

شبكة المعلومات الجامعية التوثيق الإلكتروني والميكروفيلو

بسم الله الرحمن الرحيم





HANAA ALY



شبكة المعلومات الجامعية التوثيق الإلكتروني والميكرونيله



شبكة المعلومات الجامعية التوثيق الالكتروني والميكروفيلم



HANAA ALY



شبكة المعلومات الجامعية التوثيق الإلكترونى والميكروفيلم

جامعة عين شمس التوثيق الإلكتروني والميكروفيلم قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها على هذه الأقراص المدمجة قد أعدت دون أية تغيرات



يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار



HANAA ALY



AIN SHAMS UNIVERSITY FACULTY OF ENGINEERING STRUCTURAL ENGINEERING DEPARTMENT

Effect of Foundation Soil Flexibility on The Dynamic Behavior of Multi-Story Concrete Buildings

A thesis submitted in partial fulfillment of the requirements of the degree of

Doctor of Philosophy

in Civil Engineering (Structural)

by

Sherif Gamal Abdel Hamid Abdel Hadi

Master of Science in Civil Engineering (Structural) Faculty of Engineering, Ain Shams University, 2018

Supervised by

Dr. Mohamed Nour El-din Fayed

Professor Structural Engineering Department Ain Shams University

Dr. Reham Eltahawy

Assistant professor Structural Engineering Department Ain Shams University

Cairo - (2022)



AIN SHAMS UNIVERSITY FACULTY OF ENGINEERING STRUCTURAL ENGINEERING DEPARTMENT

Effect of Foundation Soil Flexibility on The Dynamic Behavior of Multi-Story Concrete Buildings

A thesis presented by

Sherif Gamal Abdel Hamid Abdel Hadi

A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy in Structural Engineering

Examiners' Committee:	<u>Signature</u>
Prof. Dr. Nabil Ahmed Fouad	N. Fauad
Professor of Reinforced Concrete Structures	
Faculty of Engineering – Hannover University	
Prof. Dr. Mohamed Ahmed Abdel Motaal	
1101. Dr. Wonamed Annied Abdei Wotaai	•••••
Professor, Department of Geotechnical Engineering -Ain Shams University	ering Faculty of
Prof. Dr. Mohamed Nour El-din Fayed	••••••
Professor, Department of Structural Engineering	g Faculty of
Engineering -Ain Shams University	

Date: 22 January 2022



AIN SHAMS UNIVERSITY FACULTY OF ENGINEERING STRUCTURAL ENGINEERING DEPARTMENT

Effect of Foundation Soil Flexibility on The Dynamic Behavior of Multi-Story Concrete Buildings

A thesis presented by

Sherif Gamal Abdel Hamid Abdel Hadi

A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy in Structural Engineering

Supervision Committee:

Prof. Dr. Mohamed Nour El-din Fayed

Professor, Department of Structural Engineering Faculty of Engineering -Ain Shams University

Dr. Reham Eltahawy

Assistant Professor, Department of Structural Engineering Faculty of Engineering – Ain Shams University

Date: 22 January 2022

Postgraduate Studies
Authorization Stamp: The thesis is authorized at

STATEMENT

This thesis is submitted in partial fulfilment of the requirements for the

degree of Doctor of Philosophy in Structural Engineering, Faculty of

Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has

been submitted for a degree or a qualification at any other scientific entity.

Date:

/ / 2022

Name: Sherif Gamal Abdel Hamid Abdel Hadi

Signature: Sherif Gamal

RESEARCHER DATA

Name : Sherif Gamal Abdel Hamid Abdel Hadi

Date of birth : 01 June 1991

Place of birth : Cairo, Egypt

Last academic degree : Master of Science

Field of specialization : Structural Engineering

University : Ain Shams University

Date of issued degree : March 2018

Current job : Structural Engineer at ENPPI

<u>ACKNOWLEDGMENTS</u>

I would like to offer my deepest gratitude to my precious supervisor **Prof. Dr. Mohamed Nour El-din Fayed**, for his kind supervision, valuable advice, endless cooperation, helpful instruction, support, revising the thesis, and concern about my progress.

My heartfelt appreciation, and gratitude to **Dr. Reham Eltahawy**, for her trust, belief, cooperation, and continuous support throughout the stages of this research.

