Ain Shams University
Faculty of Science
Geophysics Department

SEISMIC HAZARD STUDY FOR THE NORTH WESTERN PART OF EGYPT

A Thesis
Submitted for the Doctor of Philosophy of Science
Applied Geophysics

By

Mohamed Abdelhay Ezzelarab Abozaid

Assistant Researcher at National Research Institute of Astronomy and Geophysics (NRIAG), Helwan, Egypt

Supervised By

Prof. Dr. Abd Elnasser Helal
Professor of Geophysics, Geophysics Department, Faculty of Science, Ain Shams University.

Prof. Dr. Abouelela Amin Mohamed
Professor of Seismology and Vice-president of National Research Institute of Astronomy and Geophysics (NRIAG).

Prof. Dr. Adel Mohamed Elshahat
Professor of seismology, Seismology Department, National Research Institute of Astronomy and Geophysics (NRIAG).

Asso. Prof. Mohammed Shokry Farag
Associate Professor of Geophysics, Geophysics Department, Faculty of Science, Ain Shams University.

2016

ACKNOWLEDGEMENTS

First and foremost, I express my honest gratitude to almighty Allah, who granted me believe and patience to carry out this research.

A great dept goes to Prof. Abd El-Nasser Helal (Geophysics Department, Faculty of Science, Ain Shams University) for his supervision, support and guidance throughout this study. I would like to express my sincere gratitude for my supervisor Prof. Abouela Amin Mohamed (Seismology department, National Research Institute of Astronomy and Geophysics, NRIAG) for choosing the point of research, support in the field, and his continuous encouragement. My gratefulness extends to Prof. Dr. Adel Elshahat (Seismology department, NRIAG) for helping choosing too the point of research. I do appreciate his valuable guidance, encouragement, constructive criticism, great discussions. My sincere thanks go to ass. Prof .Dr. Mohamed Shokry (Geophysics Department, Faculty of Science, Ain Shams University) for his great efforts, reviewing the manuscript and helping me in this work.

My gratefulness extends to Prof. Dr. Ahmed Deif for giving helpful comments and advises for seismic hazard calculation. Also, the author would like to thank RNDR. Jan šílený, (Geophysical Institute, Czech. Acad. Sci., Prague) for his hosting and helping me to learn the principals of moment tensor inversion. My deep

thanks to Prof. Dr. Jiří Zahradník, University of Charles, for his helping, great discussions and providing me with the code of moment tensor inversion.

I wish also to thank the missions sector in the ministry of higher education and scientific research for funding my research accommodation in Czech. Many thanks to all the staff of the seismology Department at National Research Institute of Astronomy and Geophysics, I owe them a lot. I want to thank all the Department of Geophysics, Faculty of science, Ain Shams University. I'd like to thank Earthquake Monitoring Center in Sultan Qaboos University for using their facilities and truthful help.

I dedicate this dissertation to my parents, my brothers ,and my sister and would like to express my deepest appreciation and thanks to all of them for their continuous support in all my life, their love and devotion kept me going and I am extremely grateful to them for their encouragement and support.

Finally, I would like to express my heartfelt thanks to my wife for her patience, fortitude and understanding. I thank my children, Jody and Retal, for everything they did (make me busy when I want to get rest), but after all you are the best thing in my life.

Mohamed A.Ezzelarab

2016

TABLE OF CONTENTS

Subject	Page
ACKNOWLEDGMENTS ……..	I
TABLE OF CONTENTS…….....	III
LIST OF FIGURES …….....	VI
LIST OF TABLES…...……	XIV
ABSTRACT …….	XV
INTRODUCTION	
1. Overview……..…….....	1
2. Objective and Methods……. ……	2
3. Thesis Outlines……..…….	3
4. Previous Studies at the northwestern part of Egypt……...	3
CHAPTER ONE: GEOLOGICAL CHARACTERISTICS OF THE STUDY AREA	
1.1 Geology and Tectonic Outline of Egypt…….....	6
1.2 Geological Characteristics of the Study Area……..……	9
1.3 Tectonic Framework of the study area…….	11
CHAPTER TWO: THE SEISMICITY OF THE STUDY AREA	
2.1 Introduction……....……	14
2.2: Earthquake catalogue…….....	14
2.2.1: The Paleo-seismological data …….....	15
2.2.2: Historical earthquake catalogue ……	15
2.2.3: Instrumental Earthquake catalogue ……	16
2.2.4 Determination of the magnitude of completeness…….	22
2.3 Brief Description of the Seismicity …….....	23

