Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 52(6) (2020) 383-386
DOI: 10.22060/ceej.2019.15456.5925

Effects of Freedom Degrees on Behavior Factor in Reinforced Concrete Moment-Resisting Frames with Steel Plate Shear Wall

S. R. Salimbahrami, M. Gholhaki*

Department name, Semnan University, Semnan, Iran

ABSTRACT: The influence of the strength reduction factor due to nonlinear behavior (Rμ) on the lateral strength of Single-Degree-Of-Freedom (SDOF) structures causes to limit the displacement ductility demand to the predetermined maximum tolerable ductility. In addition, Rμ is used for determining the behavior factor in Multi-Degree-Of-Freedom (MDOF) structures. Following this, in this paper, Rμ and the inelastic displacement ratio (CR) for equivalent SDOF systems under strike-parallel (NF-SP) and strike-normal (NF-SN) components of near-field ground motion, and also far-field (FF) ground motion were assessed. Furthermore, CR obtained by this study was compared with C1 proposed by FEMA440. The deflection amplification factor-to-behavior factor ratio (Cd/Ru) for different ductility levels was computed. After evaluating the nonlinear effects of SDOF structures based on Rμ factors, these factors for MDOF structure were modified considering higher mode effects, and a simplified practical expression was proposed to estimate the base shear modification factor. The results indicated that Rμ, corresponds to near and far-field ground motions can be different. In addition, CR does not depend on the type of earthquake, and it converges to 1 by increasing the period of vibration. In addition, the modification factor can be increased with period and ductility demand.

Review History:

Received: 2018-12-16
Revised: 2019-02-03
Accepted: 2019-02-04
Available Online: 2019-02-06

Keywords:

Behavior factor
Modification Factor
SDOF Structure
MDOF
Base Shear

1. INTRODUCTION

Most buildings are designed for a base shear smaller than the elastic base shear associated with strong ground motion, expecting them to deform beyond elastic behavior. Therefore, seismic codes allow reduction in design forces produced by nonlinear behavior, accounted for in force-based earthquake resistant design, through the use of strength reduction factors. These factors depend on several parameters which the ductility level of structure is the most important. So far, most relationships for strength reduction factors have been presented for structures subjected to far-field ground motion records [1-3]. Several studies have been conducted to understand the behavior of strength reduction factors in SDOF systems, but only a few have studied strength reduction factors in MDOF systems or the required modification to the results available from SDOF to be applicable to MDOF structures [1-6]. Since real structures have several degrees of freedom and various modes, such as transitional displacements and torsional, the strength reduction factor for an SDOF system should be modified for MDOF structural systems by a modification factor.

In seismic codes, the proposed response modification factor for lateral load-resisting systems is obtained from experimental studies. Also, theoretical relationships can be used. Following this, the strength reduction factor due to nonlinear behavior (R_μ) can strongly affect the response modification factor of the structure. It is worth noting that the parameters such as number of nonlinear members, damping, type of nonlinear model, site conditions, period of vibration and also soil parameters such as soil natural period, focal depth and earthquake magnitude can affect the response modification factor[2, 3, 7-11].

Furthermore, the response modification factor demand depends on the type of earthquake record. To avoid illogical responses, the average method is used. Following this, the response modification factor demand for SDOF systems under near and far-field earthquakes is different which this matter less considered by researchers. The forward-directivity has a remarkable effect on near-fault ground motions. As per researches performed on forward-directivity effect, there are two components for earthquakes. One is strike-normal and the other is strike-parallel. In this paper, these components are called as SN and SP, respectively. In addition, the normal component of the displacement has a more destructive effect compared with the parallel component. Therefore, in this paper, the modification that should be applied to strength reduction factors derived from simplified SDOF models to account for MDOF structures in near and far-field ground motions has been evaluated. Also, since Rμ depends on nonlinear time-history analysis results and also type of earthquake record, it was determined for far and near-field ground motions. To consider the effect of type of earthquake on Rμ, a comparison between far and near-field ground

*Corresponding author's email: mgholhaki@semnan.ac.ir

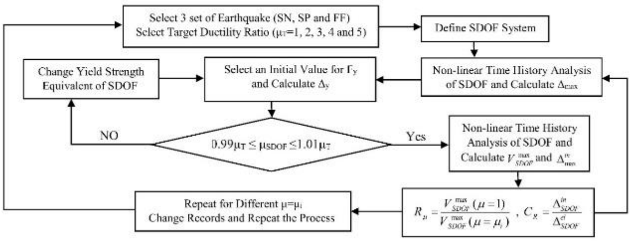

Fig. 1. Overall process of calculation of a) R_μ and C_R factors b) $\alpha_{v\text{-}MDOF}$

motions for reinforced concrete frames with steel plate shear wall has been conducted. Furthermore, to evaluate higher mode effects and MDOF, the base shear modification factor has been calculated, and an equation with effective variables has been proposed.

2. RESEARCH METHODOLOGY

Since the main objective of this study was to assess the strength reduction factor due to nonlinear behavior (R_μ) and also inelastic displacement ratio (C_R) of reinforced concrete moment-resisting frames with steel plate shear wall under far and near-field ground motions. The assumptions are presented for determining these factors.

The elastic period of vibration for the finite element models was considered in the range of 0.98-2.89 Sec; because, the period of most structures (low-, medium- and high-rise buildings) is in this range. Meanwhile, the frames have been designed for five levels of target ductility (1, 2, 3, 4, and 5), where the value of one specifies that the structure has an elastic behavior. All of the frames were modeled as the SDOF system. In this structure, the unit mass was selected and the stiffness of the element was adjusted to provide the desired period. In addition, to model the SDOF system in OpenSees software, a zero-length element was selected. Furthermore, to define the post-yield stiffness, a gradient of 3% (α=3%) for the strain-hardening region was used. For all models, the inherent structural damping ratio was assumed equal to 5%. To solve the nonlinear time history equation, the Newmark-Beta method was selected. In Fig. 1, the overall process of calculation of R_μ and C_R factors is shown.

