Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (40) No. (1) January, 2018

Assessment of Existing Non-Engineered Residential Building in Rural Area Based on Egyptian Code of Practice - A Case Study

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الملخص:

المباني السكنية في المناطق الريفية في مصر والتي يتم بناؤها دون أي تدخل من مهندس مؤهل في تصميمها أو الأشراف على بنائها تصنف على أنها مبانى غير هندسية. أكثر أنواع المباني غير الهندسيه في مصر تقع فى المناطق الريفية وتشتمل على مزيج من الهياكل الخرسانيه مع حوائط من الطوب. هذا البحث يناقش التقييم الأنشائى للمباني السكنية القائمة والتى تم تشيدها بطريقه غير هندسيه تحت تأثير الأحمال الرأسية والجانبية استنادا إلى الكود المصرى للأحمال والتي تم بناؤها من قبل مقاولين محليين غير مهنيين ودون أي تراخيص بناء أو أي إشراف هندسي. تم التطبيق عل حاله دراسية في قرية سنتريس في محافظة المنوفيه حيث تم عمل استكشاف كامل لأكثر من 50 منزلا تم بناء معظمها بطريقه غير هندسيه باستخدام الطوب الطيني والأخشاب. ولأسباب اجتماعية واقتصادية تمت إزالة هذه المنازل القديمة وإعادة بنائها باستخدام الخرسانه المسلحه وحوائط طوب. وقد تم اختيار أحد المبانى السكنيه القائمه والتى تم بناؤها بطريقه غير هندسيه منذ حوالى 27 سنة كحاله دراسيه. وقد تم بناؤه من قبل مقاول محلي. المعايير التصميميه وكذلك النظام الأنشائى للمبنى الحالي تم استخلاص المعايير عن طريق الرفع المساحى للمبنى القائم و كذلك المناقشة مع المقاول المنفذ. تم إجراء تقييم أنشائى كامل للمبنى عن طريق أعداد نموذج ثلاثى الأبعاد بأستخدام برنامج الأيتاب أصدار 16 لتقييم المبنى الحالي تحت تأثير أحمال الجاذبية والأحمال الجانبية بأستخدام الكود المصرى للأحمال وذلك فى حاله وجود حوائط وبدون حوائط. أظهرت النتائج أن أعمده الإطار الخرسانى بدون الحوائط غير آمنه لمقاومه الزلازل علاوه على ذلك الأطار الخرسانى بالحوائط المالئه يعزز إلى حد كبير مقاومة المبنى للأحمال الجانبية نتيجه الزلازل بحيث يمكن للهيكل القائم مع الحوائط مقاومة الأحمال الرأسيه والأفقيه بأمان على أساس أشترطات الكود المصرى.

ABSTRACT

Non- engineered residential buildings in rural areas in Egypt are constructed without any or little intervention from a qualified engineer in their design or construction. The most common types of non –engineered buildings in rural areas in Egypt are combined reinforced concrete (RC) skeleton with unreinforced masonry infill walls. The present study discusses the structural evaluation of existing non-engineered residential buildings under vertical and lateral loads based on Egyptian codes of practice (ECP). The buildings were constructed by local unprofessional contractors without any work permits or any engineering supervision. A case study is considered in a village called Sntric in Munafaya governorate, Egypt where a complete survey investigation of more than 50 non-engineered buildings has been explored. Most of them were constructed in the past using mud bricks and timber and due to social and economical reasons, these old buildings were removed and reconstructed using RC and infill masonry walls. One existing non-engineered building 27 years old was considered as a case study. It was built by local contractor. The structural criteria and the framing system were extracted from the existing building and from the discussion with the local contractor. Full structural assessment using 3D Etabs model version 16 was carried out to evaluate the existing building under gravity and lateral load (seismic) based on ECP with and without infill masonry wall. The results from the structural 3D model show that the frame with infill wall significantly enhances the structure to resist lateral loads from earthquake so the existing structure with infill wall can resist gravity and lateral loads safely based on the ECP provision

Keywords: Non-engineered, Etabs, infill wall, Rural, Urban, seismic load, Egyptian Code

INTRODUCTION

Buildings can be divided into two main categories, namely engineered buildings and non-engineered buildings, their percentages being quite different in developed, developing, and underdeveloped countries. The majority of the population under developed countries lives in buildings that can be considered as non-engineered. In the past in rural areas of Egypt mud bricks and timber are the most utilized building materials in the non- engineered residential housing buildings as shown in Fig.(1). Since the late eighties, the construction materials has been changed to RC Skelton with infill brick walls as shown in Fig.(2). Often these buildings are constructed in rural areas by the local contractor without any proper engineering design or supervision and based on the experience of local contractors. No measures have been taken in the construction process to resist the lateral loads.

