Seismic Hazard Evaluation of Regular and Vertical Irregular R.C. Buildings in EGYPT, for Different Ground Motion Characteristics

M. M. ELASSALY

Fayoum University, Egypt

SUMMARY:
The implementation of seismic regulation in the design process of R.C. buildings, in Egypt, is rather a new procedure. The seismic risk awareness started following the destructive earthquake that hit Cairo in 1992. The accumulated experience in the construction field, regarding the structural seismic hazard and the corresponding damage, is rather limited. Accordingly, the existing building stock in Egypt is considered highly vulnerable. The seismic performance of regular and vertical irregular R.C. building are assessed for different earthquakes, having various intensities and frequency contents. The model of the vertical irregular R.C. building, investigated herein, represents the most common type of irregular buildings, employed in Egyptian building environment; this type of buildings is distinguished with its varying first floor height. The seismic hazard evaluation is carried out through exploring damage indices, drift ratios and capacity curves of model buildings. Nonlinear dynamic analyses are performed on 2-dimensional model of R.C. building.

Keywords: Seismic hazard - vertical irregularity - ground motion characteristics - damage indices - drift ratios.

1. INTRODUCTION

In countries of low to moderate seismic activities such as Egypt, earthquakes are considered infrequent phenomenon. The occurrence of an earthquake may caught the Egyptian people and the governmental authorities unprepared. Prior to the 1992 Cairo earthquake, there were no specific articles, designated for the seismic design of R.C. buildings, in the Egyptian standards. Following that event, the Ministry of Housing, had enforced the implementation of seismic regulation in the design process of R.C. buildings. Accordingly, the accumulated experience regarding seismic hazard of R.C. buildings, may be considered limited, to a certain extent. During the last two decades, new built environment has been erected in the country, driven by the rapid increase in population. New R.C. buildings, having the maximum permissible height according to local authorities, have been built extensively, in many regions of the country. Those buildings commonly have 12 story height. Moreover, it has been noticed that many of those new buildings are turned to have vertical irregular nature; the height of the first story of many of those buildings, has been increased, in many cases, to accommodate for varying commercial usage. Those commercial activities are mainly assigned to the first story of those buildings, while upper stories are left for residential purposes. Therefore, this category of buildings is characterized by having single source of vertical irregularity; that is variation of first story height. The need to evaluate the safety margins for this growing building stock, is of vital importance.

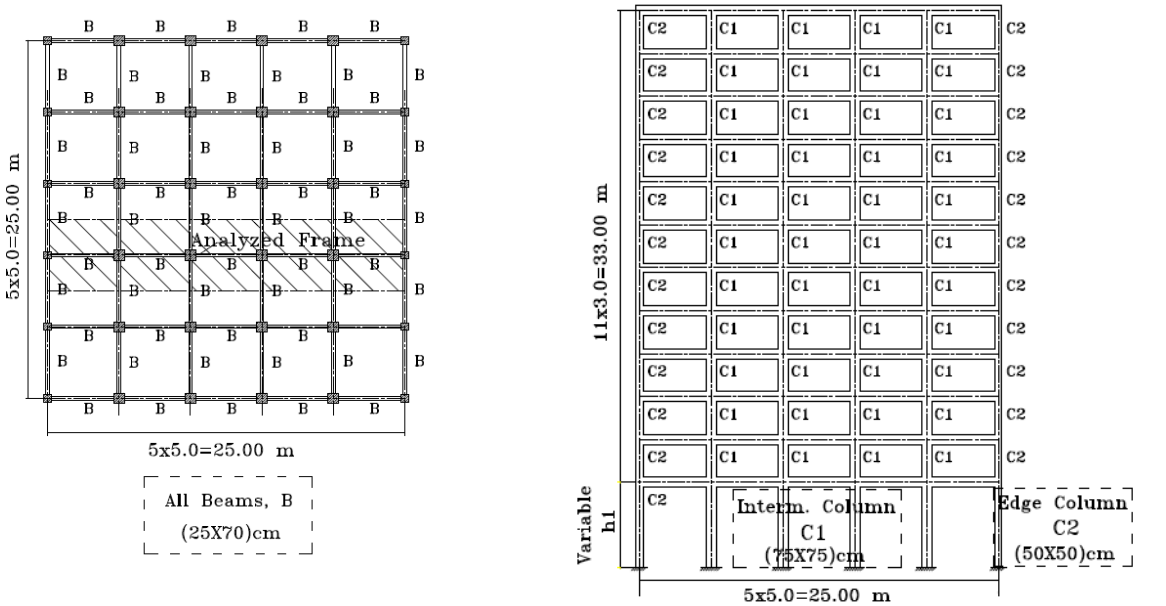
According to the Performance-Based Earthquake Engineering (PBEE) concepts for seismic assessment and design, structures are assessed with respect to specific performance levels associated with different anticipated seismic hazard levels (Priestley, 2000). The use of qualitative damage indices is commonly employed, since they reflect the significant response characteristics and correlate well to different bands of structural performance levels (Safar, 2009). The objective of the current study is to present a damage-based framework for assessing and evaluating safety margins and seismic hazards of the most commonly employed category of regular and vertical irregular R.C. buildings, designed according to current Egyptian standards (ECCS 201, 2008). The safety margin is evaluated with respect to different performance levels. The proposed framework employs damage indices, according to the Park and Ang model (1985), and the inter-story drift limits, according to FEMA-356 (2000). These two indicators are used to quantitatively express damage and performance. The seismic hazards for those R.C. buildings, are assessed for different ground motion characteristics. 21 natural ground motions, having various Peak Ground Accelerations (PGA) and frequency contents, have been employed in the study. Nonlinear time history analyses of model buildings are performed using the computer program IDARC2D V.6.1. (2006).

