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SOME PARAMETERS AFFECTING THE BEHAVIOUR OF R.C. FRAMES DESIGNED FOR GRAVITY LOADS ONLY AND SUBJECTED TO EARTHQUAKES

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ABSTRACT

Time history analysis was performed to study the effect of selected parameters in the behaviour of reinforced concrete frames under earthquake loads. The RC frames were designed for gravity-loads only as typically found in most seismic prone countries before the introduction of adequate seismic design code provisions. The parameters considered in this study were the number and span of bays, the number of stories, and the presence of infill wall (full infilled frame and infilled frame with open ground stories). It was observed that the presence of infill wall may affect the seismic behaviour of frame structure to large extent, and the infill wall increases the strength and stiffness of the structure. Also it was observed that infilled frames are preferred in seismic regions than the open ground story ones, because the story drift of first story in open ground story frames is very large than the upper stories, this may probably cause the collapse of structure.

1. Introduction

Multistory reinforced concrete (RC) framed structures are very common in many countries in the world, especially in developing countries, and are the predominant structural system in Arab Countries. The extensive use of this system is attributed to the rapid growth of urban population and to its relatively low initial cost compared to other materials such as steel. Masonry infill walls are frequently used as interior partitions and exterior wall in RC frames. Usually, the infill walls are treated as non structural element and their influences on the structural response are generally ignored. In fact, the interaction between the infill and the frame has a dual effect: it may or may not improve the seismic performance of the structure due to several reasons such as regular distribution and continuity of infill.

Many RC buildings constructed in recent times have a special feature, the ground story is left open for the purpose of parking (Fig. 1.), i.e., columns in the ground story do not have any partition walls (of either masonry or RC) between them. Such buildings are often called open ground story buildings. These buildings look as if they are supported by chopsticks! Open ground story buildings have consistently shown poor performance during past earthquakes across the world [1].

Earthquakes are one of nature’s greatest hazards to life on this planet. The impact of this phenomenon is sudden with little or no warning to make preparations against damages and collapse of buildings/structures.

Recent earthquakes across the world, including the 1982 Dhamar earthquake in Yemen, the 1992 Cairo earthquake in Egypt, the 1995 Hyogo-ken Nanbu earthquake in Japan, the 1999 Izmit and Ducze earthquakes in Turkey, the 2001 Bhuj earthquake in India, the 2001 Chi Chi earthquake in Taiwan, the 2003 Boumerdes earthquake in Algeria, the 2009 Southern Sumatra in Indonesia, and the 2011 Van earthquake in Turkey revealed major

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seismic deficiencies in the RC buildings, some of which led to catastrophic collapses causing a death toll measured in thousands. One of the major causes of seismic vulnerability associated with these buildings is that, in the developing countries, a large number of the existing RC frame buildings have been designed to resist only vertical loads and had insufficient lateral resistance and the architects and engineers were without formal training in the seismic design and construction and have been built by inadequately skilled construction workers [1 - 6].

Fig. 1. Typical example of open ground story building[1]

In the recent years, special attention has been given to the investigation on the seismic behavior of reinforced concrete buildings designed for gravity load only. Most of these structures have been typically designed and built before the introduction of adequate seismic design code provisions. In the Arab World, until late 1990s, there was no regulation to design and construct building structures for seismic resistance and most building structures were designed to resist gravity loads only, for example. in Egypt the first official code of practice to consider seismic loading was published by the Ministry of Housing in 1989[3], and in Syria the seismic design for buildings was mandatory as a law in 1997 [7]. Whereas, unfortunately, no building seismic codes are available for the Arabian Peninsula states[8] and Yemen[2].

Because there is a large inventory of buildings that were designed and constructed without considering the seismic loads, it is believed that many of these structures may pose an unacceptable life-safety hazard in the event of a major earthquake. This fact explains the basic need for identification of such buildings, the evaluation of their expected seismic performance, and if needed, their seismic strengthening.

There are different types of analyses to treat the seismic forces on a structure. Most codes specify both static and dynamic analyses, The static analysis is an indirect method of considering the effect of the ground motion on the structure and it normally incorporates some of the dynamic features of the problem, such as fundamental period of the building, the soil effect and the earthquake hazard. The Time history dynamic analysis on the other hand is a direct method in which a selected earthquake record in the form of an acceleration –time history is used as the input. Time history analysis can be used for both linear and nonlinear analysis, and it is one of the most effective for the solution of non-linear response, among the many methods available.

In the present study, with using ABAQUS V6.10 software, the nonlinear time history analysis was used to study the effect of some parameters on the behaviour of multistory RC frames designed for gravity loads only under earthquake load. The parameters under study are the:

1) number of bays ("n"= 1, 2, 3, and 4-bays),
2) number of stories ("b"= 2, 4, 6, and 8-stories),
3) bay span ("L"= 4, 6 and 8m),
4) and the presence of masonry infill: a) full infill frames, and b) full infill frames with open ground story

2. Time History Analysis

Time-History analysis is the most important methods nowadays at disposal for a structural engineer when performing a seismic analysis of a given structure. It is a step-by-step procedure where the loading and the response history are evaluated at successive time increments, t–steps. During each step the response is evaluated from the initial conditions existing at the beginning of the step (displacements and velocities) and the loading history in the interval. With this method the non-linear behaviour may be easily considered by changing the structural properties (e.g. stiffness, k) from one step to the next. This method is one of the most effective for the solution of non-linear response, among the many methods available [9].

This paper includes the time history analysis of a series of multistory RC frames two, four, six, and eight story with different number of bays one, two, three, and four bays. In addition to different infilled structure such as completely infilled (IN), bared frame (BF) and completely infilled with open ground story (OG). The analysis is done for El-Centro 1940 earthquake. The results such as roof lateral displacement (RLD), maximum interstory drift ratio (IDR) and base shear (BS) are generated from ABAQUS software.

2.1. General description of ABAQUS software

ABAQUS, is a powerful engineering simulation program, based on the finite element method, and it was used as the basic program for this study. This program can solve problems ranging from relatively simple linear analyses to the more complex nonlinear simulations [10]. In previous study done by the authors[11], the software program was validated, an experimental test by Mehrabi[12] has been modeling; a selective sample is chosen (test No. 1) from Mehrabi collection test[12]. The material properties and geometric specifications and its designed details of reinforced concrete frames have been described in our previous study[11]. Analysis results are plotted together with the test data as in Fig. 2. The graphs indicate that the models predict the behavior with acceptable accuracy.