Non-engineered residential buildings are constructed with unreinforced infill masonry for functional and architectural reasons. Unreinforced masonry infill walls are normally considered as non-structural elements and their stiffness contributions are in practice generally ignored. However, infill walls tend to interact with the frame when the structure is subjected to lateral loads. [1], [2], [3], [4], [5], [6], [7], [8], [9]. The term 'infilled frame' is used to denote a composite structure formed of the combination of a moment resisting plane frame and infill walls. The infill may be integral or non-integral depending on the connectivity of the infill to the frame. The method of construction of infill wall is to build brick walls between two columns using anchorage rebar then reinforced concrete beam will be cast over the brick wall.

A physical surveying study is focused on Sntric village in Egypt which lies in the northern part of the Menoufia Governorate. Sntric located approximately 25 Km from Cairo. In the village of Sntric , investigation study on more than 50 non-engineered residential buildings which were constructed using RC skeleton and infill masonry wall has been carried out. From the physical survey of the existing buildings in the study area based on the construction materials and techniques, non engineered residential building which was constructed 27 years ago before the 1992 Cairo earthquake was selected as a case study as illustrated in Fig. (3).

Architectural dimensions of the existing building, the structural dimensions of framing elements, as well as other building information have been collected and surveyed on site and confirmed with the contractor in charge of the selected building. The selected building is modeled and analyzed under gravity and lateral loads (seismic) as per ECP using the finite element package ETABS. Structural analysis was performed using the existing framing system and estimated material characteristic. Two 3-D Etabs models are prepared, one of them represents the bare frames and the second one represents infilled frames [10].

In the case study under consideration, integral connection is assumed according to method of construction. Lateral behavior from analysis of the case study building using 3-D Etabs model is assessed and compared for the two cases, bare and infilled frames. Assessment of the lateral behavior of the existing selected building is done by correlating the results from the analysis with the ECP provision [11], [12], [13].

Fig. (1) Mud brick Building

Fig. (2) Replacement Mud Brick Building with RC frame With Infill Masonry wall

OBJECTIVES OF PRESENT STUDY

The objectives of present study can be summarized as follows:

1- To survey and investigate existing more than 50 non-engineered residential buildings with different types to select one for structural assessment.
2- To prepare two structural models using Etabs software based on geometry and materials which were collected by physical measurement and from the contractor who executed the building. One of the models was for bare frame and second one for frame with infill walls. All loads based on Egyptian building code.
3- To conduct seismic analysis using the response spectrum method for two structural models in order to predict the behavior of the infilled system.
4- To evaluate the structural model results based on gravity loads and also lateral seismic load and contribution of infill wall to enhance the structure against lateral load.

SITE INVISTIGATION

The selected building consists of two floors above ground floor and has a rectangular shape with dimensions 10.75m x 15.50m. The height of the ground floor is 4.0m, the height of the two repeated floor is 2.70 m. The selected building consists of reinforced concrete skeleton rested on RC isolated footings connected with smells at foundation level. The bare frames are filling in the empty spaces of the frames with non reinforced brick wall, which is considered the most common type of non-engineered building in rural and urban area in Egypt. The Type of structure is ordinary moment resisting RC frame. In the absence of architectural and structural drawings, full measurements were conducted on site on order to determine all building dimensions and prepare As Built Arch. Plan as well as all exposed structural elements dimension such as beams and columns were measured to confirm their exact dimensions as illustrated in Fig. (4). Any other data related to the embedded steel reinforcement or foundation were taken from the contactor.