CHAPTER THREE: IDENTIFICATION OF SEISMIC SOURCES

3.1 Introduction ……... 28

3.2 Previous Seismotectonic Models…….……..... 28

3.3 Moment tensor inversion for the recent earthquakes..……. 31

3.3.1 Moment tensors inversion of the 19th October, 2012 earthquake..... 34

3.3.2. Moment tensor Inversion of the 17th January, 2013 earthquake…… 40

3.3.3 Moment tensor inversion of the 31st August, 2013 earthquake……... 42

3.4. The proposed Seismotectonic Model…….. 44

CHAPTER FOUR: SEISMIC HAZARD ASSESSMENT

4.1 Introduction……....…….. 47

4.2 Methods of Seismic Hazard Assessment……..... 47

4.3 Probabilistic Seismic Hazard Assessment……..... 48

4.3.1: The Mathematical Framework of the Classic PSHA Procedure…….. 51

4.3.2. Uncertainties in PSHA…….. 50

4.3.3 Steps of PSHA……... 51

4.3.3.1 Identification of the seismic sources…… 53

4.3.3.2 The Specification of the magnitude distribution and the activity rate…… 54

4.3.3.3 Ground-Motion Predication Equations (GMPEs) ……. 59

4.3.4 Logic Tree……..…….. 62

4.3.5 PSHA Calculations and Results ……..……. 63

4.4 De-aggregation of PSHA results……...…… 89

4.5 Deterministic seismic hazard analysis…… 94
4.5.1 Methodology ……..... 94
4.5.2 Calculation and Results……..……... 95
4.6 Discussion……..... 104
CHAPTER FIVE: SITE EFFECT ESTIMATION AT BORG EL-ARAB CITY
5.1 Introduction……..……... 106
5.2 Fundamental Resonance Frequency based on Microtremor Measurements.……..... 107
5.2.1 Methodology ……. 109
5.2.2 Field Measurements ……..…..…….. 111
5.2.3 Data processing ……. 115
5.2.4 Results ……..…… 118
5.3 Generation of Compatible Time Histories …….. 123
5.3.1 Approaches to spectrum matching…….. 124
5.3.2 Selection and matching of the initial ground motion records…… 124
5.3.3 Site Response Analysis ……. 130
5.3.3.1 Input data …… 130
5.3.3.2 Results ……..……... 131
5.4 Conclusions……. 134
CHAPTER SIX: SUMMARY AND CONCLUSION 135
References...... 142
Arabic Summary ……. 162

LIST OF FIGURES

Figure	Figure Caption	Page
1	Location of the study area……	1
1.1	Sketch of the structural aspects of the Nubian Arabian shield margin in Egypt. (after Said, 1990)…….	6
1.2	Basement structure map of Egypt (Meshref, 1990, after Abdel-Fattah et al., 2014)……...	7
1.3	Surface tectonic elements in Egypt (after EGSMA, 1981)……...	8
1.4	The geological map of the northwestern part of Egypt (after EGSMA, 1981)…….	10
1.5	Western Desert Basins developed at different rates and different times (after Schlumberger, 1995)……	11
1.6	Tectonic setting in and around the northwestern part of Egypt (Compiled from McClusky et al., 2000; Suleiman and Doser 1995 and EGSMA, 1981)…….	13
2.1	Locations of the collected historical earthquakes……	16
2.2	Magnitude dependent space and time windows used for removal of aftershocks (dependents events). The asterisks below the window lines are taken to be dependent events.	20
2.3	Spatial distribution of the declustered instrumental catalogue……	21
2.4	Magnitude-time plot for the declustered instrumental	21

