



**EFFECT OF NONLINEAR BEHAVIOR OF RC COUPLING
BEAMS ON THE SEISMIC RESPONSE OF
COUPLED SHEAR WALLS SYSTEM**

By

Omar Magdy Mohamed Badr Nofal

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
STRUCTURAL ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2017



**EFFECT OF NONLINEAR BEHAVIOR OF RC COUPLING
BEAMS ON THE SEISMIC RESPONSE OF
COUPLED SHEAR WALLS SYSTEM**

By

Omar Magdy Mohamed Badr Nofal

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
STRUCTURAL ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2017

**EFFECT OF NONLINEAR BEHAVIOR OF RC COUPLING
BEAMS ON THE SEISMIC RESPONSE OF
COUPLED SHEAR WALLS SYSTEM**

By

Omar Magdy Mohamed Badr Nofal

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
STRUCTURAL ENGINEERING

Under the supervision of

Prof. Dr. Adel Y. Akl

Professor of Structure Engineering
Structural Engineering Department
Faculty of Engineering, Cairo University

Dr. Mostafa ElSayed

Assistant Professor of Structure Engineering
Structural Engineering Department
Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2017

**EFFECT OF NONLINEAR BEHAVIOR OF RC COUPLING
BEAMS ON THE SEISMIC RESPONSE OF
COUPLED SHEAR WALLS SYSTEM**

By

Omar Magdy Mohamed Badr Nofal

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
STRUCTURAL ENGINEERING

Approved by the Examining Committee

Prof. Dr. Adel Y. Akl

Thesis Main Advisor

Prof. Dr. Waleed Attia

Internal Examiner

Prof. Dr. Osman Shaalan

External Examiner

Professor of Structure Engineering Zagazig University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2017

Engineer's Name: Omar Magdy Mohamed Badr Nofal
Date of Birth: 01/05/1991
Nationality: Egyptian
E-mail: engomarmagdy855@gmail.com
Phone: 01062948746
Address: Hadyek Helwan, Cairo
Registratio Date: 01/3 /2014
Awarding Date: / / 2017
Degree: Master of Science
Department: Structural Engineering
Supervisors:
Prof. Dr. Adel Y. Akl
Dr. Moustafa ElSayed



Examiners:
Prof. Dr. Adel Y. Akl – Cairo University (main advisor)
Prof. Dr. Waleed Attia – Cairo University (Internal Examiner)
Prof. Dr. Osman Shaalan – Zagazig University (External Examiner)

Thesis Title:
**Effect of Nonlinear Behavior of RC Coupling Beams on The
Seismic Response of Coupled Shear Walls System**

Key Words:
Shearwalls - Coupling beams - Pushover - Nonlinear analysis - Finite element analysis

Summary:

Reinforced concrete coupled shear walls is considered one of the most remarkable research topic within the last decades. It is globally introduced as an efficient lateral load resisting system which enhances the behavior of the overall structure subjected to lateral loads. Such system is widely used in the zones, which are expected to be exposed to severe seismic hazards. The coupled shear walls enable two walls or more than two to act as one wall with a certain efficiency, depending on how much coupling is going to be provided by what is known as the coupling beam. Coupling beams are going to be provided at each floor to connect the walls and constrain their behavior. Those beams are going to limit the axial deformation in each wall in terms of tension in the windward wall and compression in the leeward wall. Such action is going to induce internal couple due to the existing of the coupling beam. Finally, the overall behavior of the walls is going to be improved by the added beams in terms of energy dissipation, wall rotation, inter-story drift, peak roof drift, base shear and deflection profile. In this research, an extensive parametric had been undertaken to investigate the effect of the nonlinear behavior of the coupling beams on the coupled shear walls response in terms of system capacity to resist lateral load, roof drift, load-displacement relationship, crack pattern and the induced coupling ratio.

Acknowledgments

First of all, I would like to thank my main supervisor Prof. Mohamed Naiem for his continuous support throughout my master study, patience, immense knowledge, motivation, and enthusiasm. His guidance assisted me a lot while getting my way in this research.

Special thanks to Prof. Adel Y. Akl for his support and standing as a father in the hard times.

Besides my main supervisor, I would like to thank Dr. Mostafa Abd El Wahab, my second advisor, who helped me with all possible ways (Data, Papers, References and advices) to complete my master thesis. He is always planning the research, solving problems and guiding me throughout my master.

I would like to thank my family for their support and encouraging me to do my best until finishing my master thesis.

Special thanks to my beloved wife for her support, patience and helping me to complete my thesis and keep helping me until my defense day.

