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Determining Hysteretic Parameter Model for RC Shear Wall

M. Sharifi*, M. A. Fathali, M. A. Ansaripour, A. R. Mohammad Amri

Department of Civil Engineering, University of Qom, Qom, Iran.

ABSTRACT: In seismic performance-based design, this is required to have comprehensive knowledge about the nonlinear behavior of components. In time history analysis which is the most power full tool for predicting the structural response, the hysteretic model of the plastic hinge is needed. Hysteretic models are defined with some parameters that show strength, stiffness, ductility, deterioration, degradations, and other characteristics such as reversal path. Hysteretic parameters can be adopted from different methods including experimental results, finite element analysis, and mechanical engineering relation. The main goal of this research is to determine and extracting the shear wall hysteretic parameter from the existing experimental test results. The hysteretic parameters have been extracted from 135 sample test data for the slender shear wall and 99 sample test data for the squat shear wall in this study. All experimental test data has been simulated in OpenSees software using the modified Ibarra-krawinkler models and their hysteretic parameters are extracted. Finally, some statistical analysis has been performed and the representative values of these statics are presented.

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1- Introduction

Reinforced concrete shear walls are used as one of the reliable structural elements to resist lateral loads in steel and concrete buildings. Shear walls are divided into two categories based on the aspect ratio of the wall geometry. Walls with a height to width ratio of greater than 1.5 (and sometimes one) are called slender shear walls and smaller than 1.5 are called squat shear walls [1]. Usually, shear behavior is observed in squat walls and flexural behavior in slender walls.

Nonlinear analysis is a more reliable tool for predicting the seismic response of structures especially those experience nonlinear zone, including plastic deformation, strength, and stiffness deterioration. The nonlinear behavior of structural components under cyclic loads is expressed using a "hysteretic curve". To properly evaluate and correctly estimate the performance of new and existing structures, in analytical models it is required to consider the important features of nonlinear behavior of structural components or hysteretic model. So far, many hysteretic models have been developed and introduced. There are lots of hysteretic models that are useful and common. Among that, Rahnama and Krawinkler present modifications to bilinear, peak-oriented, and pinching models [2]. This model eventually led to the introduction of the modified Ibarra-Krawinkler model [3, 4]. The proposed model is complete and has the capability of providing cyclic behavior and is therefore used in this study.

The main goal of this research is to determine and extracting the shear wall hysteretic parameter from the existing experimental test results. The hysteretic parameters have been extracted from 135 sample test data for the slender shear wall and 99 sample test data for the squat shear wall in this study. All experimental test data has been simulated in OpenSees software using the modified Ibarra-Krawinkler models and their hysteretic parameters are extracted [5]. Finally, some statistical analysis has been performed and the representative values of these statics are presented.

2- Analytical modeling of hysteretic model

The Ibarra-Krawinkler model is one most famous hysteretic models in which complete different behaviors of components are considered. This model consists of three well-known types of bilinear, peak-oriented, and pinching models based on basic cyclic behavior. These models take into account the effects of cyclic loading such as stiffness and strength deterioration, and the pinching phenomenon. In this study, the modified Ibarra-Krawinkler cyclic deterioration model was used to simulate the experimental test results

The experimental results were adopted from the "Seismic Engineering Research Infrastructures for European Synergies (SERIES)" database [6]. The data used in this study have complete information including force-displacement diagrams, wall geometry, failure mode, and other required information. In this study, OpenSees software was used for the analytical modeling of shear walls. The inelastic behavior of the shear walls is modeled in a concentrated hinge and according to Magna and Kunnath [7]; so that each wall contains an elastic element and a zero-length plastic hinge at its ends. According