Fig.(3) Typical Non-engineered Concrete Frame with Infill Wall Building Chosen for Analysis

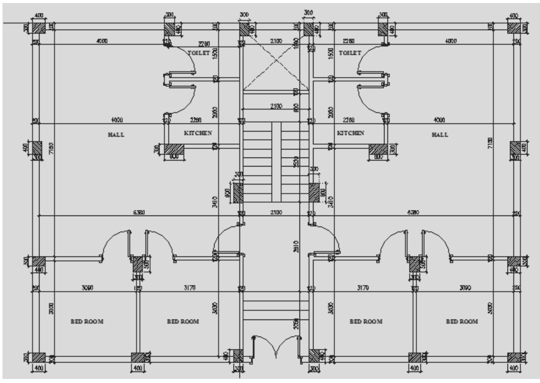

Fig. (4) Arch. As Built Drawing for Ground Floor Plan for Selected Building

Foundation type, size and reinforcement

Foundations are RC isolated footings with thickness 60 Cm rested on plain concrete with thickness 40 Cm. The dimensions of isolated footings in the middle 2.00x3.00m, reinforced with bottom steel reinforcement Dia12@150 in two directions. Isolated footings for corners and edges have dimensions 1.50x2.50m with bottom steel reinforcement Dia12@150 in two directions. All isolated footings are connected with smells in the level of isolated footings and have concrete dimensions 25x60cm reinforced with 3Dia12 top and bottom and stirrups 6Dia8/m.

Floor system

Floor system is solid slab with projected beam. Concrete slab thickness is 15 Cm with one layer steel reinforcement Dia10@200 in two directions. Concrete beam dimension is 12x65 cm with steel reinforcement 3Dia12 top and bottom and stirrups 6Dia8/m. floor slab are commonly cast after the construction of the masonry walls is complete.

Columns Concrete dimensions and steel reinforcement

Table 1 shown the concrete dimensions and steel reinforcement according to the data which was taken from the contractor.

Table 1: Columns Cross Sectional Dimensions and Steel Reinforcement

Span	Height	Column Dimension and Steel Reinforcement		
		Edge	**Corner**	**Middle**
Up to 4.00m	2.70m	25x40 cm 6Dia12	25x40 cm 6Dia12	25x50 cm 8Dia12
Up to 4.00m	4.60m	30x40 cm 6Dia12	30x40 cm 8Dia12	30x50 cm 10Dia12
From 4.40m to 5.50m	2.70m	25x40 cm 6Dia12	25x50 cm 6Dia12	25x60 cm 10Dia12
From 4.40m to 5.50m	4.60m	30x40 cm 6Dia12	30x50 cm 8Dia12	30x60 cm 10Dia12

All stirrups are 6Dia8/m

STRUCTURAL MODELLING

Two 3D models were built for (GF + Four Typical stories) (existing 2 typical stories and expected upcoming 2 stories) and analyzed for static, response spectrum using the finite element package Etabs, one of them for bare frame and Second one for bare frame with infill wall under gravity and seismic load as shown in Figs(6) and (7).

- Bare frame without infill wall under gravity and seismic load
- Bare frame with infill wall under gravity and seismic load

Brick infill wall was modeled as a shell element and reinforce concrete framing system as a line element. Infill panel was considered as homogenous material. Design criteria which implemented in the 3D models are as following:

Material Characteristics

- Concrete

Typical concrete with cube compressive strength 20 Mpa was utilized with concrete ingredient as shown in Table (2). The concrete was mixed and placed manually.

Table 2: Assumed Concrete Ingredient for 1m^3 Concrete

Concrete Grade & Composition	(K200)
Location	Foundation, Columns, Beams and slabs
28 Days cube strength kg/cm^2	200
Maximum W/C ratio	0.5
Cement type I	OPC
Cement Content kg/m^3	7 bags 350 KG/m^3
sand m^3	0.4
Gravel m^3	0.8
Maximum free water L/m^3	175

Concrete density 2.5 t/m^3

Modulus of elasticity = 4400 $\sqrt{fcu}$ N/mm^2= 19.68 Gpa

Equivalent cylinder compressive strength = 0.8 x 20 = 16 Mpa

Poisson ratio = 0.2

- Steel Reinforcement

Steel reinforcement grade is 360/520 with minimum yield stress 360 Mpa
Steel reinforcement grade for stirrups is 240/350 with minimum yield stress 240 Mpa
Elastic modulus 200 Gpa

- Bricks [14]

The bricks infill wall is made of 65x120x250mm solid silt bricks using running bond with mortar.
Unit weight 1.6 t/m^3
Minimum compressive strength for non bearing solid block is 5 Mpa

- Mortar

Mortar type 4 with minimum compressive strength after 28 days 2 Mpa
Characteristics compressive strength for masonry wall is defined by type of mortal and brick unit 1.8 Mpa
Elastic modulus 700 f_m = 700 x 1.8 = 1.26 Gpa
Shear Modulus G= 0.4 E = 0.504 Gpa
Poisson ratio of brick wall= 0.2