3. CONCLUSIONS

Since the strength reduction factor due to nonlinear behavior (R_μ) and also the inelastic displacement ratio (C_R) are used for determining the response modification factor of MDOF structures and, also the required target displacement for performance-based seismic design, in this paper, the effects of NF-SN, NF-SP and FF ground motions on R_μ and C_R have been investigated. Also, C_R obtained from this study was compared with C_1 proposed by FAMA440. Furthermore, the modification factor for R_μ of MDOF systems was evaluated considering the fundamental period (first mode). Finally, the effects of higher modes and MDOF on the base shear modification factor (α_{v-MDOF}) and the behavior modification factor ($1/\alpha_{v\text{-}MDOF}$) were assessed. The following conclusions can be drawn from this investigation:

1- By increasing the period of vibration, R_μ is constantly increased for NF-SN and NF-SP ground motions. This factor in FF ground motion is decreased up to a specific value and after that is increased. In low-rise buildings, R_μ, corresponds to FF ground motion, is greater than NF ground motions. Furthermore, the maximum amount of R_μ in high-rise building was determined for NF-SP ground motion. Therefore, the most effect of FF and NF-SP earthquakes is related to low and high-rise buildings, respectively.

2- For the structures with a short period, and subjected to near-field ground motions, R_μ does not depend on the ductility demand (μ). Also, for small values of ductility, by increasing T, R_μ converges to μ. It is called the equal displacement rule.

3- The use of R_μ, corresponding to FF ground motion may lead to a conservative value for NF ground motion. In addition, R_μ related to NF ground motion is lower than FF ground motion. For T>1.59 Sec, R_μ, corresponds to NF-SP ground motion is higher than FF ground motion. Following this, the use of R_μ, corresponds to FF ground motion may lead to a conservative value for NF-SP ground motion.

4- By increasing T, C_R converges to 1. In addition, in low-rise buildings, C_R depends on μ and T, severely.

5- C_R(SN)-to-C_R(FF) ratio is increased by increasing μ. By considering the fact that this ratio is greater than 1, the use of C_R(FF) is nonconservative in comparison with C_R(SN). For T<1.59 Sec, C_R(SP)-to-C_R(FF) ratio corresponding to ductility levels is greater than 1. Meanwhile, for T>1.59 Sec, this ratio is decreased and converges to lower than 1, by increasing μ.

6- Base on the comparison of C_R with C_1 proposed by FEMA440, the use of C_1 for near-field earthquakes and low-rise building, is conservative. Furthermore, C_R, corresponds to NF-SN ground motion, and for T<1.59 Sec, is greater than 1.4 times compared with C_1. In addition, C_R(SN)-to-C_1 ratio is increased by increasing μ. Meanwhile, for NF-SN ground motion, this ratio is greater than 1 and also C_R(SP)-to-C_1 ratio is less than 1. Therefore, the use of C_1 proposed by FEMA440 is conservative for NF ground motions.

REFERENCES

[1] N.M. Newmark, W.J. Hall, Procedures and criteria for earthquake-resistant design, in: Selected Papers By Nathan M. Newmark: Civil Engineering Classics, ASCE, 1973, pp. 829-872.

[2] A.A. Nassar, H. Krawinkler, Seismic Demand for SDOF and MDOF Systems, in, Stanford University, Stanford, 1991.

[3] E. Miranda, Site-dependent strength-reduction factors, Journal of Structural Engineering, 119 (1993) 3503-3519.

[4] G. Seneviratna, H. Krawinkler, Evaluation of Inelastic MDOF Effects for Seismic Design, in, Stanford, California, 1997.

[5] A. FEMA, 440, Improvement of nonlinear static seismic analysis procedures, FEMA-440, Redwood City, (2005).

[6] I.S. Code, Iranian code of practice for seismic resistant design of buildings 2800 (2014), (2014).

[7] R.S. Jalali, M.D. Trifunac, STRENGTH-REDUCTION FACTORS FOR STRUCTURES SUBJECTED TO NEAR-SOURCE DIFFERENTIAL STRONG GROUND MOTIONS, ISET JOURNAL OF EARTHQUAKE TECHNOLOGY, 285.

[8] M. Izadinia, M.A. Rahgozar, O. Mohammadrezaei, Response modification factor for steel moment-resisting frames by different pushover analysis methods, Journal of Constructional Steel Research, 79 (2012) 83-90.

[9] A.K. Chopra, C. Chintanapakdee, Inelastic deformation ratios for design and evaluation of structures: single-degree-of-freedom bilinear systems, Journal of structural engineering, 130 (2004)

1309-1319.

[10] J. Ruiz-García, E. Miranda, Inelastic displacement ratios for evaluation of existing structures, Earthquake Engineering & Structural Dynamics, 32 (2003) 1237-1258.

[11] S.M. Parsaeian, H. Hashemi, A.R. Sarvghad Moghadam, Inelastic Displacement Ratios for Structures on Firm Soil Sites Subjected to Iran Earthquakes Records, Modares Civil Engineering journal, 12 (2013) 11-25.

HOW TO CITE THIS ARTICLE

S.R. Salimbahrami, M. Gholhaki, Effects of Freedom Degrees on Behavior Factor in Reinforced Concrete Moment-Resisting Frames with Steel Plate Shear Wall, Amirkabir J. Civil Eng., 52(6) (2020) 383-386.

DOI: 10.22060/ceej.2019.15456.5925