2. NEW BUILDING ENVIRONMENT IN EGYPT

The uncontrolled and rapid increase in population in Egypt, has led the Ministry of Housing to permit maximum land use of each building site in crowded cities. A height of 1.5 times the width of the facing street, of each building, is allowed, with a maximum height of 36 meter. Therefore, a new building environment is being created, where the majority of these buildings has 36 m height; that is almost equivalent to 12 story buildings. On the other hand, the economical consideration of the owners of those buildings, may lead to reassigning the use of the first story from residential to commercial purposes. Accordingly, the height of the first story may vary to accommodate for the specific needs of the intended commercial usage. Thus, a common case of vertical irregular building has been noticed lately, where the height of the first story is greater than the regular height of upper stories.

3. CONFIGURATION OF INVESTIGATED MODELS

The investigated models are assumed to have 12 story height, representing the majority of the new building environment in Egypt. Regular 3 meter floor height is assigned for all stories, except that for the first floor height h1. The height h1 is taken to be as 3, 6 or 9 meters for the three cases, intended for the study of vertical irregularity effects. The selected models are assumed to have regular plans with 5 equal bays with a spacing of 5 meter in the longitudinal and transverse directions; base columns are assumed to be fixed to the foundation. The selected models are designed according to the current seismic design code ECCS-201 (2008). Figure 3.1. depicts the configurations of the selected models.



a. Plan b. Elevation

Figure 3.1. Configuration of selected models

Table 3.1. presents cross-sectional area and reinforcement details of intermediate column C1, edge column C2 and connecting beam B; these configurations are assumed to be kept constants for all stories of all investigated models.

Table 3.1. Cross-sectional Area and Reinforcement Details of Selected Model

Item	Member	Cross-sectional area (cmxcm)	Reinforcement Details	
			Longitudinal Bars	Horizontal Ties
1	Intermediate Column, C1	75x75	26 bars (size 16 mm)	Size 8 mm @ 200 mm
2	Edge Column, C2	50x50	12 bars (size 16 mm)	Size 8 mm @ 200 mm
3	Connecting Beam, B	25x75	5 bars (size 16 mm), (Top & Bot.)	Size 8 mm @ 200 mm

4. SEISMIC ACTIVITY IN EGYPT

The seismicity of Egypt was studied by many authors, e.g., Kebeasy (1990) and Abou Elenean (1997) to define the seismotectonic sources. Egypt is located in the northeastern part of Africa (Figure 4.1.), where three tectonic plates interact with each other. These plates are the African-Eurasian plate margin, the Levant transform fault, and the Red Sea plate margin. The sub-plate called Sinai block, is partially separated from the African plate by rifting along the Gulf of Suez. In addition, there are two mega-shear zones running from southern Turkey to Egypt. The seismic activities in northern part of Egypt are concentrated in four narrow belts (Gomaa et al., 2000): 1- Gulf of Aqaba-Dead Sea Trend, 2- Northern Red Sea-Gulf of Suez-Cairo-Alexandria Trend, 3-Cairo-Fayoum-Eastern Mediterranean Trend, and 4- Mediterranean Coastal Dislocation Trend. Figure 4.1. presents the distribution of epicenters of earthquakes in Egypt for the time period 1900 - 1996 (El-Sayed, 2000). The capital Cairo lies in the northern part of Egypt; it is highly praised with its very high density of population. The area southwest of Cairo was subjected to many historical and recent large earthquakes such as: The 10 Oct. 1801, 7 August 1847, Dec. 1859, 17 Nov. 1886, 7 Dec. 1895, 7 Oct., 1920 and 12 Oct.1992 (Ambraseya et. al., 1994). The largest magnitude of earthquakes that occurred in and around Cairo is less than 6.8. The enormous damages, that were reported in 1992 event, were due to the thick unconsolidated sediments characterizing the Nile Delta and Nile valley regions. Number of surface distortions that associated with the main shock were noticed in the area just after the earthquake, such as, surface fissures, upsurge of water mud, land subsidence and a displacements of about 150 cm in the asphalt roads between Cairo and El-Fayoum (Badawi and Murad, 1994). This earthquake, having a magnitude (m_b=5.9), caught the Egyptian people, governmental authorities and institutions unprepared; it caused 561 deaths and injured 9832. The latest big event that hit Egypt was the Aqaba earthquake (m_b=6.2), which occurred on 22 Nov. 1995. It led to destruction of a number of domestic and touristic buildings, and left several casualties (Elassaly, 2000).

Lines represent active fault zones:

(1) Levant Fault zone,
(2) Northern Red-Sea-Suez-Cairo-Alexandria fault zone,
(3, 4) Eastern Mediterranean - Cairo - El-Fayoum fault zone,
(5 and 6) Eastern Mediterranean subduction zone.

Dashed parts of the fault zones denote the areas where the activity occurs as small earthquakes (m_b < 4.5)

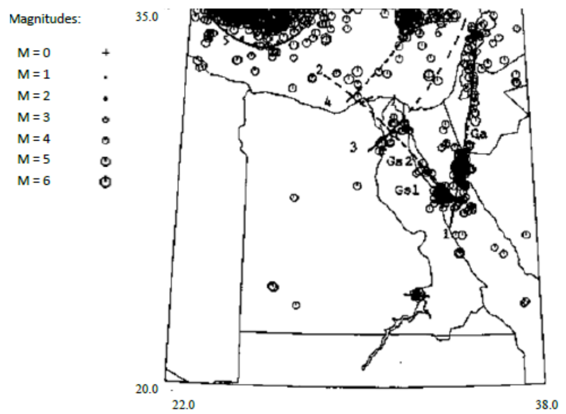


Figure 4.1. Distribution of epicenters of earthquakes ($m_b \geq 4.5$) in Egypt from 1900 to 1996 (El-Sayed, 2000).