<u>Loads</u>

- Gravity load

Self own weight of building
Wall loads (wall density is 1600kg/m^3)
Flooring loads (as per ECP201-2012)
Live loads (as per ECP201-2012)

- Lateral loads

Lateral loads are considered in the 3D model as per ECP201-2012. Earthquake loads shall comply with the (ECP 201-2012) provisions for zone 2. Zone factor a_g equal to 0.125g. g = 9.81 m/sec^2

Hence, the design base shear will be calculated in each direction as follows:

$$F_b = \frac{S_d(T1).\lambda}{g} W$$

Where:
λ : Correction factor $= 0.85$ if $T1 \leq 2Tc$
$= 1.0$ if $T1 > 2Tc$

W: Total weight of building due to dead load + 0.25 Live Load
$S_d(T)$: Design response spectrum …. Clause (8.4.2.5), Equations (8-11 to 8-14)
TC, TB, TD, S: Table (8.3.A)
η : Damping Factor = 1.0 …. (Table 8.4)
R : Response Modification Factor …. (Annex 8-A) (Table A)
R = 5 ………. For Bar frame system
R = 4.50 ….. For Infill Wall system
γI: Importance factor (Table 8.9) = 1.0 …. For residential buildings
T1: Fundamental periodic time of the structure = $C_t.H^{0.75}$
C_t = 0.075 …. (Concrete Frames)
H: Building height from foundation level

The building seismic Characteristics are:

Zone area category =	2	
Damping factor η =	1	
Importance factor γ_I=	1	
Ground acceleration g =	9.81	m/sec.^{2}
Soil type =	c	

Framing plan

Framing plan which implemented in Etabs 3D model is illustrated in Fig. (5)

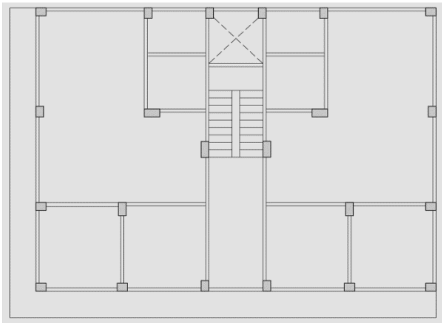

Fig. (5) Structural Framing Plan for Repeated Floor

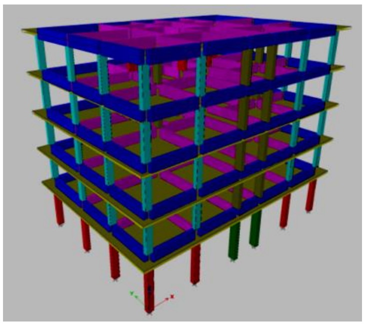

Fig.(6) 3D Model for Bare Frame

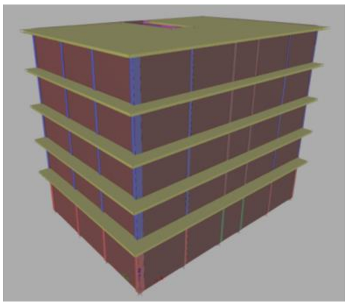

Fig.(7) 3D Model for Bare Frame with infill wall

Response Spectrum Functions

Response spectrum curve was calculated based on Egyptian code of practice as shown in Figs. (8) & (9).

Table 3 - Response Spectrum for Infill Wall

Name	Period sec	Acceleration	Damping %
ECP	0	0.1250	5
ECP	0.02	0.1208	
ECP	0.04	0.1167	
ECP	0.06	0.1125	
ECP	0.08	0.1083	
ECP	0.1	0.1042	
ECP	0.13	0.1042	
ECP	0.16	0.1042	
ECP	2.2	0.0250	
ECP	2.4	0.0250	
ECP	2.8	0.0250	
ECP	3	0.0250	
ECP	3.2	0.0250	
ECP	3.4	0.0250	
ECP	3.6	0.0250	
ECP	3.8	0.0250	

Name	Period sec	Acceleration	Damping %
ECP	0.19	0.1042	
ECP	0.22	0.1042	
ECP	0.25	0.1042	
ECP	0.44	0.0592	
ECP	0.63	0.0413	
ECP	0.82	0.0318	
ECP	1.01	0.0258	
ECP	1.2	0.0250	
ECP	1.4	0.0250	
ECP	1.6	0.0250	
ECP	1.8	0.0250	
ECP	2	0.0250	