I am deeply thankful to my wife, Eng. Rasha Attia Ahmed, for her unequivocal support, endless care, her trust in me and unconditional love for which my mere expression of gratitude does not suffice. She was the one who first believed I should go this path; this work is the outcome of her encouragement.

Sherif Gamal Abdel Hamid Abdel Hadi

Dedication

I dedicate this thesis to my father, my mother, my brother for raising me on the value of insistence and determination, setting an example of whom I would be so proud to be, sacrificing their comfort to provide the perfect atmosphere for me and praying for me to accomplish success in my life.

I would also like to acknowledge my daughter **Lily**, for only her presence in our life is such a blessing from god. Her innocent smiles motivated me towards overcoming the exhaustion due to the long days of work.

Sherif Gamal Abdel Hamid Abdel Hadi

TABLE OF CONTENTS

LIS	ST OF FIGURES	I
LIS	ST OF TABLES	X
Cha	apter 1: INTRODUCTION	- 4 -
1.1	GENERAL	- 4 -
1.3	RESEARCH OBJECTIVES	- 7 -
1.4	RESEARCH METHODOLOGY	- 8 -
1.5	CONTRIBUTION TO SCIENCE	- 8 -
1.6	THESIS OUTLINE	. 9 -
Cha	apter 2: LITERATURE REVIEW	12
2.1	INTRODUCTION	12
2.2	DYNAMIC BEHAVIOR OF SOIL	12
2.3	FREE FIELD GROUND MOTION	16
2.4 FO	MODELLING TECHNIQUES TO SIMULATE SOIL- UNDATION-STRUCTURE INTERACTION (SFSI)	21
	2.4.1 Beam-on-Elastic Foundation Methods (Winkler methods) 2.4.2 Elastic Continuum Methods	22 23
	SOIL STRUCTURE INTERACTION UNDER SEISMIC FECT (NUMERICAL STUDIES)	25
	SOIL STRUCTURE INTERACTION UNDER SEISMIC FECT (EXPERIMENTAL STUDIES)	64
	2.6.1 Model the soil in shaking table tests	
2.7	SEISMIC PERFORMANCE ANALYSIS	
2.8	BUILDING CODES CONCERNING SEISMIC SOIL- RUCTURE INTERACTION	

	2.8.1 American Society of Civil Engineers (ASCE 7-16)	
	2.8.3 ASCE/SEI 41-17	
	2.8.4 Eurocode	
	2.8.5 ECP-201 (2012)	
	apter 3: SEISMITY IN EGYPT, CODE REQUIREMENTS AND SPOSE REDUCTION FACTOR DEFINITION	ND
3.1	INTRODUCTION	83
3.2	SEISMISTY IN EGYPT	83
	3.2.1 Regional Tectonics	83
	3.2.2 Egyptian National Seismic Network (ENSN)	87
	3.2.3 Seismicity of Egypt	
	3.2.4 Seismic Hazard Maps	89
3.3	E-Q GROUND MOTION AND PERFORMANCE CRITER	IA .93
	3.3.1 E-Q Ground Motion	93
	3.3.2 Performance Criteria	94
3.4	E-Q GROUND MOTION AND PERFORMANCE CRITER	IA .95
	3.4.1 E-Q Ground Motion	95
3.5	CODE REQUIREMENTS	97
	3.5.1 Base Shear and Design Response Spectra in International C 97	odes
3.6	RESPONSE REDUCTION FACTOR	106
	3.6.1 Over Strength Factor	107
	3.6.2 Ductility Factor	
	3.6.3 Damping Factor	108
	3.6.4 Redundancy Factor	108
	RESPONSE REDUCTION/MODIFICATION FACTOR (R)	
EC.	P AND OTHER BUILDING CODES	
	3.7.1 ECP (Egyptian Code of Practice 2012)	
	3.7.2 ASCE (American Society of Civil Engineers)	
	3.7.3 Eurocode	110
3.8	METHODS OF ANALYSIS	112
	3.8.1 Non-Linear Static Pushover Analysis	112