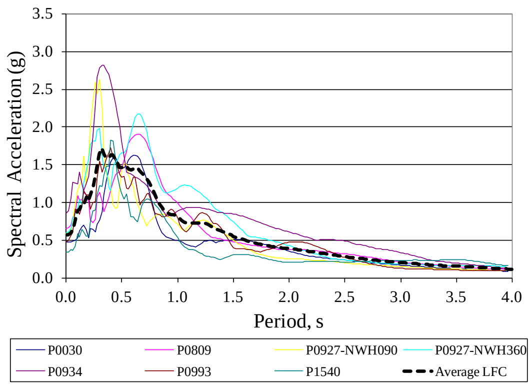
5. SELECTION OF INPUT EXCITATION

Despite the long history of reported earthquake incidents, in Egypt, a serious lack exists in the available data base regarding the recorded accelerographs of these incidents. Accordingly, for the sake of a comprehensive study, the input excitation used in the present study, is selected among 21 natural ground motions, presented in Table 5.1. These earthquakes represent wide range of intensities and frequency contents of seismic waves (PEER, 2000). These records are allocated into three groups: LFC, MFC and HFC for Low, Medium and High Frequency Content records, respectively. These groups, are based on a/v ratio of each ground motion, following the classification method according to Sawada et al. (1992); where a equals PGA, in terms of g, and v equals the PGV, in terms of m/s. Figures 5.1.a, 5.1.b and 5.1.c depict the spectral acceleration of the three groups of natural ground motions: LFC, MFC and HFC, respectively; the average of each group is demonstrated, as well.

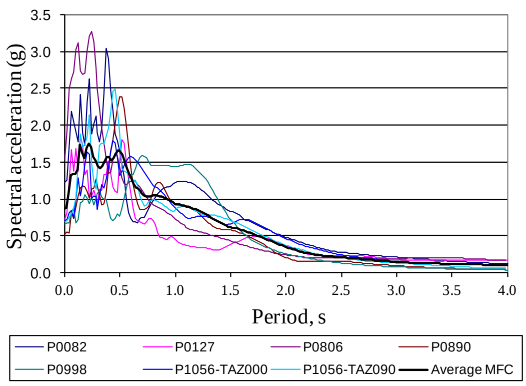
Table 5.1. Characteristics of Different Classes of Natural Ground Motions (PEER, 2000).

class	ID	Earthquake/ Component	Date	M	Soil Type*	PGA** (g)	PGV*** (m/s)	a/v ratio
Low frequency contents (LFC)	P0030	PARKF/C02065Parkfield /	28/06/1966	6.1	A	0.476	75.1	0.63
	P0809	Cape Mendocino / CAPEMEND/PET090	25/04/1992	7.1	A	0.662	89.7	0.74
	P0927	NORTHR/NWH090Northridge /	17/01/1994	6.7	A	0.583	75.5	0.77
	P0927	NORTHR/NWH360Northridge /	17/01/1994	6.7	A	0.59	97.2	0.61
	P0934	NORTHR/SYL360Northridge /	17/01/1994	6.7	A	0.843	129.6	0.65
	P0993	NORTHR/STC180Northridge /	17/01/1994	6.7	A	0.477	61.5	0.78
	P1540	Duzce, Turkey / DUZCE/DZC180	12/11/1999	7.1	A	0.348	60	0.58
Medium frequency contents (MFC)	P0082	San Fernando / SFERN/PCD164	09/02/1971	6.6	B	1.226	112.5	1.09
	P0127	GAZLI/GAZ090Gazli, USSR /	17/05/1976	6.8	C	0.718	71.6	1.00
	P0806	Cape Mendocino / CAPEMEND/CPM000	25/04/1992	7.1	C	1.497	127.4	1.18
	P0890	Northridge / NORTHR/MUL279	17/01/1994	6.7	D	0.516	62.8	0.82
	P0998	NORTHR/PAR--LNorthridge /	17/01/1994	6.7	Unknown	0.657	75.2	0.87
	P1056	Kobe / KOBE/TAZ000	16/01/1995	6.9	E	0.693	68.3	1.01
	P1056	Kobe / KOBE/TAZ090	16/01/1995	6.9	E	0.694	85.3	0.81
High frequency contents (HFC)	P0409	Coalinga / COALINGA/D-OLC270	22/07/1983	5.8	B	0.866	42.2	2.05
	P0449	Morgan Hill / MORGAN/CYC285	24/04/1984	6.2	C	1.298	80.8	1.61
	P0729	Superstitn Hills(B) / SUPERST/B-SUP135	24/11/1987	6.7	C	0.894	42.2	2.12
	P0810	CAPEMEND/RIO360	25/04/1992	7.1	D	0.99	42.1	2.35
	P0935	Northridge / NORTHR/TAR090	17/01/1994	6.7	B	1.779	113.6	1.57
	P1021	Northridge / NORTHR/KAT000	17/01/1994	6.7	B	0.877	40.9	2.14
	P1551	Duzce, Turkey / DUZCE/375-N	12/11/1999	7.1	B	0.97	36.5	2.66