	catalogue ……...……	
2.5	Cumulative number of earthquakes versus time to show the period of completeness for different magnitude range.	22
3.1	Seismotectonic model of Egypt and its surrounding proposed by Abou Elenean (2010)……..……..	30
3.2	Seismotectonic model of Egypt proposed by El-Hadidy (2012)……...……..	31
3.3	Representation of moment tensor solutions for different faults, (modified after Kikuchi and Kanamori, 1991)……	33
3.4	Location of the 19th of October 2012 earthquake and the seismic station around it (Upper Panel) and the SNR for velocity record at NKL station (Lower Panel)……...	35
3.5	Crustal model used in the moment tensor inversion of 19th October 2012 earthquake……..……...	36
3.6	Horizontal grid points around the 19th of October, 2012 earthquake……...	34
3.7	Plotting of the Correlation vs. source depth for 19th of October, 2012 earthquake in vertical grid search. …….	38
3.8	Source mechanism for 19th of October, 2012 earthquake..	40
3.9	Source mechanism of 17th of January, 2013 earthquake ...	42
3.10	Location and mechanism of 31st of August, 2013 earthquake……..	43
3.11	Visualization the correlation vs. depth for 31st of August, 2013 earthquake…….	44

3.12	The proposed seismotectonic model for studying the seismic hazard at the north western part of Egypt……..	46
4.1	Steps of probabilistic seismic hazard analysis for a given site……..	52
4.2	Logic tree used in PSHA at the northwestern Egypt (bold numbers are the weights)……...	63
4.3	Grid points for calculating PSHA……..…...	64
4.3	Seismic hazard curves for PGA at rock sites in Alexandria City…….	67
4.4	Seismic hazard curve for PGA at rock site in Borg El-Arab City……	67
4.5	Seismic hazard curve for PGA at rock site in Mersa Matruh City……	67
4.6	Example of UH spectrum construction. In the left panel the exceedance curves computed through a PSHA analysis at 8 vibration periods are displayed, as well as their intersection with a line corresponding to the selected rate of exceedance (0.1, that corresponds to an exceedance probability of 10% in the next 50 yr. and thus to a return period of 475 yr.). In the right panel the resulting UH spectrum is shown……..…….	68
4.7	Uniform hazard spectra for rock site in Alexandria city.	69
4.8	Uniform hazard spectra for rock site in Borg El-Arab city.	69
4.9	Uniform hazard spectra for rock site in Mersa Matruh	70

city…….

4.10 Mean peak ground acceleration (cm/sec^2) on the rock sites, with 50% probability of exceedance in 50 year (72 years return period) …….. 71

4.11 Mean peak ground acceleration (cm/sec^2) on the rock sites, with 10% probability of exceedance in 50 year (475 years return period…… 72

4.12 Mean peak ground acceleration (cm/sec^2) on the rock sites, with 2% probability of exceedance in 50 year (2475 years return period……. 73

4.13 Mean spectral acceleration for 0.1 sec spectral period (cm/sec^2) on rock site with 50% probabilit y of being exceeded in 50 years (72 years return period)…… 74

4.14 Mean spectral acceleration for 0.1 sec spectral period (cm/sec^2) on rock site with 10% probabilit y of being exceeded in 50 years (475years return period)……... 75

4.15 Mean spectral acceleration for 0.1 sec spectral period (cm/sec^2) on rock site with 2% probability of being exceeded in 50 years (2475 years return period)…… 76

4.16 Mean spectral acceleration for 0.2 sec spectral period (cm/sec^2) on rock site with 50% probability of being exceeded in 50 years (72 yeas return period)……. 77

4.17 Mean spectral acceleration for 0.2 sec spectral period (cm/sec^2) on rock site with 10% probability of being exceeded in 50 years (475 yeas return period)……... 78

4.18 Mean spectral acceleration for 0.2 sec spectral period (cm/sec^2) on rock site with 2% probability of being exceeded in 50 years (2475 yeas return period)……. 79