Name	Period sec	Acceleration	Damping %
ECP	4	0.0250	

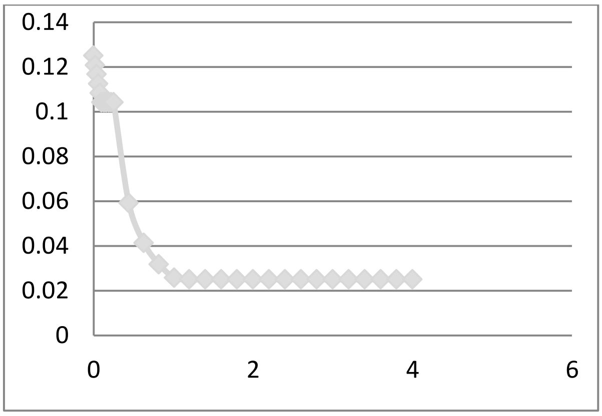

Fig. (8) Response Spectrum Curve for Infill Wall

Table 4 - Response Spectrum for Bare Frame

Name	Period sec	Acceleration	Damping %
ECP	0.00	0.1250	5
ECP	0.02	0.1188	
ECP	0.04	0.1125	
ECP	0.06	0.1063	
ECP	0.08	0.1000	
ECP	0.10	0.0938	
ECP	0.13	0.0938	

Name	Period sec	Acceleration	Damping %
ECP	1.60	0.0250	
ECP	1.80	0.0250	
ECP	2.00	0.0250	
ECP	2.20	0.0250	
ECP	2.40	0.0250	
ECP	2.60	0.0250	
ECP	2.80	0.0250	

Name	Period sec	Acceleration	Damping %
ECP	0.16	0.0938	
ECP	0.19	0.0938	
ECP	0.22	0.0938	
ECP	0.25	0.0938	
ECP	0.44	0.0533	
ECP	0.63	0.0372	
ECP	0.82	0.0286	
ECP	1.01	0.0250	
ECP	1.20	0.0250	
ECP	1.40	0.0250	
ECP	1.60	0.0250	
ECP	1.80	0.0250	
ECP	2.00	0.0250	

Name	Period sec	Acceleration	Damping %
ECP	3.00	0.0250	
ECP	3.20	0.0250	

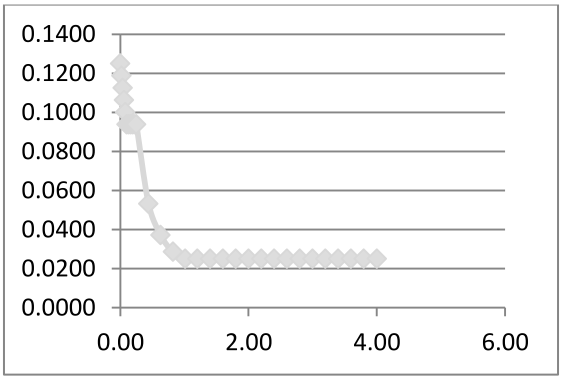

Fig. (9) Response Spectrum curve for Bare Frame

RESULTS AND DISCUSSION

Results from two 3D models

Table 5 Columns Utilization Factor Extracted from Etabs Models.

Column ID	Column section	Utilization factor for Bare Frame case	Utilization factor for Bare Frame with Infill Wall case
C1	30x40	1.1	0.607
C2	30x40	1.06	0.552
C3	30x50	1.002	0.447
C4	30x50	1.001	0.436
C5	30x40	1.066	0.484
C6	30x40	1.05	0.458
C7	30x40	1.318	0.789

C8	30x60	1.093	0.551
C9	30x60	1.091	0.534
C10	30x40	1.208	0.595
C11	30x60	1.006	0.545
C12	30x60	1.005	0.539
C13	30x40	1.13	0.734
C14	30x50	1.063	0.709
C15	30x50	1.041	0.688
C16	30x40	1.036	0.585
C17	30x40	1.12	0.667
C18	30x40	1.22	0.702
C19	30x50	1.09	0.619
C20	30x50	1.09	0.615
C21	30x40	1.22	0.671
C22	30x40	1.165	0.549