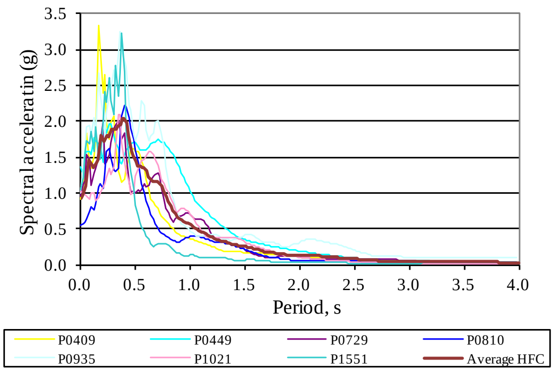
* A: Deep broad, B: Sallow stiff, C: Rock, D: Deep narrow, E: Soft deep



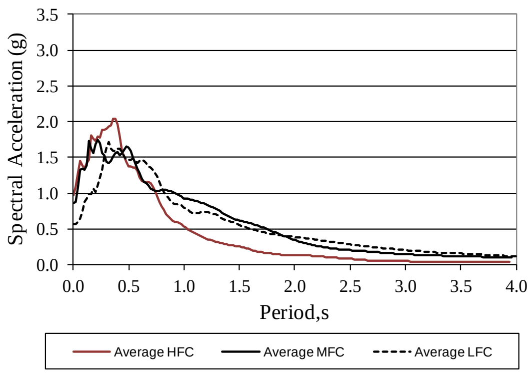
a. Spectral acceleration of LFC group.



b. Spectral acceleration of MFC group.



c. Spectral acceleration of HFC group.



d. Spectral acceleration of average groups.

Figure 5.1. Spectral acceleration of the different groups of ground motions

Figure 5.1.d highlights the differences between the significant features of each group, where a comparison is held among the average spectral acceleration of these groups. The HFC group has the largest average spectral acceleration in the high frequency range (low period; T<0.45s.); whereas the MFC is considered the dominant group in the range (0.8<T <1.5~1.8s). For the low frequency range (T>1.5~1.8s), the LFC group has the largest spectral acceleration. Therefore, each group of ground motion is expected to be the prevailing group that affects different set of buildings according to their fundamental frequencies. For the present study to evaluate the seismic hazard of R.C. buildings, three earthquakes are selected to represent the varying ground motions. The records P0030 (Parkfield EQ., 1966), P0082 (San Fernando EQ., 1971), and P0935 (Northridge EQ., 1994), are selected as representative of LFC, MFC and HFC groups, respectively. The spectral accelerations of the these records are depicted in Figure 5.2. The LFC record P0030 has the greatest spectral accelerations in the low frequency range, whereas the HFC record P0935 has the highest amplitudes in the high frequency range. Finally, the figure presents also the fundamental periods of investigated models, having h1=3, 6 and 9m, respectively.

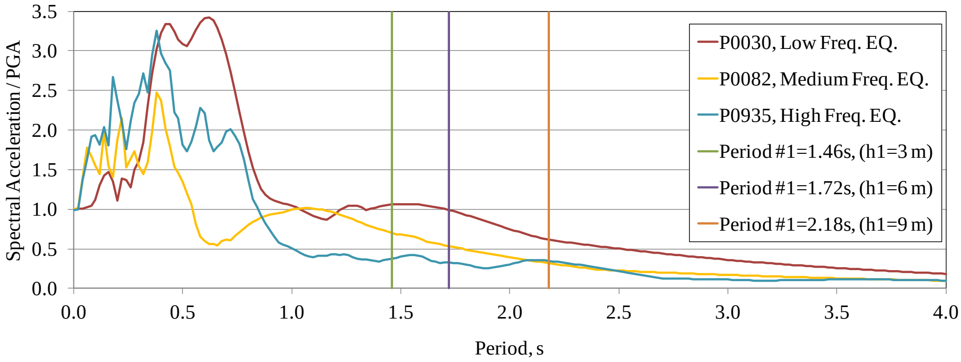


Figure 5.2 Spectral acceleration of selected and used ground motions.

6. SEISMIC PERFORMANCE EVALUATION

The seismic hazard associated with the structural performance of R.C. buildings, when subjected to earthquakes, is commonly correlated to damage and inter-story drift limits. If those limits are surpassed, deformation in structure may exceed the available plastic rotation capacity and would result in excessive shear stresses; that would lead eventually to structural failure. Seismic performance evaluation represents a comparison between structural capacity and demand. The difference between these two quantities is assessed using performance indicators. For a damage-based assessment, a quantitative damage index is used as performance indicator through defining different bands of structural damage. The Park-Ang damage index expresses the structural seismic deformation as a linear combination of two terms: the first term represents the damage caused by excessive deformation and the second term reflects cumulative damage caused by repeated cyclic response. It is expressed mathematically as: (Park et al., 1987)

$$DI = \frac{\delta_m}{\delta_u} + \frac{\beta}{\delta_u P_y} \int dE_h \qquad (6.1)$$

In which δ_m is the maximum deformation of element, δ_u is the ultimate deformation and β is a dimensional constant parameter with average experimental value of 0.15 for concrete structures as reported in literature (Park and Ang, 1985) . $\int dE_h$ is the hysteretic energy absorbed by element during the earthquake, and P_y is the yield strength of element. Global damage index for part or all of a structure is the average of the relevant local indices, weighted by the corresponding local energy absorptions. Conclusively, the Park and Ang damage index represents, in essence, a comparison between the capacity and demand. For both terms of the index, the numerator expresses the demand, while the denominator represents the capacity. Higher demand to capacity ratio reflects higher degree of structural damage. Correlation between damage index limit states, according to Park et al. (1987), and damage status of building, is presented in Table 6.1. Five damage states of building are defined: none, slight, minor, moderate and severe. On the other hand, the other performance indicator, used herein, is the maximum inter-story drift limits. Table 6.2. presents those limits as proposed by FEMA-356 (2000). Three distinct limit states are defined: Immediate Occupancy (IO), Life Safety (LS), and Collapse Prevention (CP).

