conservative and it is recommended that this ratio should be reduced to value less than 0.003 with a reliable factor of safety.

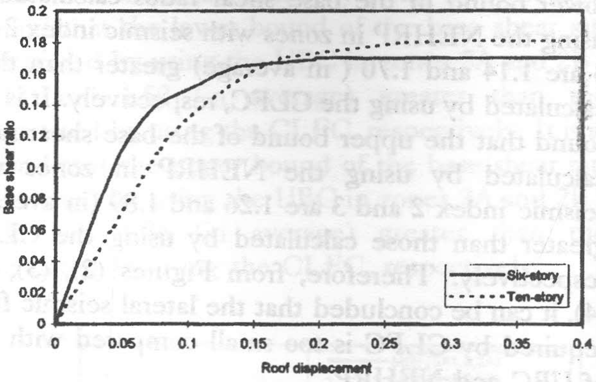

Figure 8. Drift Ratio versus Load Factor.

CONCLUSION AND RECOMMENDATION

The earthquake-resistant design provisions in the Egyptian Code; namely The Calculation of Loads and Forces Codes, are evaluated. This is done through two faces of study. In the first one, a comparison is made between the base shear ratios calculated by using seismic and wind forces for buildings having heights ranging from ten to a hundred meters and located in the highest seismic zone of Egypt. Then, seismic forces as required by other foreign codes; namely the UBC and the NEHRP, are also calculated for buildings with the same range of heights and located in zone having similar seismic activity as that of the highest seismic zone of Egypt. A comparison is made between the base shear ratios of buildings calculated by using these foreign codes and those calculated by using the Egyptian code. In the second face of study, the results of these analyses are examined on two buildings of regular configurations. Six-story and ten-story reinforced concrete moment resisting frame buildings are designed according to the Egyptian Code. Their structural dynamic behaviors are examined and evaluated.

It has been found that seismic forces as required by the CLFC start to be biased as the ratio of the height of the building to its width reaches 2.2 and 4.5 for moment resisting ductile frame system (MRF) and moment resisting frame-shear wall; dual system (DS) in the lowest wind pressure area (in average) respectively. On the other hand, this ratio reaches 1.2 and 2.3 for MRF and DS in the highest wind pressure area (in average) respectively. It has also been found that the base shear ratios calculated by using the CLFC are 60% and 56% (in average) of those calculated by using the UBC and the NEHRP respectively. Therefore, it can be concluded that the design seismic force calculated by using CLFC are underestimated and needs to be enlarged. It is recommended that earthquake-resistant design provisions in the CLFC should be similar to that of zone 2B of the UBC since they have similar expected peak ground acceleration.

The analysis of the two mathematical models shows that the maximum base shear ratio demand is somewhat independent on the natural period of the structure. It is recommended that if some provisions are given in the ECPD to insure global failure, the supplied base shear ratio may increase significantly compared with local failure mechanism. The results also show that the maximum drift ratio given by the CLFC is non-conservative and it is recommended that this ratio should be reduced to value less than 0.003 with a reliable factor of safety.

APPENDIX (1)

In the CLFC formula of the seismic base shear (Eq. 1); the seismic zoning factor (Z) is equal to 0.1, 0.2, and 0.3 for zone one, two, and three respectively. The importance factor (I) is equal to 1.25 for buildings which can be used after earthquakes as emergency facilities such as hospitals, police stations, communication centers, ...etc. and is equal to 1.0 for any other buildings. The structural system factor (K) is equal to 0.67 and 0.8 for ductile and non-ductile moment resisting frames respectively. It is also equal 1.00 and 1.33 for compound system consisting of shear wall and moment resisting frames and box system consisting of shear wall or rigid frames respectively. The soil factor (S) is equal to 1.0, 1.15, and 1.3 for stiff, medium, and loss soil respectively.

In the CLFC formula of wind load (Eq. 4); the wind pressure (q) has a range from 50 kg/m^2 to 90 kg/m^2 and is equal to 80 kg/m^2 in Alexandria. The factor (k) is equal to 1 and 1.1 for heights from 0 to 10 ms and from 10 ms to 20 ms respectively. k increases by 0.2 for each following ten meters range and is equal to 2.3 for height more than 160 ms. The pressure or the suction factor (C_e) on the outer shape of rectangular buildings is equal to 0.8 and 0.5 respectively.

In the UBC formula of seismic base shear (Eq. 5); the seismic zoning factor (Z) is equal to 0.15 and 0.2 for zones 2A and 2B respectively. The importance factor (I) is equal to 1 except for essential and hazard facilities is equal to 1.25. R_w is the structural factor ranging from 4 to 12 and is equal to 8 and 12 for moment-resisting concrete frames and concrete dual systems respectively. The site coefficient S is equal to 1, 1.2, 1.5, and 2.0 for rock, stiff, medium stiff, and soft soil respectively.

In the NEHRP formula of seismic base shear (Eq. 7); the coefficient A_v which representing effective peak velocity-related acceleration is equal to 0.1 and 0.15 for zones with seismic index 2 and 3 respectively. The coefficient S is equal to 1, 1.2, 1.5 for rock, stiff, soft soils respectively. The response modification factor R is equal to 8 for moment resisting concrete frame and concrete dual system.

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