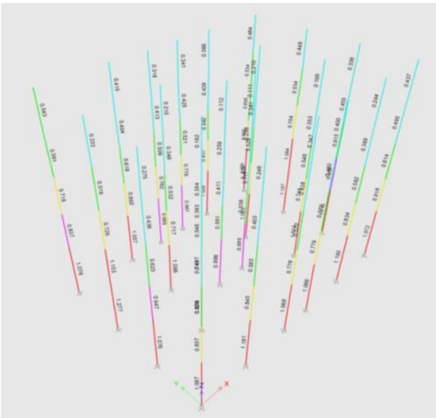

Fig.(10) column utilization factor for Bare Frame

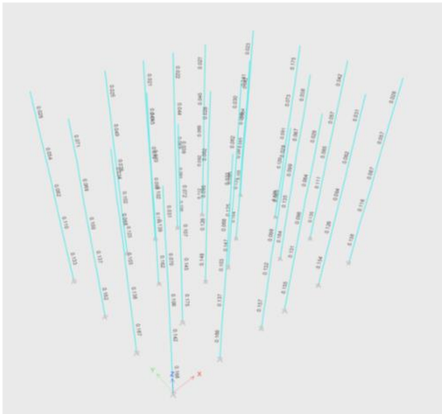

Fig.(11) column utilization factor for Bare Frame with Infill Wall

Figs. (10), (11) and Table 5 show the following:

1- Most of utilization factor for main supporting elements exceed than 1 in case of bare frame that mean unsafe.
2- Infill brick walls increase the demand capacity and reduce the vulnerability of bare frame due to gravity and seismic loads about 2 times because it will work with framing system laterally.

CONCLUSIONS.

1- Infill brick walls are effective in increasing the lateral capacity of the building against seismic load by 200 % comparing with bare frame structure.
2- Infill walls enhanced the utilization factor of frame members subjected to gravity and lateral loads
3- From numerical analysis which carried out by Etabs, frame structure with infill wall for Non- engineered building is safe against gravity and lateral loads (seismic load) from safety point of view.
4- It is not recommended in non engineered buildings to remove any block wall because it will act as structural element

REFERENCES

1- Anand S ARYA, "Non-engineered Construction in Developing Countries –An Approach Toward Earthquake Risk Prediction" 12WGEE2000.
2- Aikaterini Papanikolaou, Fabio Taucer, "Review of Non-engineered Houses in Latin America with Reference to Building Practices and Self Construction Projects", EUR 21190EN, 2004.
3- A. M. ABDEL ALEEM, M. O. RAMADAN AND A. A. FOUDA, "Behavior of Brick Masonry in Compression Using the Egyptian Local Materials" Faculty of Engineering (Shobra), Banha University, December 1999.
4- Boen, T., (2006) "Yogya Earthquake-Structural Damage Report" Indonesia", Structural Damage Report.
5- Lokesh Choudhary, Ankit Pachouri, "Analysis of Non-engineered Structure Using SAP 2000", 2^{nd} International Conference on Science, Technology and Management, University of Delhi (DU), 27 September 2017.
6- A. Castillo, F. López-Almansa, L. G. Pujades, "Seismic Risk Analysis of Urban Non-engineered Building: Application to an Informal Settlement In MÉRIDA, VENEZUELA, November 2011, Volume 59, Issue 2, pp 891–916.
7- Lisa Holliday, Thomas Kang, "Earthquake Performance of Non-engineered Construction in Nicaragua" 15 WCEE, LISBOA 2012.
8- Muhammad Tariq A. Chaudhary, "Seismic Vulnerability Mitigation of Non-engineered Building" World Academy of Science, Engineering and Technology International Journal of Structural and Construction Engineering Vol:8, No:4, 2014.
9- Paz, M., "Structure Dynamics Theory and Computation" 3rd edition, Van Nostrand Reinhold, New York, USA
10- Analysis and design software ETABS for structural and earthquake engineering, Computer and Structures, Inc.
11- Housing and Building National Research Center, Egyptian Code for Designing and Constructing Reinforced Concrete Structures (ECP 203-2007), 2007 edition, Cairo, Egypt.
12- Egyptian Code for Loads, ECP 201-2012, National Housing and Construction Research Centre.
13- Egyptian Society for Earthquake Engineering "Regulations for Earthquake Resistant Design of Buildings in Egypt" January, 1988.
14- Housing and Building National Research Center, Egyptian Code for Design and Construction of Masonry Works ECP 204-2005, 2005 edition, Cairo, Egypt.