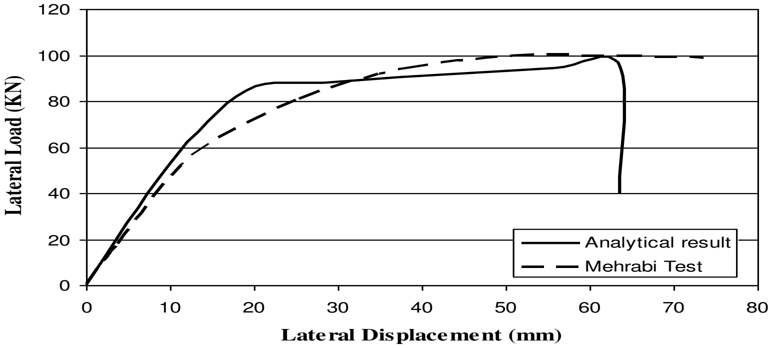

Fig. 2. Comparison between analytical results and experimental results obtained by Mehrabi [12].

2.2. Design of models under study

For the time history analysis a series of multistory RC frames (with different number of bays, stories and with different bay span) were designed for gravity loads only (1.4D.L+1.7L.L) without considering the seismic loads (no lateral loads were considered for the design). All frame models have a constant 3m story height except the ground story is 4m (Fig. 3). The parameters considered for each RC frame model under study are: number of stories ("n"= 2, 4, 6, and 8 stories), number of bays ("b" = 1, 2, 3, and 4 bays) and the bay span ("L" = 4, 6, and 8m) and presence of infill wall (full infill "IN" and full infill with open ground story "OG"). The detailing for the structure was in accordance with the general non-seismic provisions of the ACI 318-89 Code[13].

2.3. Modeling and material properties

The frames were assumed to be fixed at the bottom. The columns and beams of the frame are modeled as 8-node 3D hexahedron element to model the concrete and 2-node truss element embedded in the concrete surfaces to model both of main and shear reinforcements [14]. This means that the end nodes of the steel rods are considered to be slave nodes to the concrete master nodes, and thus, that the steel nodes follow the deformations of the concrete nodes[10], [15]. Fig. 4 illustrates cyclic modeling of steel. Von Mises yield criterion with normality flow rule was adopted to account for nonlinearity of steel after yielding [14]. Nonlinearity of concrete was taken into account through constitutive equations of both uncracked and cracked concrete. For uncracked concrete, we utilized a model proposed for concrete under compression and based originally upon theory of plasticity [14] as shown in Fig.5. This model was modified to take into account the effect of shear reinforcement on increasing both of the ultimate strength of concrete and the corresponding strain due to confinement. For cracked concrete, constitutive equations based on smeared crack model were used. More details of the model were illustrated in previous works by Khairy H. [14]. The main parameters used for concrete and steel materials are listed in Table 1 and Table 2.

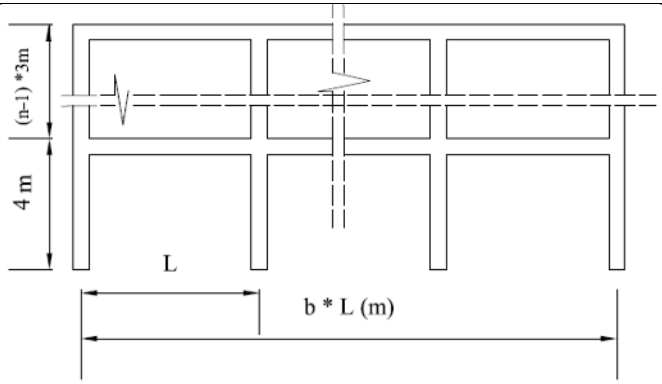

Fig. 3. RC frame models under study, where "n" is the number of stories, "b" is the number of bays and "L" is the bay span.

Table 1.
Parameters used for concrete model

E (GPa)	υ	ρ (Kg/m3)	ψ	Eccentricity	f_{co} MPa	f_{cu} MPa	f_t MPa	f_{bo}/f_{co}	K_c
21.5	0.2	2400	33.32	0.1	15.4	20.7	1.85	1.16	0.667

E= Young modulus, υ: Poisson ratio, ρ: Density, ψ: Delatation angle, f_{bo}/f_{co}: the ratio of initial equibiaxial compressive yield stress to initial uniaxial compressive yield stress, K_c: Invariant stress ratio

Table 2.
Parameters used for steel model

Young modulus E (GPa)	Poisson ratio υ	Density ρ Kg/m^3	f_y MPa
210	0.3	7800	420

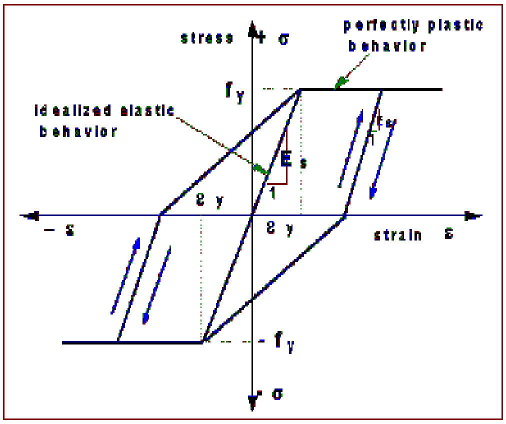

Fig. 4. Cyclic modeling of steel [14]

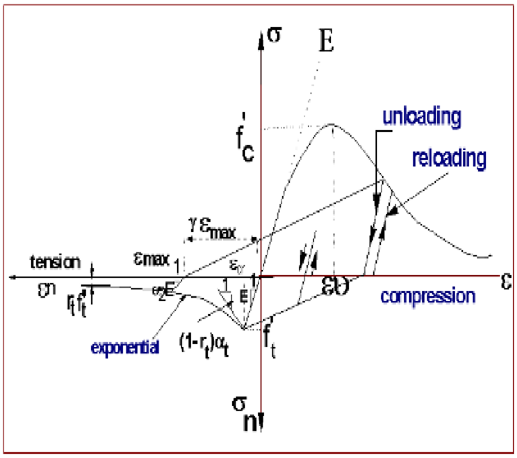

Fig. 5. Modeling of Concrete in Compression[14].