Table of Contents

Acknowledgment.....	i
Table of Content.....	ii
List of Tables	v
List of Figures.....	vii
Nomenclature.....	xv
Abstract.....	xvi
CHAPTER 1: INTRODUCTION.....	1
1.1 GENERAL	1
1.2 PROBLEM STATEMENT.....	2
1.3 RESEARCH OBJECTIVES	2
1.4 RESEARCH SCOPE AND METHODOLOGY	3
1.5 THESIS OUTLINE.....	4
CHAPTER 2: LITERATURE REVIEW	6
2.1 INTRODUCTION	6
2.2 LATERAL LOAD RESISTING SYSTEMS	7
2.2.1 Innovative Techniques.....	7
2.3 SEISMIC ANALYSIS METHODS.....	8
2.3.1 Linear Static Procedure	8
2.3.2 Linear Dynamic Procedure.....	9
2.3.3 Nonlinear Static Procedure	9
2.3.4 Nonlinear Dynamic Procedure.....	10
2.7 THE COUPLING BEAM EFFECT ON A SYSTEM OF WALLS	10
2.8 THE COUPLING BEAM PREVIOUS RESEARCH PROVISION	11

CHAPTER 3: MODELING AND EXPERIMENTAL VERIFICATION.....	14
3.1 INTRODUCTION	14
3.2 METHOD OF ANALYSIS	15
3.3 EXPERIMENTAL VERIFICATION	15
3.3.1 Experimental Data of Tested Coupling Beams	16
3.3.2 Experimental Test Configuration	17
3.3.3 Numerical Modeling of the Coupling Beam	18
3.3.4 Numerical Results	22
3.4 CONCLUSION	28
CHAPTER 4: RESEARCH METHODOLOGY	29
4.1 INTRODUCTION	29
4.2 COUPLED SHEAR WALLS ANALYSIS AND DESIGN	30
4.2.1 ETABS 2016 Findings	30
4.2.2 The Design Force	31
4.2.4 Concrete and Steel Properties	34
4.3 NON-LINEAR ANALYSIS OF THE COUPLED SHEAR WALLS	35
4.3.1 Modeling on VecTor2	35
4.3.2 The Evaluation Criteria	40
4.3.2 Results from VecTor2	41
CHAPTER 5: RESULTS DISCUSSION	119
5.1 INTRODUCTION	119
5.2 THE EFFECT OF INCREASE THE COUPLING BEAM DEPTH:	119
5.2.1 Effect of Depth on The Induced Internal Forces	119
5.2.2 Effect of Depth on The Ultimate Roof Drift Δ_r	121
5.2.3 Effect of Depth on Coupled Shear Wall Load-Disp. History	122
5.2.4 Effect of Depth on Coupling Beam Crack Pattern	123
5.2.5 Effect of Depth on the coupling ratio CR	128
5.3 THE EFFECT OF INCREASE THE COUPLING BEAM DIAGONAL RFT:	129
5.3.1 Effect of Diagonal RFT on The Induced Internal Forces	129
5.3.2 Effect of Diagonal RFT on The Ultimate Roof Drift Δ_r	131
5.3.3 Effect of Diagonal RFT on Coupled Shear Wall Load-Disp. History	132

5.3.4 Effect of Diagonal RFT on Coupling Beam Crack Pattern	134
5.3.5 Effect of Diagonal RFT on the coupling ratio CR	140
5.4 THE EFFECT OF INCREASE THE COUPLING BEAM WIDTH:	141
5.4.1 Effect of Width on The Induced Internal Forces.....	141
5.4.2 Effect of Width on The Ultimate Roof Drift Δ_r	143
5.4.3 Effect of Width on Coupled Shear Wall Load-Disp. History	144
5.4.4 Effect of Width on Coupling Beam Crack Pattern	145
5.4.5 Effect of Width on the coupling ratio CR.....	149
5.5 THE EFFECT OF INCREASE THE COUPLING BEAM FLEXURE TOP AND BOTTOM RFT	150
5.5.1 Effect of Flexure RFT on The Induced Internal Forces	150
5.5.2 Effect of Flexure RFT on The Ultimate Roof Drift Δ_r	152
5.5.3 Effect of Flexure RFT on Coupled Shear Wall Load-Disp. History.....	153
5.5.4 Effect of Flexure RFT on Coupling Beam Crack Pattern	154
5.5.5 Effect of Flexure RFT on the coupling ratio CR	159
5.6 THE EFFECT OF INCREASE THE COUPLING BEAM SHEAR RFT STIRRUPS:.....	159
5.6.1 Effect of Shear RFT on The Induced Internal Forces	160
5.6.2 Effect of Shear RFT on The Ultimate Roof Drift Δ_r	161
5.6.3 Effect of Shear RFT on Coupled Shear Wall Load-Disp. History	162
5.6.4 Effect of Shear RFT on Coupling Beam Crack Pattern	164
5.6.5 Effect of Shear RFT on the coupling ratio CR	169
CHAPTER 6: SUMMARY AND CONCLUSION.....	170
6.1 SUMMARY	170
6.2 CONCLUSION	171
6.3 FUTURE WORK.....	173
REFERENCES.....	174