



**AIN SHAMS UNIVERSITY  
FACULTY OF ENGINEERING**

**TOWARDS A CONSISTENT SEISMIC  
DESIGN EGYPTIAN CODE**

**By**

**Eng.Safinaz Saeed Khalifa**

**B. Sc, Civil Engineering – Zagazig University 1994**

**M.Sc. Ain Shams University 2005**

**A Thesis**

**Submitted In Partial Fulfilment For The Requirement Of Degree Of  
Ph.D. In Structural Engineering**

**Supervised by**

**Prof. Dr. Amin Saleh Aly**

(Prof. of Structural Engineering

Ain Shams university)

**Prof. Dr. Essam Ahmed El Kordi**

(Prof of Structural Engineering

Alexandria university)

Cairo 2013



**AIN SHAMS UNIVERSITY  
FACULTY OF ENGINEERING**

**TOWARDS A CONSISTENT SEISMIC  
DESIGN EGYPTIAN CODE**

**By**

**Eng.Safinaz Saeed Khalifa**

**B. Sc, Civil Engineering – Zagazig University 1994**

**M.Sc. Ain Shams University 2005**

**A Thesis**

**Submitted In Partial Fulfilment For The Requirement Of Degree Of  
Ph.D. In Structural Engineering**

**Supervised by**

**Prof. Dr.Amin Saleh Aly**  
(Prof. of Structural Engineering  
Ain Shams university)

**Prof.Dr.Essam Ahmed El Kordi**  
(Prof of Structural Engineering  
Alexandria university)

**Cairo 2013**



**AIN SHAMS UNIVERSITY**  
**FACULTY OF ENGINEERING**

**EXAMINATION COMMITTEE**

**Name** :- Eng. Saffnaz Saeed Khalifa  
**Title of thesis** :- TOWARDS A CONSISTENT SEISMIC  
DESIGN EGYPTIAN CODE  
**Degree** :- Doctor of Philosophy

**Committee:-**

<b>1.</b>	<b>Prof. Dr. Amin Saleh Aly</b>	(.....)
<b>2.</b>	<b>Prof. Dr. Mohammed M. Attaby</b>	(.....)
<b>3.</b>	<b>Prof. Dr. Hadad Said Hadad</b>	(.....)

Date : ...../...../ 2013

## STATEMENT

This dissertation is submitted to Ain Shams University in partial fulfilment for the requirements of the degree of Doctor of Philosophy in structural engineering.

The work included in the thesis was carried out by the author in the structural engineering department, ain shams university.

No part of this thesis has been submitted for a degree or a qualification at any other university or institution

Date ..... / ..... / 2013

Name : :- **Eng. Saffnaz Saeed Khalifa**

Signature : .....



**AIN SHAMS UNIVERSITY**  
**FACULTY OF ENGINEERING**

Structural engineering department

Abstract of the Ph.D. thesis submitted by **Eng. Safinaz Saeed Khalifa**

**Title of thesis        :- TOWARDS A CONSISTENT SEISMIC  
DESIGN EGYPTIAN CODE**

**Supervisors**

**Prof. Dr. Amin Saleh Aly**  
(Prof. of Structural Engineering  
Ain Shams university)

**Prof. Dr. Essam Ahmed El Kordi**  
(Prof of Structural Engineering  
Alexandria university)

**ABSTRACT**

Several Egyptian codes of practice have been published in Egypt during the past two decades, for example “The Regulation of Earthquake – Resistant Design of Building in Egypt” [ESEE 1988], “The Egyptian Code for Load and Forces” [ECLF 1993] released in 1993, “the Egyptian Code of Practice for Loads and Forces” [ECLF 2003] released in January 2003, forwarded by the [ECLF 2008]. Great inconsistencies (variances) were observed among the different Egyptian seismic codes and the international current well known seismic building codes namely the Eurocode [EC8:2003] and the international building code [IBC 2009] concerning the absolute values of the calculated base shear forces obtained by the considered seismic codes, in addition to great difference concerning the method of determining the

equivalent static base shear forces and the parameters constituting the presented equations.