	3.8.2 Non-Linear Time History Analysis	115
	apter 4: FINITE ELEMENT MODELLING & CALIBRATION FTWARE MODELS	
4.1	INTRODUCTION	119
4.2	FINITE ELEMENT SOFTWARE	120
	4.2.1 ABAQUS Elements	
	4.2.2 Solid Elements	
	4.2.3 Properties of Beam Structural Elements	
	4.2.4 Soil Elements	
	4.2.5 Interface Elements	
	4.2.7 Element Size	
	4.2.7 Diement Size	177
4.3	EXPERIMENTAL AND ANALYTICAL DATA	150
	4.3.1 Calibration Model-1 (S. Z. Korkmaz, 2010):	150
	4.3.2 Calibration Model-2 (Ch. G. Karayannis et al., 2005):	
	4.3.3 Calibration Model-3 (Behzad Fatahi, 2012):	161
	4.3.4 Calibration Model-4 (Behzad Fatahi, 2012):	167
4.4	COMMENTS	174
Cha PE	COMMENTSapter 5: EVALUATION OF SEISMIC CAPACTIY RFORMACE FOR RC MULTI STORY BUILDINGS NSIDERING SSI	
Cha PE CO	apter 5: EVALUATION OF SEISMIC CAPACTIY RFORMACE FOR RC MULTI STORY BUILDINGS NSIDERING SSI	
Cha PEI CO 5.1	apter 5: EVALUATION OF SEISMIC CAPACTIY RFORMACE FOR RC MULTI STORY BUILDINGS NSIDERING SSI	76 - 76 -
Cha PEI CO 5.1	apter 5: EVALUATION OF SEISMIC CAPACTIY RFORMACE FOR RC MULTI STORY BUILDINGS ONSIDERING SSI	76 - 76 - ES
Cha PE CO 5.1 5.2	apter 5: EVALUATION OF SEISMIC CAPACTIY RFORMACE FOR RC MULTI STORY BUILDINGS INSIDERING SSI 1 INTRODUCTION 1 NON-LINEAR NUMERICAL MODEL FOR RC STRUCTUR - 177 1 5.2.1 Element Model 1	76 - 76 - ES 77 - 77 -
Cha PE CO 5.1 5.2	apter 5: EVALUATION OF SEISMIC CAPACTIY RFORMACE FOR RC MULTI STORY BUILDINGS ONSIDERING SSI	76 - 76 - ES 77 - 77 - 85 - d 89 -

	5.3.4 The 4 th phase (Seismic capacity performance of multi-story buildings considering irregularity in elevation):	196 -
5.4	RESULTS AND DISCUSSION FOR THE 1ST PHASE	197 -
	5.4.1 Pushover results for multi-story buildings considering fixed in modelling: -5.4.2 Time history results: -5.4.2 Time history re	197 -
5.5	RESULTS AND DISCUSSION FOR THE 2 ND PHASE	207 -
5.6	RESULTS AND DISCUSSION FOR THE 3 RD PHASE	221 -
5.7	RESULTS AND DISCUSSION FOR THE 4 TH PHASE	234 -
Cha	apter 6: CONCLUSIONS	237 -
6.1	SUMMARY	237 -
6.2	CONCLUSIONS	238 -
	6.2.1 Modelling approach using ABAQUS program 6.2.2 Seismic capacity performance of multi-story buildings considering fixed base in modelling 6.2.3 Amplification factor for different types of soil considering different peak absolute accelerations 6.2.4 Seismic capacity performance of multi-story buildings considering SSI with different soil types (B, C & D) in modelling	238 - 239 -
	6.2.5 Irregularity	241 -
6.3	RECOMMENDATIONS	242 -
RE	FERENCES	244 -
Ap	pendix- A: R CALCULATION DETAILS	259 -
Apj	pendix- B: DIFFERENT SOILS PROPERTIES	265 -
Ap	pendix- C: ETABS MODELS	273 -
	pendix- D: ABAQUS MATERIAL MODELLING & UNDATION-SOIL INTERACTION DEFINITION	280 -
	pendix- E: EFFECT OF CHANGING SOIL ANGLE OF ICTION ON SEISMIC RESPONSE OF RC STRUCTURES	291 -

Appendix- F: FFECT OF INCREASING EQ GROUND MOTION	
DURATION ON SIMULATION ANALYSIS 297	7 -