Table 6.1. Damage index and corresponding damage state, Park et al. (1987)

Descriptions		Damage Index	Damage State of Building
Slight	Sporadic occurrence of cracking	< 0.1	No Damage
Minor	Minor cracks; partial crushing of concrete in columns	0.1-0.25	Minor Damage
Moderate	Extensive large cracks; spalling of concrete in weaker elements	0.25-0.4	Repairable
Severe	Extensive crashing of concrete; disclosure of buckled reinforcement	0.4-1.0	Beyond Repair
Collapse	Partial or total collapse of building	>1.0	Loss of Building

Table 6.2. Inter-story Drift Limit States FEMA-356 (2000)

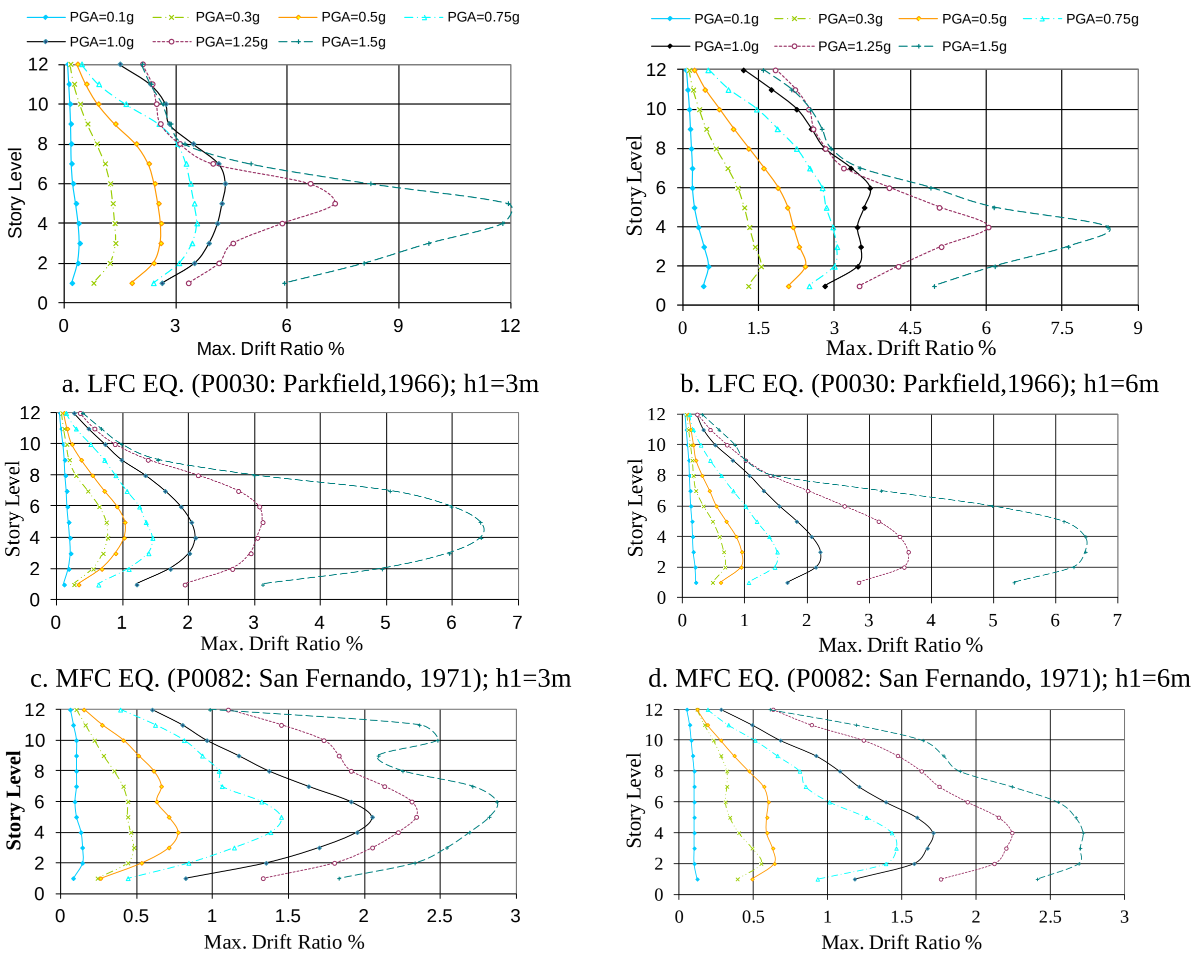
Structural performance levels	Drift (%)
Immediate Occupancy (IO)	1
Life Safety (LS)	2
Collapse Prevention (CP)	4

7. NONLINEAR TIME HISTORY ANALYSIS

Seismic hazards of R.C. buildings are assessed by nonlinear time history analyses. Two-dimensional models of interior frames of sample buildings, are investigated. Torsion effects are ignored since all investigated models are assumed to have regular plan configurations. Effects of infill walls on the overall stiffness of models, are not accounted for. A time step of 0.001s and a 5% Rayleigh proportional damping are selected. The computer program IDARC2D (2006), is employed. The analysis takes into consideration the P-delta effects. A smooth hysteretic model is used to simulate the elastic-yield transition and the shape of unloading; it incorporates stiffness degradation, strength deterioration, non-symmetric response, slip-lock and a tri-linear monotonic envelope. Significant structural features, including damage indices, inter-story drift ratios and base shear are calculated for each investigated case. Finally, displacement controlled capacity curves are generated for each case.