The thesis presents a parametric study followed by an analytical study concerning nine residential moment-resisting frame reinforced concrete structure buildings (models), with a regular configuration and regular stiffness in plan and elevation. The buildings are assessed according to the regulations of the ECLF 2008. The chosen case studies represent the mid-rise up to the level of high-rise multistory building used in Egypt from the structural system, ductility requirements, occupancy and use aspect. Also, the models undergo the precautions recommended by the ECLF 1993 (the total height of the building does not exceed 100m. and also does not exceed five times the dimension in the direction of the earthquake excitation) , so that the equivalent static method of analysis could be applicable. The considered models are being split into 3 groups as three heights are considered governing the range of mid-rise up to high-rise multi storey buildings (45m, 60m, 90m). The three groups are divided into three categories, each category is concerned with a specified factor  $K$  (geometrical aspect ratio) which is the ratio between the total height of the building ( $H$ ) to the dimension ( $b$ ) in the direction of excitation ( $K=3, 4, 5$ ). The study undergoes the implementation for the equivalent static method for determining the equivalent static base shear value according to the six seismic building codes under consideration. In order to obtain a reasonable and realistic comparison, common conditions are presented, such as the same type of soil, the same type of foundation, and the same ductility considered (D.C.M). The Peak Ground Acceleration PGA considered is 0.3g. is Then the three dimensional dynamic response spectrum method of analysis is applied to obtain the actual dynamic base shear values by using the SAP200 software program for structural analysis. Then the

analytical study is presented through the regression analysis by using the (IBM SPSS V.20) software program.

The current study presents more consistent equations for the determination of the fundamental natural time period concerning the mid-rise up to high rise regular MRF RC buildings. The study gives the allowance for the implementation of the equivalent static method of analysis for heights exceeding the height limitation presented in the EC8:2003, the ECLF 2008 and the Euro code EC8:2003. The study also presents new seismic factors such as  $K_D$  which governs the relationships among the absolute actual dynamic base shear forces in the different seismic codes presented in addition to the factor  $R_0$  that represents the relationship between the equivalent static base shear forces and their corresponding actual dynamic base shear forces in each seismic code presented. Finally the thesis presents a more consistent and economic base shear values in comparison to the current seismic codes considered.

## **ACKNOWLEDGEMENT**

First and foremost I would like to thank ALAH for giving me the will and the patience to complete this work. I hope it could be useful for researchers practice in the future.

I want to express my sincere appreciation and gratitude to Prof. Dr. Amin Saleh Aly, Professor of Structures, Structural Engineering Department, Faculty of Engineering, Ain Shams University, for his continued support, guidance, assistance and encouragement throughout this research and for his careful review of the manuscript and his helpful comments throughout every step in the work. Also, I would like to express my deep gratitude and sincere thanks to Prof. Dr, Essam El Kordy Dean of Faculty of Engineering, Alexandria University, for his guidance, support, helpful comments and valuable discussions that enriched this research.

Special thanks and regards go to my husband Eng.Ashraf Kandil, for his kind patience, and all kinds of unlimited support. Besides, I would like to express my sincere love and thanks for my three little kids for their love, forgiveness and support.

Finally, I am very appreciative of the love from my parents for their never-ending encouragement, support, and their kind words that helped me overcoming the rough times. Special regards to my father Prof. Dr.Saeed Khalifa, Professor of community medicine, faculty of medicine, Zagazig University, I hope I am worth of his appreciation



## CONTENTS

STATEMENT .....	iv
ABSTRACT .....	v
ACKNOWLEDGEMENT .....	viii
CONTENTS .....	ix
LIST OF FIGURE .....	xii
LIST OF TABLES .....	xviii
Chapter (1) Introduction .....	1
1.1 General .....	2
1.2 Objectives Of The Thesis .....	4
1.3 Methodology And Approach .....	4
1.4 Layout of The Thesis .....	6
Chapter (2) Literature Review .....	7
2-1 General .....	8
2-2 Historical Development Of International Seismic Building Codes .....	10
2-2-1 The SEAOC .....	10
2-2-2 Revision of the (SEAOC) .....	11
2-2-3 UBC 85 Provisions .....	13
2-2-4 BOCA-87 And ANSI-82 Provisions .....	18
2-2-5 SEAOC and UBC-88 Provisions .....	21
2-2-6 (NEHRP-85) And (ATC 3-06) Provisions .....	25
2-2-7 UBC 1997 Earthquake Design .....	28
2-2-8 IBC 2009 Provisions .....	32
2-2-8-1 Design Ground Motion .....	33
2-2-8-2 Design Response Spectrum .....	35
2-2-8-3 Seismic Use Groups .....	36
2-2-8-4 Seismic Design Category .....	37
2-2-8-5 Methods of Structural Analysis .....	37
2-2-8-6 Dynamic Analyses Procedure .....	42
2-2-9 Eurocode EC8:2003 .....	43
2-2-9.1 Ground Conditions .....	44
2-2-9.2 Seismic Action .....	45
2-2-9.3 Seismic Zones .....	45
2-2-9.4 Horizontal Design Response Spectrum for Elastic Analysis .....	45
2-2-9.5 Vertical Design Response Spectrum for Elastic Analysis .....	48
2-2-9.6 Design ground displacement .....	48
2-2-9.7 Methods of Structural Analysis .....	48
2-3 Seismic Codes in Egypt .....	52
2-3-1 General .....	52
2-3-2 Regulations of the Egyptian Society For Earthquake Engineering (ESEE 1988) .....	52