*Corresponding author's email: m.sharifi@qom.ac.ir

to the pattern of the experimental hysteretic model, for the squat and slender shear walls, the pinching and peak-oriented behavioral models of the modified Ibarra-Krawinkler cyclic model are selected to the concentrated hinge of the wall, respectively. The analytical model requires seven parameters (yield bending moment (M_y), yield rotation (θ_y), strain hardening stiffness (K_s), cap rotation (θ_c), post-capping stiffness (K_c), cyclic deterioration parameter (λ), and rate of deterioration (c)) for generating the hysteretic behavior. These parameters are extracted by simulating experimental existing test results. The purpose of the calibration of experimental data is to determine the stiffness, peak point, unloading stiffness, cyclic strength deterioration, and cyclic stiffness degradation of slender and squat reinforced concrete shear walls for use in simulating and modeling reinforced concrete structural systems. Due to a large number of specimens, each experimental specimen was calibrated based on the backbone curve and engineering judgment, and according to the procedure proposed by Haselton *et al.* [8].

3- Analytical modeling results and their calibration

For each specimen, the experimental results are simulated with appropriate estimates of the cyclic parameters. Fig. 1 shows an example of these simulations.

The extracted cyclic behavior parameters are the following: effective initial stiffness, yield point rotation (θ_y), plastic rotation capacity (θ_p), post-capping plastic rotation capacity (θ_{pc}), strain hardening ratio (M_c/M_y), ductility ratio (θ_c/θ_y), basic strength deterioration parameter (λ_s), post-capping strength deterioration parameter (λ_c), unloading stiffness deterioration parameter (λ_k), accelerated reloading stiffness deterioration parameter (λ_a). Shear wall design parameters are shear wall aspect ratio, axial load ratio, compressive strength of wall shear concrete (f_c), yield strength of wall reinforcement bars, longitudinal and transverse reinforcement ratio of the web, longitudinal and transverse reinforcement ratio of boundary element.

In addition, for describing the result, some scatter diagrams have been prepared. For example, Fig. 2 shows the scatter diagrams for ductility ratio (θ_c/θ_y) versus to compressive strength of concrete for slender shear walls.

Minor statistical analyses have been performed and some representative values are calculated. The obtained ranges for cyclic behavior parameters of the shear walls are reported in Table 1.

4- Conclusions

According to the calibration of the extracted cyclic parameters of the slender and squat shear walls, in summary, the following results can be stated:

For calibration, based on experimental cyclic behavior patterns, it is better to use the pinching model for squat shear walls and the peak-oriented model for slender shear walls; because experimental results show that squat walls have pinching behavior and slender shear walls often have peak-oriented behavior.

The results of the calibration show that the different values of λ_k and λ_a for the squat shear walls do not make much difference in the results and can be considered equal to the strength deterioration values. It is suggested that the unit value be considered for these cycle deterioration parameters. Also, in squat shear walls, given the limited data and no residual

