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EXTENDED ABSTRACT

Inelastic Displacement Ratio for Degrading SDOF Systems under the Effect of Pulse-like and Non-pulse-like Near-Fault Ground motions

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1. Introduction

For the seismic evaluation of structures, it is required to determine the inelastic displacement ratio. Indeed, the inelastic displacement ratio is one of the most important coefficients in codes which is used in force-based design method as well as in performance-based seismic engineering (Miranda, 2000a, b). This study attempts to evaluate the inelastic displacement ratio, (C_{μ}), for single-degree-of-freedom (SDOF) systems that is defined as follows:

$$C_{\mu} = \frac{\Delta_{inelastic}}{\Delta_{elastic}} = \frac{u_m}{u_o} \quad (1)$$

Where u_m is the peak lateral inelastic displacement demand, and u_0 is the peak lateral elastic displacement (Chopra, 2012). Several studies focused on the effect of near-fault records with forward-directivity effect on C_{μ} (Chopra & Chintanapakdee, 2001; Lu, 2012; Li et al., 2017). On the other hand, there is no research investigation to take into account the effect of fling step and non-pulse-like near-fault records. Therefore, determining the inelastic displacement ratio under the effect of these records is of great importance. The present paper aims to study the inelastic displacement ratio using far-fault and pulse-like and non-pulse-like near-fault ground motions.

2. Methodology

Single-degree-of-freedom (SDOF) systems subjected to 78 near- and far-field ground motions recorded on site classes C and D (according to NEHRP 2003) were evaluated. Near-field ground motions include records with fling step, forward directivity and non-pulse characteristics. The influence of the period of vibration of the system, pulse period, ductility level and damping ratio were also studied. Moreover, in order to investigate the effects of cyclic deterioration, the bilinear hysteretic behavior using the modified Ibarra-Medina-Krawinkler (IMK) deterioration model was used in the OpenSees software environment.

3. Results and discussion

The results indicate that C_{μ} is strongly influenced by the vibration period, ductility level, and cyclic deterioration, while the effect of damping ratio can be neglected. Similar to previous studies, the dependency of the inelastic displacement ratio on the period of the system and the level of ductility is confirmed. In addition,

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a comprehensive study was done to evaluate the C_μ ratios in the case of far-fault and pulse-like and non-pulse-like near-fault ground motion records. Finally, equations for different types of ground motion records were proposed as follows:

$$C_\mu = \left[\frac{\mu}{\left[1 + (\mu - 1)(\theta_1 + \theta_2) e^{\left(\frac{1}{\mu}\right)} \left(1 + e^{-\theta_1 \left(\frac{1}{T - 0.02}\right)^{0.6}} + (\mu - 1)\theta_2 T^{0.4} - e^{-\theta_3 T^{0.8}} + \theta_4 T^2 e^{-\theta_5 T^{0.75}}\right) \right]} \right] \tag{2}$$

which θ_i is a fitting constant, dependent on the ductility and the constant values of $P_{1,i}$, P_{2i} and $P_{3,i}$. Also, θ_i is calculated according to the following formula. For instance, for the fling step records, the coefficients $P_{1,i}$, P_{2i} and $P_{3,i}$ can be derived from Table 1.

$$\theta_{i=1,2,3,4,5} = P_{1,i}\mu^2 + P_{2,i}\mu + P_{3,i} \tag{3}$$

Fig. 1 shows the inelastic displacement ratio, C_μ, based on regression analysis and the results derived from the time history analysis for the ductility level of μ=4 for different types of ground motions. As shown in the figure, the proposed equation is in good agreement with those resulting from the time history analyses. Also, the results indicate that the existing equations for calculating C_μ based on far-fault ground motions cannot be directly applied to pulse-type near-fault earthquake records, especially for near-fault ground motions with fling step effect that it makes the design unsafe

Table 1. Fitting constants for fling step records

Fling step	$P_{1,i}$	$P_{2,i}$	$P_{3,i}$
$i = 1$	0.01824	-0.03708	0.10867
$i = 2$	0.00942	-0.12693	0.48729
$i = 3$	0.00010	-0.00375	-0.01270
$i = 4$	-0.07201	0.40097	-0.36652
$i = 5$	0.12058	-0.78475	1.72192

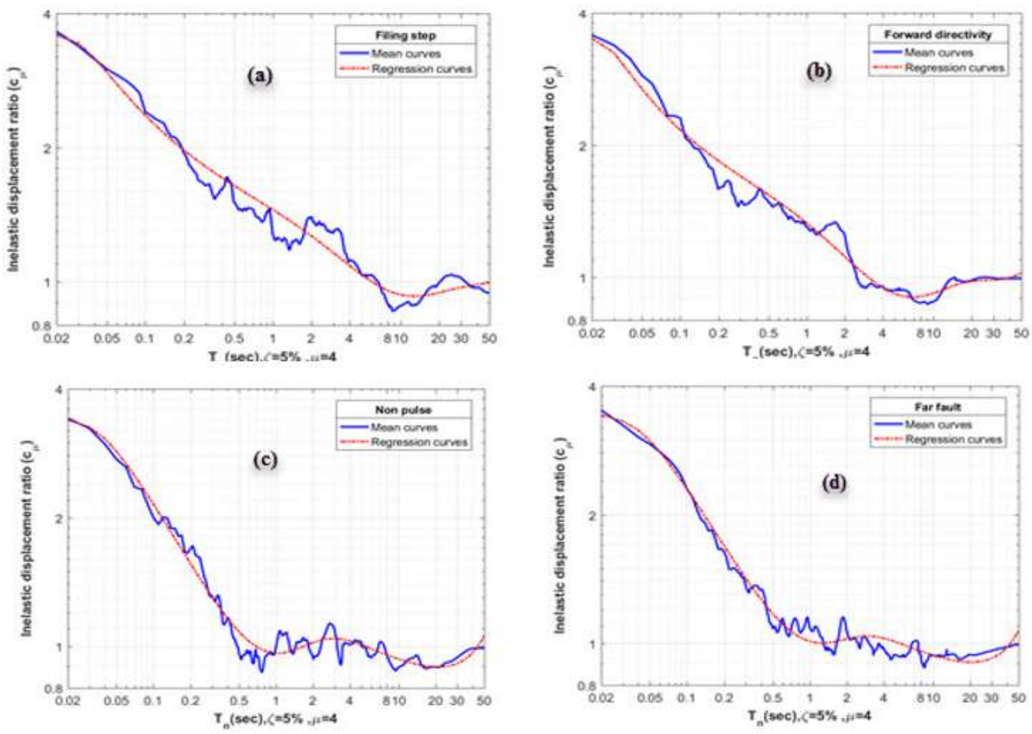

Fig. 1. Inelastic displacement ratio obtained from the time history analysis and regression analysis for μ=4 under the effect of different types of ground motions: a) Fling step, b) Forward directivity, c) Non pulse, d) Far-fault records

4. Conclusions

The inelastic displacement ratio was exhaustively studied in this research investigation by using far-fault, and pulse-like and non-pulse-like near-fault ground motion records. The results show that the equation proposed by FEMA 440 underestimates the inelastic displacement ratio for near-fault records especially for fling step characteristics. Also, records with a larger pulse period lead to larger inelastic displacement ratio. The increase in the strength and stiffness deterioration increases the inelastic displacement ratio. Finally, equations were proposed for the inelastic displacement ratio in terms of the period of the system and the level of ductility by means of the nonlinear regression analysis for different types of ground motion records. The results indicate that the proposed equations predict accurately the inelastic displacement ratio.

5. References

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