8. RESULTS AND DISCUSSION

The seismic performance and associated hazards of regular model building (h1=3m) and vertical irregular models (h1=6 and 9 m), are assessed, for the selected LFC, MFC and HFC earthquakes. The applied ground motions are assumed to have various intensities; the PGA of each selected ground motion, is scaled up and down, to be as 0.1g, 0.3g, 0.5g, 0.75g, 1.0g, 1.25g and 1.5g. Figure 8.1. depicts the variation of maximum inter-story drift ratios, along the height of regular model (h1=3m) and vertical irregular model (h1=6m), when subjected to various intensities of LFC, MFC and HFC ground motions. In general, the LFC record leads to the highest inter-story drift ratios; whereas the lowest values occur when applying the HFC record. This behaviour of regular and irregular models are justified by the high spectral accelerations corresponding to their fundamental periods, for the LFC record compared to those of the MFC and HFC records (Figure 5.2.). In addition, Figures 8.1.a and b show that the rate of increase of maximum drift ratios with PGA, accelerates for values of PGA>1.0g. For those values of high intensities of ground motions, the drift ratios far exceed the collapse prevention (CP) limit states, defined by FEMA-356 (2000). For those cases, plastic hinges are noticed to be formed at many joints of the models, when investigating the failure mechanism (not shown) of those buildings. On the other hand, the figure shows that drift ratios of the investigated configuration of vertical irregularity (h1=6m), are considerably less than those of regular configurations, for the LFC record. For the MFC and HFC records, insignificant differences in the values of the maximum drift ratios, are noticed for the regular and irregular models. Thus, it could be concluded that the seismic performance of these irregular buildings may be considered, in some cases, superior than that of regular configurations, regarding drift ratios limitations. Finally, the figure shows that the investigated types of regular or irregular R.C. buildings, designed according to ECCS-201 (2008), would sustain earthquakes having PGA≤1.0g, according to collapse prevention criteria (CP); this conclusion holds irrespective of the frequency content of the ground motion. Earthquakes having higher intensities PGA>1.0g, could be sustained by R.C. buildings, if ground motion is classified as MFC or HFC.



a. LFC EQ. (P0030: Parkfield,1966); h1=3m

b. LFC EQ. (P0030: Parkfield,1966); h1=6m

c. MFC EQ. (P0082: San Fernando, 1971); h1=3m

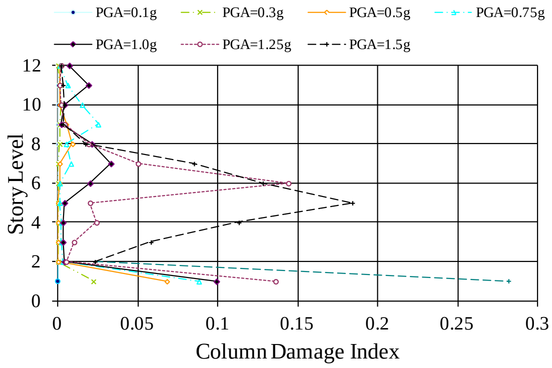
d. MFC EQ. (P0082: San Fernando, 1971); h1=6m

e. HFC EQ. (P0935: Northridge, 1994); h1=3m

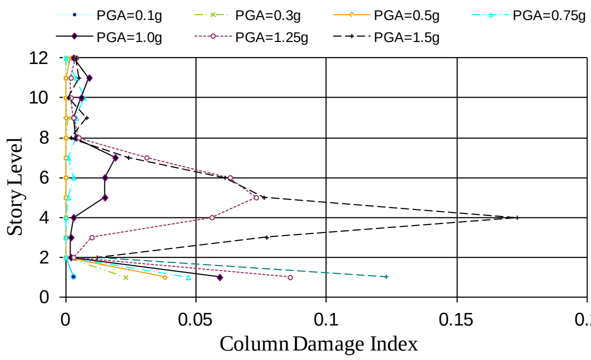
f. HFC EQ. (P0935: Northridge, 1994); h1=6m

Figure 8.1. Variation of maximum inter-story drift ratios, along the height of investigated models, when subjected to different earthquakes having various intensities.

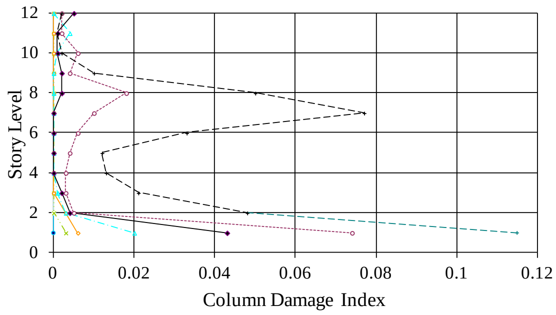
Figure 8.2. depicts the variation of damage indices of story columns, along the height of investigated models, for the various employed ground motions. In general, base columns, of most of the examined cases, are expected to experience the highest values of damage indices; however, a contradictory behaviour may occur in some cases. Figure 8.2.b shows that for the case of LFC record, the story columns, located below mid-height of irregular model (h1=6m), may have greater values of damage indices, compared to those of base columns. Figure 8.2. shows that LFC record would generally lead to the highest damage indices compared to those resulting from MFC or HFC records. In addition, Figure 8.2. shows that the HFC record affect mainly base columns; whereas, minor effects are noticed for the rest of columns, located at upper stories. For LFC and MFC records, columns located around mid-height stories, may be subjected to considerably high values of damage indices. On the other hand, comparing parts a, c and e of Figure 8.2. with parts b, d and f, it can be concluded that column damage indices of irregular model are, in general, less than those of regular model configurations. This confirms the conclusion that the seismic performance of this type of irregular buildings may be considered, superior than that of regular configurations, regarding damage indices of story columns.