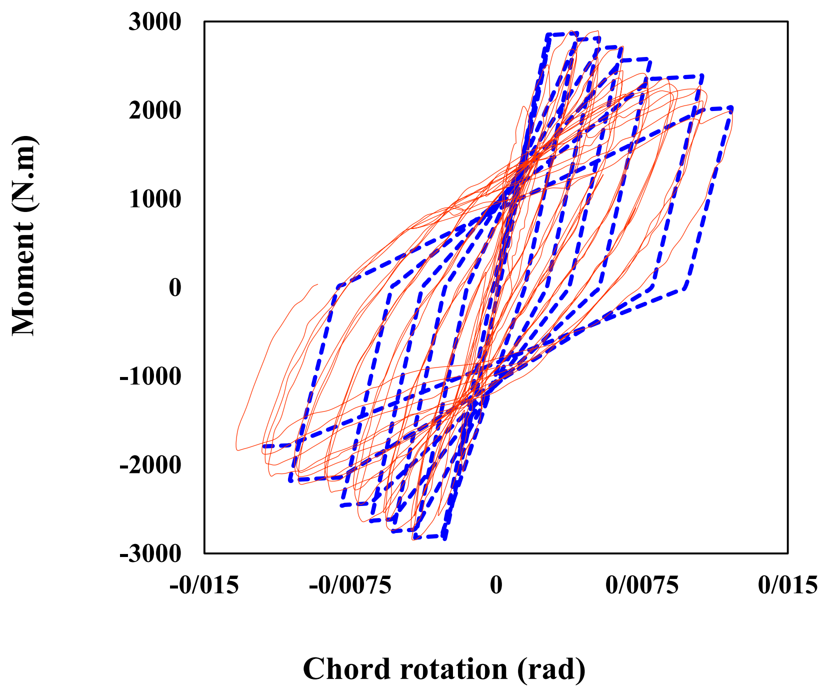

Fig. 1. Calibrations of cyclic test of Salonikios-LSW5 test.

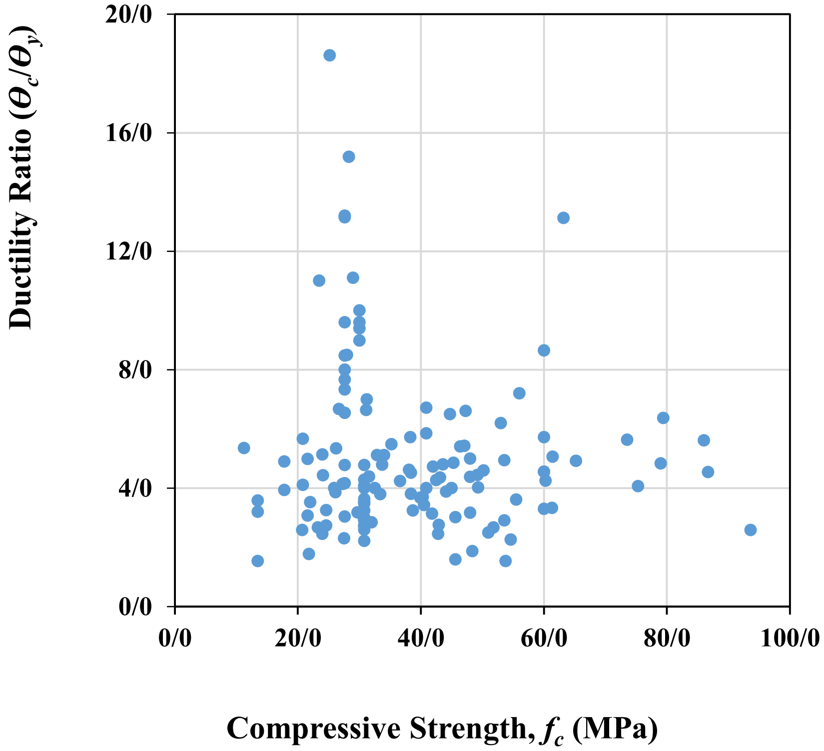

Fig. 2. Scatter diagram of ductility ratio versus fc for the slender shear wall.

Table 1. The obtained ranges for cyclic behavior parameters of the slender and squat shear walls.

Parameter	Slender shear wall	Squat shear wall
θ_y (rad)	0.0025 - 00.75	0.0015 - 0.0020
θ_p (rad)	0.010 - 0.015	0.0055 - 0.0085
θ_{pc} (rad)	-	0.0015 - 0.0024
M_c/M_y	1.00 - 1.75	1.10 - 1.35
θ_c/θ_y	2.50 - 7.50	-
λ_s	0.25 - 0.75	0.230 - 0.305
λ_c	0.15 - 0.55	0.20 - 0.32
λ_a	0.95 - 1.00	1.0
λ_k	0.25 - 0.55	1.0

resistance observed in the cyclic curve of experimental data, it is recommended that the residual resistance parameter is conservatively set to zero or close to zero.

Parameter λ_a has a small effect on the hysteresis response of the slender shear wall and the value of this parameter can be considered the unit value in modeling the slender shear walls.

Among the slender shear wall design parameters, axial load ratio, longitudinal and transverse reinforcement ratio of the web of the shear wall, and transverse reinforcement ratio of boundary element affect mostly the values of cyclic behavior parameters.

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