The masonry infill was modeled as equivalent diagonal struts, of the same material and having the same thickness as the infill panel. The basic parameter of these struts is their equivalent width, which affects their stiffness and strength. In previous study[11], the authors presented a comparative study between several expressions proposed by researchers to calculate this equivalent width. It shows that the expression proposed by Paulay and Priestley[16], (0.25 0f the infill diagonal length), is the most suitable choice for calculating the diagonal equivalent strut width, due to its simplicity and because it gives an approximate average value among different methods comparative in the study. Consequently, the Paulay and Priestley's expression will be used herein to calculate the equivalent strut width. The main parameters used of masonry material are listed in Table 3.

Table 3.
Parameters used for masonry

Young modulus *E* (GPa)	Poisson ratio υ	Density ρ Kg/m^3	f_m MPa
7	0.15	1600	7.2

2.4. Earthquake acceleration input

The North-South EL-Centro 1940 earthquake acceleration is used as the input ground accelerations for the time-history analysis. The North-South component of the El Centro earthquake was recorded with 0.02 second interval. 31.18 seconds of the earthquake are used for time history analysis. The maximum peak ground acceleration value is 0.319g. Fig. 6. shows acceleration time histories of the 31.18 seconds recorded in the EL-Centro 1940 earthquake.

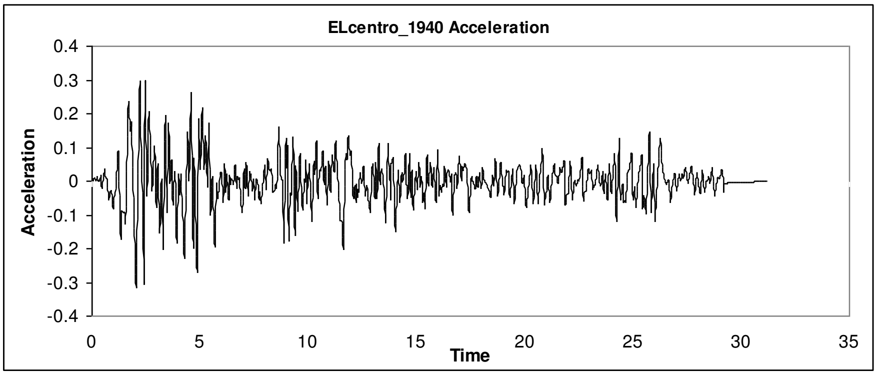

Fig. 6 : N.S. EL-Centro 1940 earthquake acceleration which was used as the input load during the Time History Analysis

3. Results and Discussions

The time history analysis of all the frame models that includes bare frame, infilled frame and open ground story frame has been done by using ABQUS V6.10 software and the results are shown below. the lateral displacement, interstory drift ratio, and the base shear as affected by some parameters are considered in this study. The parameters are; number of stories, number of bays, and bay span. In addition, the frame type (bare frame, infilled frame and open ground story frame).

3.1. Lateral displacement

The maximum lateral displacement of each story level for each model with different number of stories (2, 4, 6, 8story) and bays (1, 2, 3, 4bays), and different types of frame (bare frame "BF", infilled frame "IN", and infilled frame with open ground story "OG") are illustrated in Table 5. to Table 7.These displacement values are the maximum lateral displacement of each story for the total time range of an earthquake. Maximum lateral displacement may occur at different time for different story level. Generally, It is observed that in all models the lateral displacement increases as the story level increases. The increase in lateral displacement is non-linear and the rate of the increases becomes less as the number of story increases in all models except in models with open ground story it observed that the lateral displacement is concentrated on the first story whereas the other infill stories moves together as one block, and most of the horizontal displacement of the building occurs in the open ground story itself.

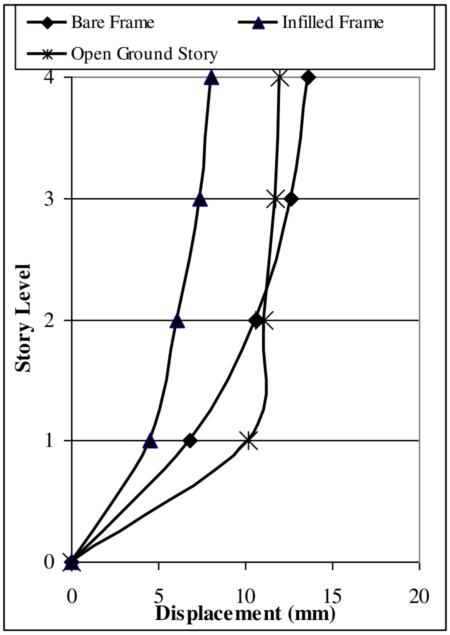

Fig. 7. Lateral displacement for four-story model with different frame type

Table 4.
Maximum roof lateral displacement for the two stories models

Story Level	One-Bay BF	One-Bay IN	One-Bay OG	Two-Bay BF	Two-Bay IN	Two-Bay OG	Three-Bay BF	Three-Bay IN	Three-Bay OG	Four-Bay BF	Four-Bay IN	Four-Bay OG
1st	8.35	1.55	11.92	7.08	1.26	9.85	6.87	1.13	8.85	6.85	1.10	8.51
2nd	10.03	2.07	12.25	9.06	1.75	10.19	8.64	1.56	9.14	8.52	1.46	8.84

Table 5.
Maximum roof lateral displacement for the four stories models

Story Level	One-Bay BF	One-Bay IN	One-Bay OG	Two-Bay BF	Two-Bay IN	Two-Bay OG	Three-Bay BF	Three-Bay IN	Three-Bay OG	Four-Bay BF	Four-Bay IN	Four-Bay OG
1st	8.36	4.91	12.19	6.83	3.96	9.89	6.89	4.41	9.99	6.81	4.53	10.13
2nd	13.36	7.98	13.38	10.57	6.88	10.94	10.65	6.33	11.00	10.55	6.08	11.06
3rd	16.30	9.45	14.41	12.83	8.66	11.68	12.92	7.82	11.71	12.59	7.38	11.73
4th	17.49	9.82	14.83	13.95	9.46	11.98	13.91	8.47	12.00	13.61	8.04	11.98

