SEISMIC RESPONSE MODIFICATION FACTOR FOR REINFORCED CONCRETE SHEAR WALLS BASED ON NON-LINEAR PUSHOVER ANALYSIS AND TIME HISTORY ANALYSIS

By

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A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science in structural engineering

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2018

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STATEMENT

This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science 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.

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ACKNOWLEDGEMENT

I like to say that no words can express my gratitude, love and appreciation to my wife, my father, my brother and my mother, whose help and encouragement were the main motive for me to complete this work. Thank you for supporting me throughout my entire life, words fail to explain how grateful I am for having you as my family.

I would like to express my gratefulness to my supervisors, Dr. Marwan Shedid, Dr. Ezz El Deen Mostafa and Dr. Bahaa Sharf Tork. Thank you for your guidance, support and assistance throughout this research, I am indebted to all of you with the knowledge and experience I gained. It was an honour working under your supervision.

My greatest appreciation goes to all my instructors and colleagues at the Faculty of Engineering, Ain Shams University. Each and every one of you participated in the achievement I made, by teaching, supporting and encouraging me throughout different stages. Thank you.

Finally, I would like to dedicate this work to my wife. She was the one who first believed I should go this path; this work is the outcome of his encouragement.

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LIST OF ABBREVIATIONS AND SYMBOLS

- CM: Center of Mass
- CR: Center of Rigidity
- L_p is the plastic hinge length
- L_s is the distance between maximum and minimum moment of wall height
- D_b is the bar diameter
- L_w is the wall length
- A_r is the wall height to length ratio
- DBE: Displacement Based Element
- FBE: Force Based Element
- FE: Finite Element
- R: Response Reduction/Modification Factor
- RC: Reinforced Concrete
- RCM: Reinforced Concrete Masonry
- μ : Ductility Capacity
- $R\mu$: Ductility Factor
- Ω: Over-Strength Factor
- EQ : Earthquake
- V_e: Max elastic Base Shear
- V_d: Design Base Shear
- V_u: Maximum Base Shear
- $\Delta_{0.8u}$: Displacement At 20% Strength Degradation
- Δ_d: Design Displacement
- Δ_y: Yield Displacement
- F_{cu}: Concrete Compressive Strength
- f_y: Steel Yield Stress
- E_s: Steel Young's Modulus
- E_c: Concrete Young's Modulus
- LLRS: Lateral Load Resisting System

- Δ_{max}: Chosen Maximum Displacement Limit
- Δ_y: Yield Displacement
- f'_m: Masonry Prism Compressive Strength
- f_y: Steel Yield Stress
- f_u: Steel Ultimate Strength
- PGA: Peak Ground Acceleration

ABSTRACT

Earthquakes are one of the most common natural disasters, which affect both human life and property. To avoid negative effects of earthquake, the nonlinear response of structures under dynamic loading should be accurately modelled to investigate their actual behaviour under earthquake loading to ensure safe and sound design. To yield proper results, accurate representative structural models should be developed for the elements resisting lateral loading and representative ground motions pertaining to the site should be employed. Then relating such response to that of elastic behaviour should be conducted to correlate response modification factors in design codes with actual response. The main objective of the research is to study factors affecting response modification factor for reinforced concrete shear walls such as vertical reinforcement ratios, aspect ratios and levels of axial stress, and then comparing calculated response reduction/modification factors for reinforced concrete shear walls with those recommended in ECP and in international codes.

A total of 60 analytical models for RC shear walls structures analysis models using push over analysis and time history analysis. The models were chosen to test the effect of different parameters on the behaviour of the structure, namely, lateral load eccentricity, wall arrangement and presence of walls orthogonal to the loading direction. The software used in this study is Seismostruct 2016.

The research was carried out over three phases. The first was a review of previous literature related to the focus of the study. This was carried out in order to have a clear and broad understanding of the previous findings in this field.

During the second phase, a modelling technique for RCM/RC walls and buildings was developed and verified against the experimental results of seven individual walls and full structure available in literature. Some factors and recommendations regarding the modelling of RCM/RC walls under lateral loading using Seismostruct 2016 were extracted from this phase. It was found that the devised technique could be incorporated for the RC shear walls considered in the parametric study.

The results of the verification phase served as a basis for the last phase of the research during which a parametric study was generated in order to investigate the behaviour of the system level. The parameters tested were the aspect ratios, the levels of axial stress and the vertical reinforcement ratios.. Throughout this phase, it was found some results such as:

- The response reduction / modification factor (R) value is sensitive to the variation in vertical reinforcement ratio more than the variation in level of axial stress.
- By increasing the aspect ratio, the R-value decreases. As an example; from W1-3, W1-6 to W1-12, R decreases with ratios of 10.1 % and 9.4 % respectively.
- By increasing the aspect ratio, the V_u-value decreases. As an example; from W1-3, W1-6 to W1-12, V_u decreases with ratios of 46.3 % and 52.5 % respectively.
- By increasing the aspect ratio, the Δ0.8u-value increases. As an example; from W1-3, W1-6 to W1-12, Δ0.8u decreases with ratios of 170.9 % and 178.0 % respectively.
- Increasing the vertical reinforcement ratio leads to lower μ and then lower R-value.
- Increasing aspect ratio leads to lower μ, and then lower R-value.
- By increasing the vertical reinforcement ratio and the level of axial stress, the structural stiffness increases.
- The R-values recommended in design codes are almost matching with the calculated values for the R-factor.
- R-values calculated using non-linear time history is considered more accurate than those calculated using pushover analysis as they don't depend on any assumption as R-value calculated bases on pushover analysis, that the R_μ depends on the time period as suggested by New mark and Hall.