4.19 Mean spectral acceleration for 0.3 sec spectral period (cm/sec^2) on rock site with 50% probability of being exceeded in 50 years (72 yeas return period)……. 79

4.20 Mean spectral acceleration for 0.3 sec spectralperiod (cm/sec^2) on rock site with 10% probabilit y of being exceeded in 50 years (475 yeas return period)……... 81

4.21 Mean spectral acceleration for 0.3 sec spectral period (cm/sec^2) on rock site with 2% probability of being exceeded in 50 years (2475yeas return period)…… 82

4.22 Mean spectral acceleration for 1 sec spectralperiod (cm/sec^2) on rock site with 50% probabilit y of being exceeded in 50 years (72 years return period)…… 82

4.23 Mean spectral acceleration for 1 sec spectralperiod (cm/sec^2) on rock site with 10% probabilit y of being exceeded in 50 years (2745) years return period)…… 84

4.24 Mean spectral acceleration for 1.0 sec spectralperiod (cm/sec^2) on rock site with 2% probability of being exceeded in 50 years (2475 years return period)…… 85

4.25 Mean spectral acceleration for 2 sec spectralperiod (cm/sec^2) on rock site with 50% probabilit y of being exceeded in 50 years (72 yeas return period)……. 86

4.26 Mean spectral acceleration for 2 sec spectralperiod (cm/sec^2) on rock site with 10% probabilit y of being exceeded in 50 years (475 years return period)……. 87

4.27 Mean spectral acceleration for 2 sec spectralperiod (cm/sec^2) on rock site with 2% probabilit y of being exceeded in 50 years (2475 yeas return period)……. 88

4.28 De-aggregation results showing the relative contribution to the peak ground acceleration (upper panel) and spectral accelerations of 3.0 s (lower panel) as a function of magnitude and distance at rock site in Alexandria City for return period of 475 years. 90

4.29 De-aggregation results showing the relative contribution to the peak ground acceleration (Upper Panel) and spectral accelerations of 3.0 s (Lower Panel) as a function of magnitude and distance at rock site in Borg El-Alarab City for return period of 475 years……. 92

4.30 Deaggregation results showing the relative contribution to the peak ground acceleration (Upper Panel) and spectral accelerations of 3.0 s (Lower Panel) as a function of magnitude and distance at rock site in Mersa Matruh City for return period of 475 years……... 93

4.31 Mean (Upper Panel) and 84th (Lower Panel) peak ground acceleration (cm/sec^2) calculated using the deterministic seismic hazard approach…… 97

4.32 Mean (Upper Panel) and 84th (Lower Panel) damped 5% SA (cm/sec^2) at 0.1 sec calculated using the deterministic

seismic hazard approach…….. 98

4.33 Mean (Upper Panel) and 84th (Lower Panel) damped 5% SA (cm/sec^2) at 0.2 sec calculated using the deterministic seismic hazard approach……. 99

4.34 Mean (Upper Panel) and 84th (Lower Panel) damped 5% SA (cm/sec^2) at 0.3 sec calculated using the deterministic seismic hazard approach……. 100

4.35 Mean (Upper Panel) and 84th (Lower Panel) damped 5% SA (cm/sec^2) at 0.75 sec calculated using the deterministic seismic hazard approach……. 101

4.36 Mean (Upper Panel) and 84th (Lower Panel) damped 5% SA (cm/sec^2) at 1.0 sec calculated using the deterministic seismic hazard approach…….. 102

4.37 Mean (Upper Panel) and 84th (Lower Panel) damped 5% SA (cm/sec^2) at 2.0 sec calculated using the deterministic seismic hazard approach…….. 103

5.1 Geographic Locations of Borg EL-Arab city (up) and the sited of microtremors surveys (black dots) with the location of borehole for site response analysis (star) in the city (down)…….. 110

5.2 Panel *a* demonstrates the amplitude spectrum of three components at site-31, Panel *b* illustrates the H/V spectral ratio curve, Panel *c* shows the Damping test for the peak amplitude at frequency 1.15 (Hz) (left side) is of industrial origin and at frequency 6.37 (Hz) (right side) 118