Table 6.
Maximum roof lateral displacement for the six stories models

Story Level	Number of Bays and Frame Type											
	One-Bay			Two-Bay			Three-Bay			Four-Bay		
	BF	IN	OG	BF	IN	OG	BF	IN	OG	BF	IN	OG
1st	6.07	5.39	6.74	4.77	4.95	5.54	4.77	4.88	5.83	4.95	4.39	6.49
2nd	12.65	9.17	10.50	9.52	8.62	8.91	9.47	8.58	9.50	9.41	8.14	10.29
3rd	18.58	11.83	12.79	13.33	11.57	11.30	13.19	11.59	11.84	13.04	11.41	12.48
4th	23.32	13.94	14.58	16.71	13.84	13.50	16.00	14.00	13.70	15.76	13.98	14.12
5th	26.29	15.43	15.72	19.69	15.61	14.98	18.42	15.58	14.87	17.87	15.59	15.11
6th	27.84	16.38	16.28	20.83	16.30	15.63	19.49	16.26	15.39	18.89	16.25	15.54

Table 7.
Maximum roof lateral displacement for the eight stories models

Story Level	Number of Bays and Frame Type									
	One-Bay			Two-Bay			Three-Bay			Four-Bay
	BF	IN	OG	BF	IN	OG	BF	IN	OG	BF
1st	7.10	7.81	10.20	7.36	6.87	9.62	6.99	6.31	9.02	7.14
2nd	15.91	16.27	19.08	15.65	13.66	16.63	14.38	12.19	15.34	14.45
3rd	24.63	24.11	26.86	23.07	19.28	21.50	20.82	16.58	19.76	20.84
4th	33.12	30.49	33.31	30.11	23.33	24.74	26.54	19.57	22.32	26.50
5th	42.86	33.93	37.58	37.62	24.79	26.82	32.60	20.61	23.91	31.57
6th	49.54	36.14	39.41	43.33	26.14	28.47	37.79	21.77	25.17	35.58
7th	53.43	37.59	40.59	47.01	27.07	29.58	40.48	22.47	25.97	37.61
8th	55.15	33.49	41.37	48.61	27.57	30.22	41.82	22.84	26.39	38.57

3.1.1. Effect of number of bays (b)

To study the effect of number of bays on the roof lateral displacement of the frames under study, a comparison was done between different multistory bare frame models with different number of bays (1, 2, 3, and 4 bays), while the bay span was constant (8m) for all models compared in this case. For better comparability the maximum roof lateral displacement (RLD) for each model under study are illustrated in Fig. 8. and in Table 8. It is clear that the roof lateral displacement decreases as the number of bays increases. The rate of reduction in roof lateral displacement becomes less as the number of bay increases. The reduction in roof lateral displacement is due to the increases in the frame stiffness for resisting lateral load as the number of bays increases. The effect of the number of bays becomes more pronounced as the number of stories increases.

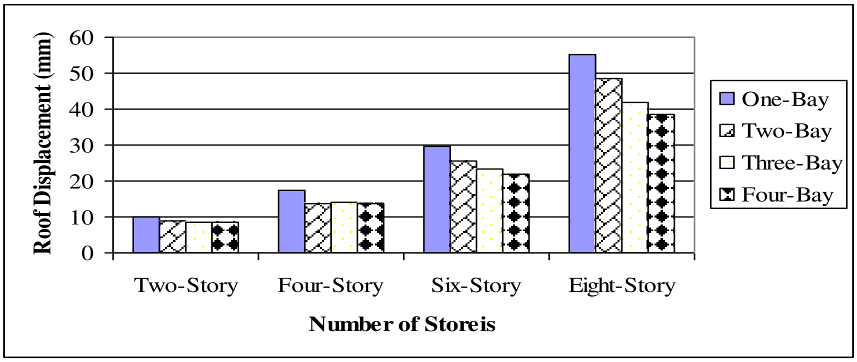

Fig. 8. Maximum roof lateral displacement for models with different number of bays.

Table 8.
Rate of reduction on roof lateral displacement due to number of bays (RRB)

Number of stories		Number of Bays			
		One-Bay	**Two-Bay**	**Three-Bay**	**Four-Bay**
Two-Story	RLD(mm)	10.03	9.06	8.64	8.52
	RRB* (%)	-	**(9.67)**	**(4.64)**	**(1.34)**
Four-Story	RLD(mm)	17.49	13.95	13.91	13.61
	RRB (%)	-	**(20.81)**	**(0.29)**	**(2.16)**
Six-Story	RLD(mm)	27.84	20.83	19.49	18.89
	RRB (%)	-	**(25.18)**	**(6.43)**	**(3.08)**
Eight-Story	RLD(mm)	55.15	46.61	41.82	38.57
	RRB (%)	-	**(25.49)**	**(10.27)**	**(7.77)**

*RRB = $(RLD_{b-1}-RLD_b)/ RLD_{a-1})$; b = number of bays.

3.1.2. Effect of bay span (L)

To study the effect of the bay span (L) on the roof lateral displacement, a comparison was done between six-story frame models with different bay span(L=4, 6, 8m). The results for six story models with different number of bays are illustrated in Fig. 9 and Table 9. It is clear that in each model the roof lateral displacement decreases as the bay span increases. The rate of reduction in roof lateral displacement becomes less as the bay span increases. This is because increasing the bay span increased the frame width and leads to increase the frame stiffness to resist the lateral load.

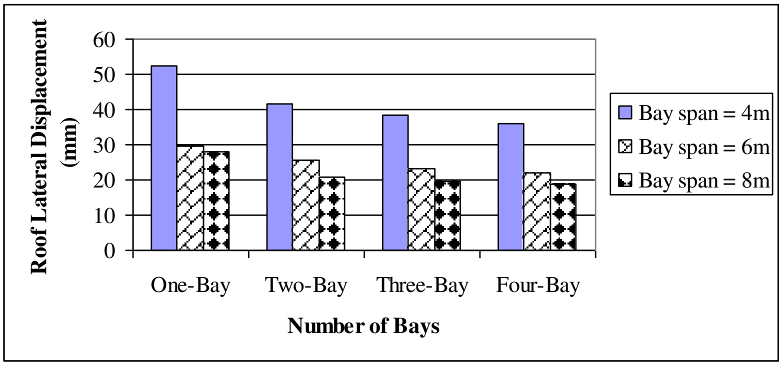

Fig. 9. Roof lateral displacement for six-story models with different bay span.