2-3-3	Egyptian Code for Loads and Forces (ECLF 1993)	61
i.	Soil Conditions	61
ii	Seismic Action	61
iii	Methods of Structural Analysis	62
2-3-4	Egyptian Code For Loads And Forces (ECLF 2003)	65
i	Soil Conditions	65
ii	Seismic Action	66
iii	Methods of Structural Analysis	73
2-3-5	Egyptian Code for Loads and Forces ECLF 2008 (Draft Edition)	79
2-5	Observations Regarding the Seismic Provisions Development	84
	Review	84
Chapter 3		87
Comparative study		87
3-1	General	87
3-2	Design Objectives	87
3-3	The Force Reduction Factor (R)	88
3-4	Relative Seismicity (Zone Factor)	90
3-5	Soil Amplification Factor (S)	92
3-6	Fundamental Natural Period	99
3-7	Building Regularity	100
3-7.1	Regularity In Plan	101
3-7.2	Plan Configuration	103
3-7.3	Regularity In Elevation	104
3-7.4	Stiffness Regularity	107
3-7.5	Mass Regularity	110
3-7.6	Strength Regularity	111
3-7.7	Torsional Regularity	112
3-8	The Equivalent Static Force Method	114
3-8.1	General	114
3-8.2	The Total Horizontal Seismic Force (Base Shear)	115
3-8.3	Distribution Of Base Shear Force	116
3-8.2	Torsional Effects	120
3-9	Damage Limitations	121
3-10	Solved Examples	127
Chapter 4	Response Evaluation	151
4-1	General	151
4-2	Conceptual Framework	151
4-3	Structural Modelling	152
4-4	Mass Modelling	157
4-5	Dynamic Analysis Software	162
4-6	Evaluation Procedure of the Seismic Response of Structures	162

4-7	Response Spectrum Method of Analysis (RSPM).....	164
Chapter 5	Analytical study.....	188
5-1	General.....	188
5-2	Analytic Observation On Base Shear Values .....	189
5-3	Observations on the Fundamental Natural Time Period of Buildings .....	193
5-3-1	The Effect of Total Height of Building (H) on The Fundamental Natural Time Period (T) of Building.....	196
5-3-2	The Effect of the Geometric Aspect Ratio $K=H/b$ on the Fundamental Natural Period (T) of Structure.....	198
5-3-3	The Effect of the Mass of Floor on The Fundamental Natural Time Period (T) .....	200
5-4	Analytical Observations Related to the 30 Stories Buildings .....	201
5-4-1	The Relationship Between the Static and the Dynamic Base Shear Values for The (30 Stories) group of Buildings .....	204
5-5	Analytical Observations Related to the (20-Stories) group Buildings .....	206
5-5-1	The Relationship Between the Static and the Dynamic Base Shear Values For The (20-Stories) buildings .....	208
5-6	Observation Related to the (15-Stories) Building (Mid-Rise) Building.....	209
5-6-1	The relationship between the static and dynamic base shear values for the (15-stories) buildings .....	211
5-7	Observations on the dynamic base shear values (comparative study) .....	212
5-8	A Modified Procedure For The Equivalent Static Method Of Analysis:- .....	214
	Example 1 :- .....	215
	Consider the equivalent static method of analysis according to The Egyptian Code for Calculating Loads & Forces .....	215
	Example 2 :- .....	218
	Consider the equivalent static method of analysis according to The Egyptian Code for Calculating Loads & Forces .....	218
Chapter 6	Conclusions and Recommendations .....	222
6-1	General .....	222
6-2	Results.....	223
6-2-1	The Base Shear Forces.....	223
6-2-2	The Fundamental Natural Time Period.....	225
6-3	Conclusions.....	226
6-4	Recommendations For The Future Work.....	227
REFERENCES	.....	253