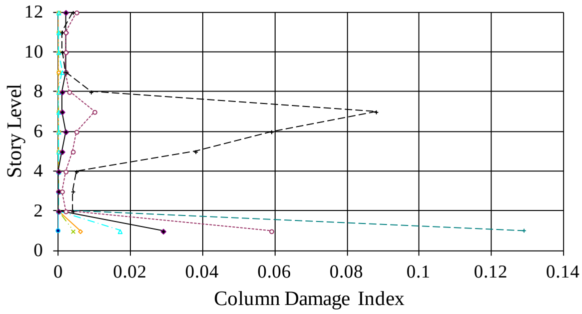
a. LFC EQ. (P0030: Parkfield,1966); h1=3m



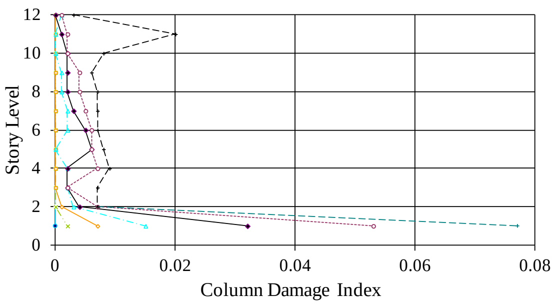
b. LFC EQ. (P0030: Parkfield,1966); h1=6m



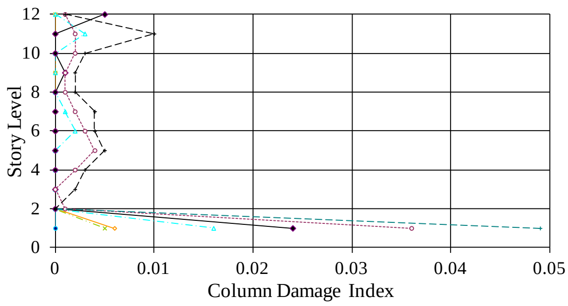
c. MFC EQ. (P0082: San Fernando, 1971); h1=3m



d. MFC EQ. (P0082: San Fernando, 1971); h1=6m



e. HFC EQ. (P0935: Northridge, 1994); h1=3m

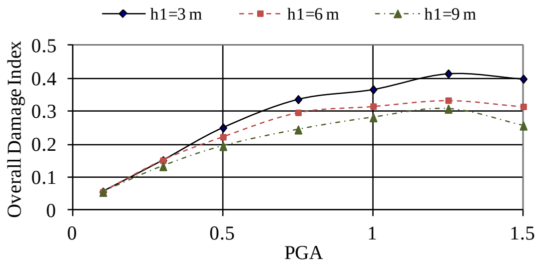


f. HFC EQ. (P0935: Northridge, 1994); h1=6m

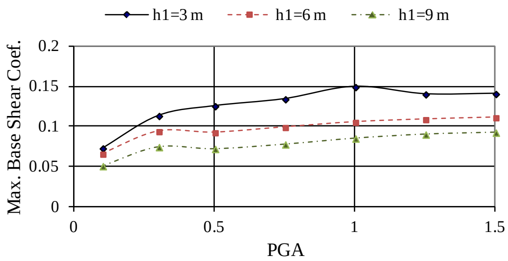
Figure 8.2. Variation of story column damage indices, along height of investigated models, for different cases

Figure 8.3. depicts the variation of two main significant features representing the structural seismic response, with PGA, for the different investigated models, subjected to the LFC record. Figure 8.3.a demonstrates virtually linear pattern for the increase of overall damage indices, of all models, with PGA, for values of PGA less than 0.75g. For higher values of PGA (PGA≥1.0g), non-linear behaviour is noticed. In addition, the figure shows that only the regular model may be subjected to Severe damage condition (damage index>0.4, Table 6.1.), when subjected to high intensities (PGA≥1.25g) of LFC record; for those cases the building might be in a beyond repair status. For the irregular configurations (h1=6m or 9m), buildings will be subjected to less values of damage indices than those of regular model; those irregular buildings will be experiencing Moderate damage condition (repairable status), for the same intensities of PGA. Figure 8.3.b demonstrates the variation of the maximum response of base shear coefficients, of the three investigated models, with PGA. The base shear coefficient is represented, herein, as the ratio of base shear to overall weight of building. The maximum response is obtained by scanning the whole duration of time history of variation of base shear. In general, the base shear increases with the PGA of applied ground motion; most of this increase occurs for the range of PGA<0.5g. For the severe intensities of PGA (PGA≥1.0g), insignificant increase, or even decrease, is expected for base shear coefficient. Again, the figure shows that base shear coefficients of vertical irregular models are less than those of regular model. Figure 8.4. depicts the variation of overall damage indices and base shear coefficients of regular model (h1=3m) and irregular model (h1=6m), with PGA. Investigated models are subjected to the LFC, MFC and HFC records. Figures 8.4.a. and b, depict virtually linear relation between damage indices and

PGA, for the MFC and HFC records; whereas, non-linear behaviour is noticed for the portion (PGA≥1.0g) of the LFC record. Figures 8.4.c and d, show that base shear progressively increases with PGA of applied excitation of MFC and HFC records; For LFC record, insignificant increase occurs for the high values of PGA (PGA ≥1.0g). Finally, the figure shows that for the same value of PGA, the LFC record would generally result in the highest response, when compared to those resulting from MFC and HFC records. Thus, it can be concluded that the structural seismic hazard, associated with LFC record may be considered higher than those corresponding to MFC or HFC records. Finally, Figure 8.5. depicts the capacity curves of the investigated models; capacity curves are produced using displacement control static pushover analyses. The figure shows that the regular model (h1=3m) has higher overall stiffness (slope of first linear portion of curve) as well as higher maximum base shear capacity, when compared to those of irregular models (h1=6m and 9m). The figure shows also that irregular model (h1=9m) has the largest capacity, regarding sustaining top displacements.