Table 9.

Rate of reduction on roof lateral displacement due to bays span (RRS)

Number of Bays		**Bay Span**		
		4m	**6m**	**8m**
One-Bay	**RLD (mm)**	52.49	33.46	27.84
	RRS (%)	-	**36.25**	**16.79**
Two-Bay	**RLD (mm)**	41.67	25.45	20.83
	RRS (%)	-	**38.92**	**18.18**
Three-Bay	**RLD (mm)**	38.52	23.16	19.49
	RRS (%)	-	**39.87**	**15.87**
Four-Bay	**RLD (mm)**	36.08	21.96	18.89
	RRS (%)	-	**39.14**	**14.00**

3.1.3. Effect of number of stories (n)

To study the effect of the number of stories (n) on the roof lateral displacement, a comparison was done between different frame models with different number of stories (n=2, 4, 6, and 8). The roof lateral displacement results for different models with different number of stories are illustrated in Fig. 10. It is clear that in each model the roof lateral displacement increases as the number of stories increases. The rate of increases in roof lateral displacement becomes greater as the number of stories increases. The increases in roof lateral displacement are due to increases in the total frame mass which leads to increase the earthquakes lateral load.

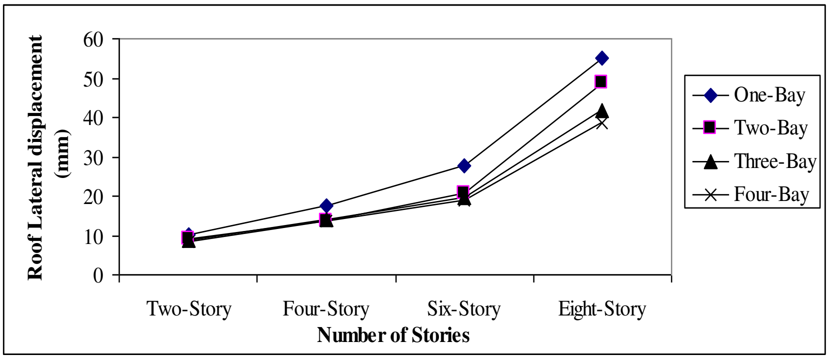

Fig. 10. Relation between roof lateral displacement and number of stories

3.1.3. Effect of infill

To study the effect of infill on the roof lateral displacement, a comparison was done between different frame models with and without infill (infilled frames and bare frames). The roof lateral displacements results for each model with different number of bays are illustrated in Fig. 11. It is clear that the presence of infill decrease the roof lateral displacement in each model. The rate of reduction in roof lateral displacement due to infill as shown in Fig 12 becomes less as the number of stories increases. It can be said that the presence of infill increased the frame stiffness to resist the lateral load.

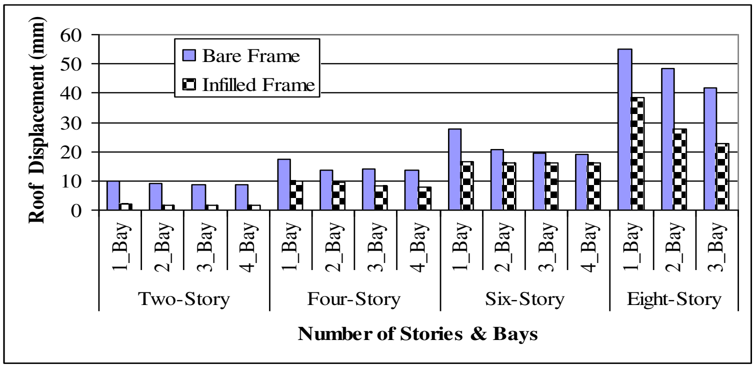

Fig. 11. Roof lateral displacement for bare frame and infilled frame models

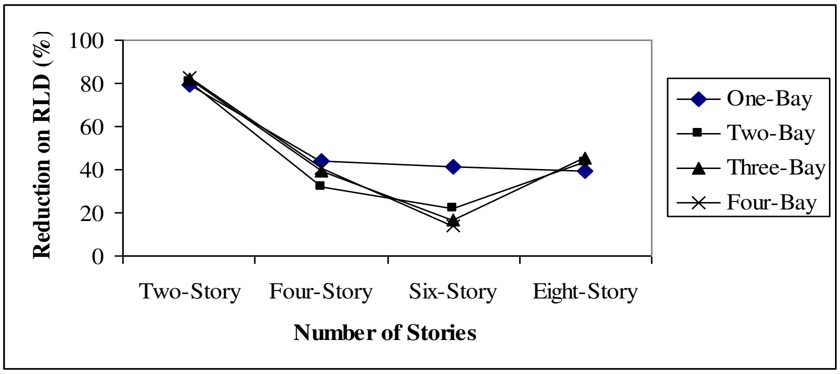

Fig 12. Relation between number of stories and the reduction in roof displacement due to presence of infill.

3.1.4. Effect of open ground story

From Fig. 7 and Tables 4-7, it is observed that for the open ground story models the upper stories move almost together as a single block, and most of the horizontal displacement of the building occurs in the open ground story itself. i.e. this type of buildings can be explained as a building on chopsticks. Thus, such buildings moves back and forth like inverted pendulums during earthquake shaking. The ground story columns act as the pendulum rod while the rest of the building acts as a rigid pendulum mass. As a consequence, large movements occur locally in the ground story alone.

3.2. Interstory drift ratio

The interstory drift ratio is very significant parameter in performance based engineering. The interstory drift ratio is calculated with the relative displacement of each story from the story below, divided by the corresponding story height. It is observed that maximum interstory is at the first story level for the two and four stories models, and at the second story level for the six and eight stories models.

3.2.1. Effect of number of bays

To study the effect of number of bays on the interstory drift ratio of the frames under study, a comparison was done between different multistory frame models with different number of bays (1, 2, 3, and 4 bays), while the bay span was constant (8m) for all models compared in this case. The maximum interstory drift ratios for each model under study are illustrated in Fig. 13.

It is clear that the interstory drift ratio decreases as the number of bays increases. The rate of reduction in interstory drift ratio becomes less as the number of bay increases.