## LIST OF FIGURE

Figure (2-1)	Design Response Spectrum, IBC 2009	35
Figure (2-2)	Deterministic Limit on Maximum Considered Earthquake MCE Response Spectrum, IBC 2009	36
Figure (2-3)	Seismic Activity Zoning Map for Egypt, ESEE 1988	56
Figure (2-4)	Coefficient of Standardized Response Spectrum C for Average Damping of 5%, ESEE 1988	60
Figure (2-5)	Seismic Activity Zoning Map for Egypt, ECLF 1993	63
Figure (2-6)	Seismic Activity Zoning Map for Egypt, ECLF 2003	68
Figure (2-7)	Shape of the Horizontal Elastic Response Spectrum, ECLF 2003	70
Figure (2-8)	Criteria for Regularity of Buildings with Setbacks, ECLF2003	76
Figure (3-1)	Comparison of Codes Soil Modified Elastic Response Spectra	96
Figure (3-2)	Comparison of Codes Soil Modified Elastic Response Spectra	96
Figure (3-3)	Comparison of Codes Soil Modified Elastic Response Spectra	97
Figure (3-4)	Comparison of Codes Soil Modified Elastic Response Spectra	97
Figure (3-5)	Plan Configuration Parameters	104
Figure (3-6)	Elevation Configuration Parameters	108
Figure (3-7)	Torsional regularity parameters	115
Figure (3-8)	Model 8 (15-4), $H=4b=45\text{m}$ , $b=11.25\text{m}$	129
Figure (3-9)	Model 5 (60-4) $H=4b=60\text{m}$ , $b=15\text{m}$	140

Figure (4-1)	(30 Stories) Moment Resisting Frame Structure Building	153
Figure (4-2)	(20 Stories) Moment Resisting Frame Structure Building	154
Figure (4-3)	(15 Stories) Moment Resisting Frame Structure Building	155
Figure (4-4)	(A) shapes of design response spectrum curve used in the analysis	166
Figure (4-5)	The equivalent static method values of base shear for considered seismic codes	169
Figure (4-6)	Comparison among static base shear values and dynamic base shear value according to seismic Egyptian regulation	169
Figure (4-7)	Eurocode 8 distribution of Force values Static / Dynamic	170
Figure (4-8)	IBC distribution of Force values Static / Dynamic	170
Figure (4-9)	The equivalent static method values of base shear for considered seismic codes	171
Figure (4-10)	Comparison among static base shear values and dynamic base shear value according to seismic Egyptian regulation	171
Figure (4-11)	Eurocode 8 distribution of Force values Static / Dynamic	172
Figure (4-12)	IBC distribution of Force values Static / Dynamic	172
Figure (4-13)	The equivalent static method values of base shear for considered seismic codes	173
Figure (4-14)	Comparison among static base shear values and	173

	dynamic base shear value according to seismic Egyptian regulation	
Figure (4-15)	Eurocode 8 distribution of Force values Static / Dynamic	174
Figure (4-16)	IBC distribution of Force values Static / Dynamic	174
Figure (4-17)	The equivalent static method values of base shear for considered seismic codes	175
Figure (4-18)	Comparison among static base shear values and dynamic base shear value according to seismic Egyptian regulation	175
Figure (4-19)	Eurocode 8 distribution of Force values Static / Dynamic	176
Figure (4-20)	IBC distribution of Force values Static / Dynamic	176
Figure (4-21)	The equivalent static method values of base shear for considered seismic codes	177
Figure (4-22)	Comparison among static base shear values and dynamic base shear value according to seismic Egyptian regulation	177
Figure (4-23)	Eurocode 8 distribution of Force values Static / Dynamic	178
Figure (4-24)	IBC distribution of Force values Static / Dynamic	178
Figure (4-25)	The equivalent static method values of Force for considered seismic codes	179
Figure (4-26)	Comparison among static base shear values and dynamic base shear value according to seismic Egyptian regulation	179
Figure (4-27)	Eurocode 8 distribution of Force values Static / Dynamic	180

Figure (4-28)	IBC distribution of Force values Static / Dynamic	180
Figure (4-29)	The equivalent static method values of base shear for considered seismic codes	181
Figure (4-30)	Comparison among static base shear values and dynamic base shear value according to seismic Egyptian regulation	181
Figure (4-31)	Eurocode 8 distribution of Force values Static / Dynamic	182
Figure (4-32)	IBC distribution of Force values Static / Dynamic	182
Figure (4-33)	The equivalent static method values of base shear for considered seismic codes	183
Figure (4-34)	Comparison among static base shear values and dynamic base shear value according to seismic Egyptian regulation	183
Figure (4-35)	Eurocode 8 distribution of Force values Static / Dynamic	184
Figure (4-36)	IBC distribution of Force values Static / Dynamic	184
Figure (4-37)	The equivalent static method values of base shear for considered seismic codes	185
Figure (4-38)	Comparison among static base shear values and dynamic base shear value according to seismic Egyptian regulation	185
Figure (4-39)	Eurocode 8 distribution of Force values Static / Dynamic	186
Figure (4-40)	IBC distribution of Force values Static / Dynamic	186
Figure (5-1)	The Three Different Heights of Buildings Under Consideration	188