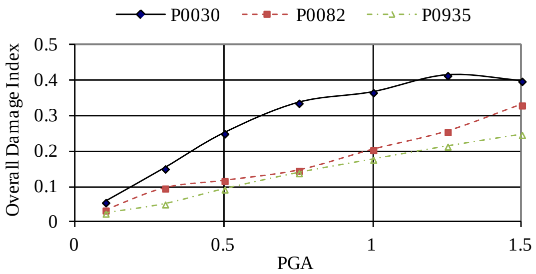


a. Overall damage versus PGA

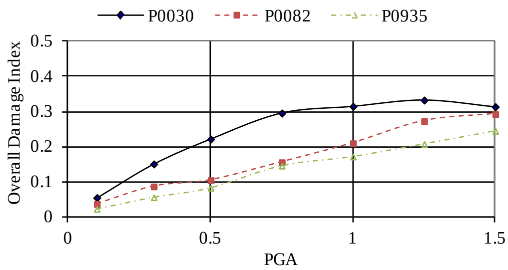


b. Max. base shear coef. versus PGA

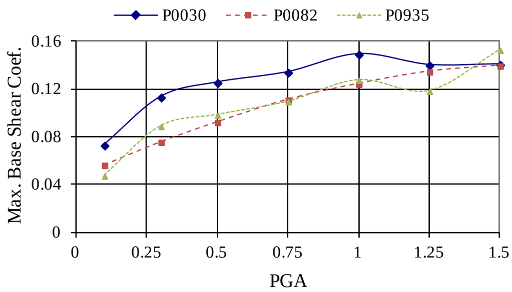
Figure 8.3. Variation of significant structural seismic response characteristics with PGA, for LFC EQ.



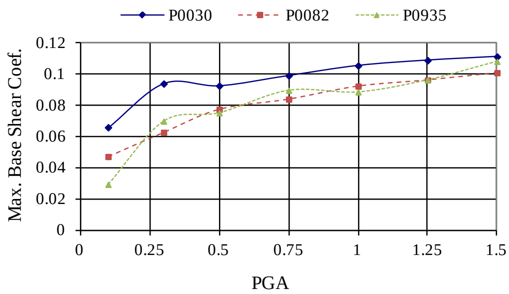
a. Overall damage versus PGA; h1=3m



b. Overall damage versus PGA; h1=6m



c. Max. base shear coef. versus PGA; h1=3m



d. Max. base shear coef. versus PGA; h1=6m

Figure 8.4. Variation of significant structural seismic response characteristics with PGA, for the different cases

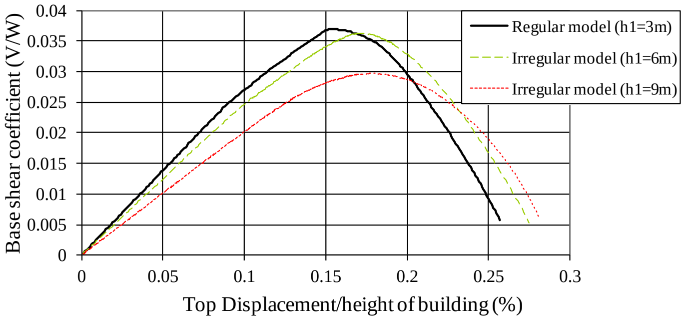


Figure 8.5. Capacity curves of investigated models

9. CONCLUSIONS

The current research work is limited to evaluating the seismic hazards associated with 12 story R.C. buildings, designed according to (ECCS-201, 2008). The seismic performance of regular and most employed type of vertical irregular R.C. buildings, is assessed through exploring damage indices, drift ratios and capacity curves. The structural seismic response is investigated for various ground motion characteristics. Based on these limitations, the following conclusions are drawn:

- The investigated types of regular or irregular R.C. buildings, would sustain earthquakes having PGA≤1.0g, according to collapse prevention criteria (CP); this conclusion holds irrespective of the frequency content of the ground motion. Earthquakes having higher intensities PGA>1.0g, could be sustained by R.C. buildings, if ground motion is classified as MFC or HFC.
- Regular R.C. buildings may be experience Severe damage condition if subjected to high intensities (PGA≥1.25g) of LFC earthquakes. For ground motions having MFC or HFC, a Moderate damage condition (repairable status) is expected for regular buildings.
- Vertical irregular R.C. buildings is expected to be experiencing Moderate damage condition (repairable status), if subjected to earthquakes having PGA≤1.5g, irrespective of its frequency content.
- The seismic performance of investigated vertical irregular R.C. buildings are considered, in some cases, superior than that of regular configuration, regarding drift ratios and damage indices limitations.
- For the same PGA, the structural seismic hazard, associated with LFC record may be considered higher than those corresponding to MFC or HFC records.

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