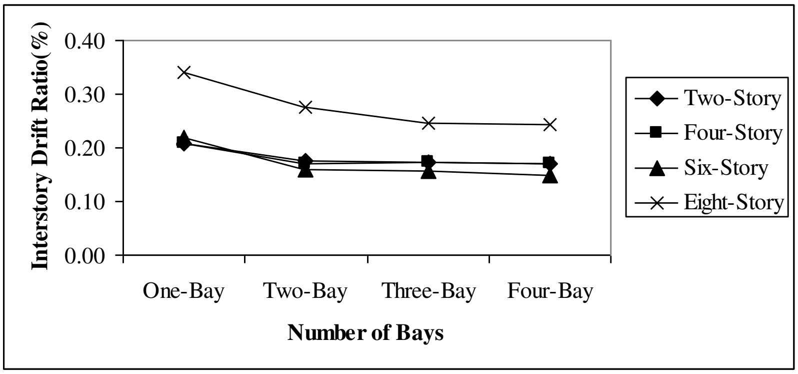

Fig. 13. Relation between number of bays and the inter story drift ratio

3.2.2. Effect of number of stories (n)

To study the effect of the number of stories (n) on the interstory drift ratio, a comparison was done between different frame models with different number of stories (n=2, 4, 6, and 8). The interstory drift ratios for different models with different number of stories are illustrated in Fig. 14. It is clear that in each model interstory drift ratio increases as the number of stories increases. The rate of increases becomes greater as the number of stories increases.

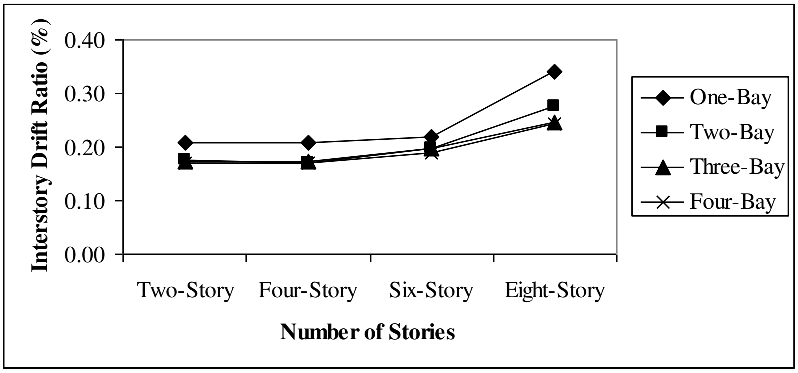

Fig. 14. Relation between number of stories and the inter story drift ratio.

3.2.3. Effect of infill

To study the effect of infill on the interstory drift ratio, a comparison was done between different frame models with and without infill (infilled frames and bare frames). The interstory drift ratios each model with different number of bays are illustrated in Fig. 15.

It is clear that the presence of infill decreases the interstory drift ratio in each model. The rate of reduction in the interstory drift ratio due to infill as shown in Fig. 16 becomes less as the number of stories increases.

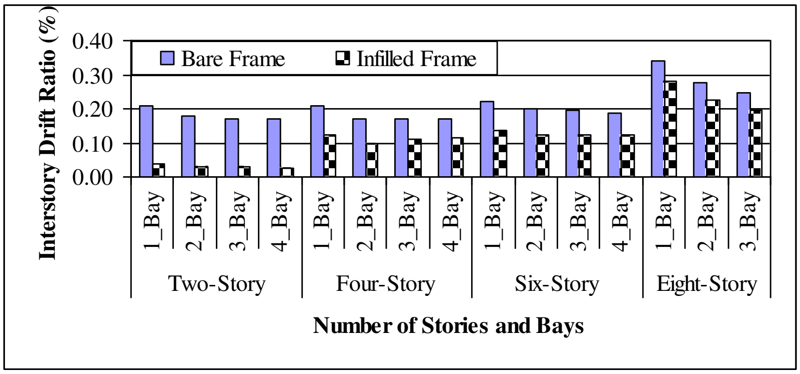

Fig. 15. Effect of presence of infill on the maximum interstory drift ratio

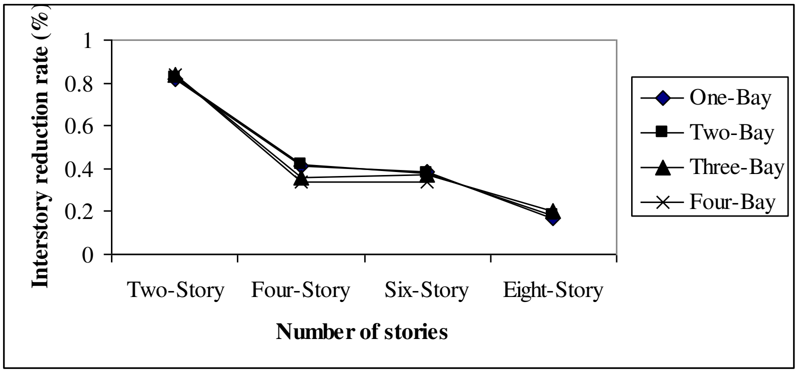

Fig. 16. Relation between the number of stories and the interstory reduction rate due to presence of infill.

3.2.4. Effect of open ground story

To study the effect of open ground story on the interstory drift ratio, a comparison was done between different infilled frame models with and without open ground story models. The interstory drift ratios for each model with different number of bays are illustrated in Fig. 17. It is clear that the interstory drift ratio at ground floor level is very high compared to other stories.

3.3. Base shear

Base shear is a very important parameter for seismic evaluation of buildings. The maximum base shear at the base of exterior column has been evaluated for all models under study and illustrated in Table **10**. it is clear that the least base shear appears at the bare frame models and the greatest appears at the infilled frame models.

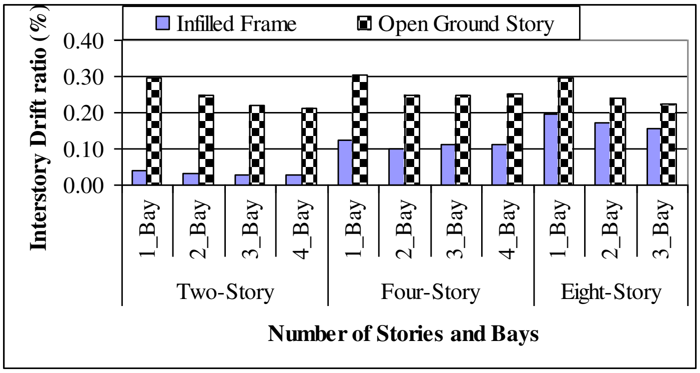

Fig. 17. Interstory drift ratio for different infilled frame models with and without open ground story.

Table 10.
Base Shear for each models under study

Number of Stories	Number of Bays and Frame Type											
	One-Bay			Two-Bay			Three-Bay			Four-Bay		
	BF	IN	OG	BF	IN	OG	BF	IN	OG	BF	IN	OG
Two-Story	23.6	65.0	29.3	19.9	40.3	27.2	19.0	36.1	26.8	19.1	37.5	26.4
Four-Story	41.4	113.6	75.4	33.2	112.9	58.9	31.9	113.2	52.6	32.0	113.4	50.9
Six-Story	69.5	158.8	154.6	59.4	164.4	146.6	60.0	163.4	136.8	62.3	162.3	142.0
Eight-Story	71.2	148.0	152.8	77.8	168.5	153.3	72.5	167.6	160.9	67.6		

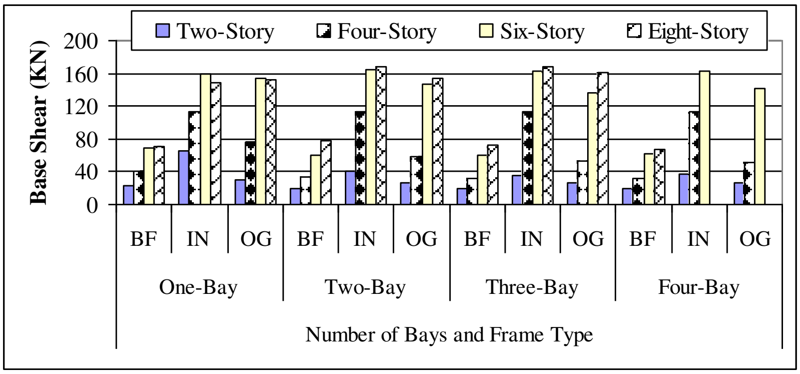

Fig. 18. Base Shear for each models under study

3.3.1. Effect of number of stories

To study the effect of the number of stories (n) on the base shear, a comparison was done between different frame models with different number of stories (n=2, 4, 6, and 8). The base shear results for different models with different number of stories are illustrated in Fig. 19. It is clear that in each model the base shear increases as the number of stories increases. The rate of increases in roof lateral displacement becomes greater as the number of stories increases.

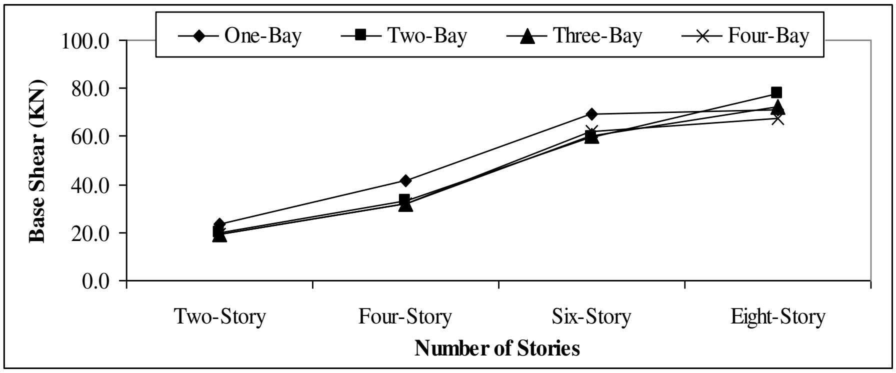

Fig. 19. Base Shear for different models as affected by the number of stories.

3.3.2. Effect of infill

To study the effect of infill on the base shear, a comparison was done between different frame models with and without infill (infilled frames and bare frames). The base shear for each model with different number of bays are illustrated in Fig. 20. It is clear that the presence of infill increase the base shear in each model.

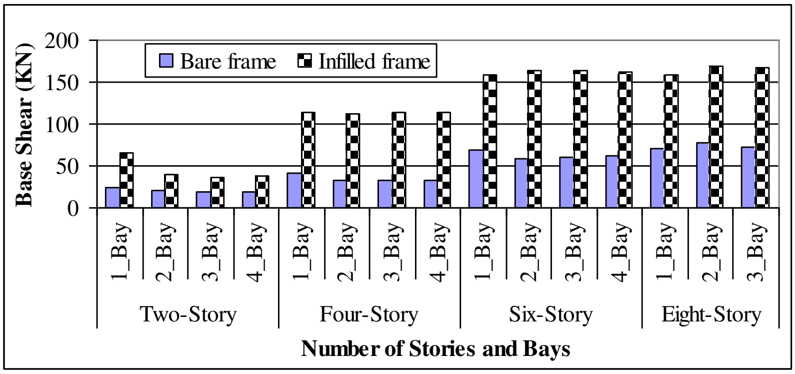

Fig. 20. Base shear for bare frame and infilled frame models

4. Conclusions

In this study, nonlinear time history analyses were performed for a series of multi-story multi-bay RC frames designed for gravity load only and subjected to earthquakes. The infill walls were modeled as equivalent diagonal struts. And seismic behaviors of RC frame with and without masonry infill walls were investigated. Some of the main conclusions are as follows:

The presence of infill wall can affect the seismic behaviour of frame structure to large extent, and the infill wall increases the strength and stiffness of the structure, as a result, there is a significant decrease in maximum roof lateral displacement and interstory drift ratio of infill frame as compare to bare frame. The maximum reduction ratio in roof displacement due to presence of the infill was found in the two-story models, which was about 80% as compared to the bare frame models. The rate of reduction becomes less as the number of story increases to be about 40% in the eight-story models.

Infilled frames are strongly preferred in seismic regions than the open ground story frame, because the story drift at the first story of open ground story frame is very large than the upper stories, this may probably cause the collapse of structure. It was found that the phenomenon of open ground story increased the first story drift compared to infilled or bare frames. The rate of increase in first story drift was about 42% compared to bare frame.

There is a significant effect of increasing the number of bays in reducing the roof lateral displacement and the interstory drift ratio, this effect becomes more pronounced as the number of stories increases. The maximum reduction ratio was found at the eight-story two-bay model (about 25%) compared to the one-bay model, this rate decreased as the number of stories decreases which was about 10% at the two-story two-bay model.

There is a significant effect of increasing the span of bays in reducing the roof lateral displacement and the interstory drift ratio, the rate of reduction becomes less as the bay span increases. It was found that the reduction in the roof lateral displacement was about 38% when increasing the bay span from 4 to 6m and about 16% when increasing the bay span from 6 to 8m.

Ignoring the presence of infilled wall in analyzing the RC frames leads to underestimation of base shear (47-72% less). The underestimation of base shear may leads to the collapse of structure during earthquake shaking.

5. References

[1] C. V. R. Murty, S. Brzev, H. Faison, C. D. Comartin, and A. Irfanoglu, *AT RISK: The Seismic Performance of Reinforced Concrete Frame Buildings with Masonry Infill Walls*. Earthquake Engineering Research Institute, Oakland, California, 2006.

[2] M. A. Al-masni, “Earthquake Building Risk Assessment in Sana’a City, Yemen,” Final Report, Asian Disaster Reduction Center, 2012.

[3] S. E. Abdel Raheem, “Evaluation of Egyptian Code Provisions for Seismic Design of Moment-Resisting-Frame Multi-Story Buildings,” *International Journal of Advanced Structural Engineering*, vol. 5, no. 3, pp. 20–34, 2013.

[4] M. Galli, “Evaluation of the Seismic Response Of Existing R.C. Frame Buildings With Masonry Infills,” PhD Thesis, University of Pavia, Italy, 2006.

[5] Ö. Çavdar and A. Bayraktar, “Pushover and Nonlinear Time History Analysis Evaluation of a RC Building Collapsed During the Van (Turkey) Earthquake on October 23, 2011,” *Natural Hazards*, 05-Sep-2013. [Online]. Available: http://link.springer.com/10.1007/s11069-013-0835-3. [Accessed: 18-Oct-2013].

[6] S. A. ALSinawi and A. Al Aydrus, *Seismicity of Yemen*. Obadi Studies & Publishing Center, Sana’a, Republic Of Yemen, 1999.

[7] A. Awad, H. Bassam, and I. Talal, “Moment Resisting Frame Designed for Gravity Loads Only,” *World Housing Encyclopedia, an initiative of Earthquake Engineering Research Institute (EERI) and International Association for Earthquake Engineering (IAEE)*. 2002.

[8] V. Pascucci, M. W. Free, and Z. A. Lubkowski, “Seismic Hazard and Seismic Design Requirements for the Arabian Peninsula Region,” in *The 14th World Conference on Earthquake Engineering. October 12-17, 2008, Beijing, China*.

[9] D. Costa, “Standard Methods for Seismic Analyses,” Report BYG•DTU R-064 2003- ISSN 1601-2917 - ISBN 87-7877-129-9, 2003.

[10] SIMULIA, “ABAQUS Analysis User’s Manual.” Version 6.10, ABAQUS, Inc, 2011.

[11] Khairy. H. Abdelkareem, F. K. Abdel-Sayed, M. H. Ahmed, and N. AL-Mekhlafy, “Equivalent Strut Width For Modeling R.C. Infilled Frames,” *Journal of Engineering Sciences*, vol. 41, no. 3, pp. 851–866, 2013.

[12] A. B. Mehrabi, M. P. Schuller, J. L. Noland, and N. S. Foundation, “Performance Of Masonry-Infilled RIC Frames Under In-Plane Lateral Loads,” *Structural Engineering And Structural Mechanics Research Series, Report CD/SR-94/6, University of Colorado at Boulder*, 1994.

[13] ACI Comminee 318, “‘Building Code Requirements for Reinforced Concrete (ACI 318-89)’,” *AmericanConcrete Institute, Detroit*. 1989.

[14] Khairy. H. Abdelkareem, “Analytical Study on Seismic Resistant Characteristics of RC Bridge Piers,” *Thesis Submitted for D.Eng. Degree, Saitama University, Japan*, 1999.

[15] B. L. Wahalathantri, D. P. Thambiratnam, T. H. T. Chan, and S. Fawzia, “A Material Model for Flexural Crack Simulation in Reinforced Concrete Elements Using Abaqus,” in *First International Conference on Engineering, Designing and Developing the Built Environment for Sustainable Wellbeing, Queensland University of Technology, Brisbane, Qld, Australia*, 2011, pp. 260–264.

[16] T. Paulay and M. Priestley, *Seismic Design of Reinforced Concrete and Masonry Buildings*. New York: Jhon Wiley & Sons, 1992.

بعض العوامل المؤثرة على سلوك الهياكل الخرسانية المسلحة المصممة لتحمل القوى الرأسية فقط والمعرضة لاحمال الزلازل

الملخص العربى:

تم دراسة تاثير بعض العوامل المختارة على سلوك الهياكل الخرسانية المسلحة المصممة لمقاومة الاحمال الرأسية فقط تحت احمال الزلازل. تم تصميم عدد من الهياكل الخرسانية المسلحة لمقاومة الاحمال الرأسية فقط بدون الاخذ بالاعتبار تأثير احمال الزلازل. والعوامل التي اخذت في الاعتبار في هذه الدراسة هي: عدد البحور بين الاعمدة والمسافة بينها وكذلك عدد الطوابق، بالاضافة الى اعتبار جميع الفراغات بين الاعمدة مملوءة بالجدران او القواطيع لجميع الادوار وحالة ترك الطابق الارضي بدون أي تعبئة. وقد وجد ان وجود القواطيع يمكن ان يؤثر بشكل كبير على سلوك المنشأ تحت الزلازل ويزيد من متانته وقوته وساهمت في تخفيض مقدار الازاحة الافقية بنسبة تراوحت بين حوالي 40 – 80% . كما وجد ايضا ان ترك الدور الارضي بدون قواطيع او جدران يعتبر فيه مخاطرة، وهناك احتمالية لانهيار المبنى تحت تاثير الزلازل ان حدثت بسبب ان الازاحة الافقية لعمود الدور الارضي اكبر بكثير من الازاحات الافقية في الطوابق الاعلى مما قد يتسبب بانهيار المبنى تحت تاثير الاحمال الافقية.