EFFECTS OF PULSE-LIKE GROUND MOTIONS PARAMETERS ON MAXIMUM INTER-STORY DRIFT SPECTRA

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ABSTRACT

This article attempts to study the effect of various pulse-like ground motion parameters on the linear response of different multi-story buildings with special shear and flexural behavior. A total of 61 near-fault pulse-like ground motions are selected for this study. The effects of peak ground velocity (PGV), arias intensity (I) and earthquake magnitude (M_w) on maximum inter-story drift spectra (MIDS) are evaluated. The multi-story buildings are modeled using a combination of a shear and flexural beams with representative lateral stiffness ratios . The results indicate that The effects of PGV and arias intensity (I) on maximum inter-story drift spectra are very significant. The near-fault pulse-like ground motions are more dangerous for multi-story buildings with Flexural behavior than those with shear behavior.

INTRODUCTION

Near-field records often have obvious long period pulses that emerge mainly at the beginning of the record and affect the response of structures. The prevailing approaches for depicting behavior of structure subjected to pulse-like ground motions can be classified two general groups. The first approach tries to simplify the input and the equivalent pulse procedure is one example of this group. The second set of these approaches tries to use a simpler model of structure instead of simplifying the input but in return it considers the propagation of waves more precisely when developing the governing equations of structural behavior. The shear or the shear-flexural beam can be referred to as an example of this group. For the first time the idea of equivalent undamped shear beam model introduced by Westergaard (1933). Iwan et al.(1997) presented a new measure of inter-story drift demands by using a continuous shear-beam model for earthquake ground motion and called it the drift spectra. Drift spectra are suitable tool for defining the local displacement demand, particularly of pulse-like ground motions. In fact, the drift spectra provides important information to near-field ground motions that cannot be obtained from the response spectra. Many research works have examined the evaluation of drift demands of structures by using a continuous shear beam model (Chopra and Chintanapakdee, 2001; Akkar and Gülkan, 2002; Akkar *et al*., 2005) .The idea of using equivalent shear beams was extended to the combination of continuous shear and flexural beams by Khan and Sbarounis (1964). For estimate the maximum inter-story drift demands in multi-story building Miranda and akkar (2006) using a shear-flexural beam model consisting of two shear and flexural cantilever beams connected by an infinite number of axially rigid members, they proposed the so-called “generalized inter-story drift spectrum”. They used the derivatives of the mode shapes of the continuous shear-flexural beams to approximate the drift ratios. More recently, Khaloo and Khosravi (2008) and (Dixiong Yang et al., 2010) used the model to estimate maximum inter-story drift demands in buildings subjected to pulse-like ground motions with velocity pulse and non-pulse motions. The quantification of pulse-like ground motion requires a good understanding of the ground motion parameters that characterize the severity and the damage potential of the earthquake and the seismological, geological, and topographic factors that affect them. In recent years, the near-fault ground motions parameters attracted attention to seismologists and engineers. Several investigations have demonstrated that peak ground velocity (PGV), maximum incremental velocity (MIV) and arias intensity (I) are important ground motion parameters to characterize the near-fault pulse-like ground motions(Wei-Ping Wen et al.,2013; Yaghmaei, 2012) .

This article attempts to study the effect of various pulse-like ground motion parameters on the linear response of different multi-story buildings with special shear and flexural behavior. These parameters include PGV, arias intensity (I) and earthquake magnitude (M_w)**.** To investigate structural response of a large variety of multi-story buildings, in this study maximum inter-story drift ratio spectrum (MIDS) are evaluated. Meanwhile, in this study buildings are modeled as a combination of a shear and flexural beams and Floor masses are assumed to remain constant along the height of the building.

MAXIMUM INTER-STORY DRIFT SPECTRA

(Miranda and Akkar, 2006) used the shear-flexural beam model, shown in Fig.1, to obtain estimates of drift demands in multi-story buildings. It assumes that these beams are consisting of two shear and flexural cantilever beams connected by an infinite number of axially rigid members. The dynamic response of undamped uniform shear-flexural beams under a horizontal acceleration $\ddot{u}_g(t)$ at the base is expressed as a partial differential equation (Miranda and akkar, 2006; Dixiong Yang et al., 2010)

$$\frac{\circ}{EI}\frac{\partial^2 u(x,t)}{\partial t^2}+\frac{1}{H^2}\frac{\partial^4 u(x,t)}{\partial t^4}-\frac{\sim^2}{H^4}\frac{\partial^2 u(x,t)}{\partial x^2}=-\frac{\circ}{EI}\frac{\partial^2 u_g(t)}{\partial t^2} \tag{1}$$

where $\circ$ denotes the mass per unit length in the model; H is the total height of the building; u(x, t) represents the lateral displacement at the dimensionless height x=z/H, which varies between zero at the base of the building and one at the roof level at time t; EI means the flexural stiffness of the flexural beam and ~ is the lateral stiffness ratio written as

$$\sim\ = H\sqrt{\frac{GA}{EI}} \tag{2}$$

Where GA denotes shear stiffness of the shear beam. A value of ~ equal to zero corresponds to a pure flexural beam and ~ equal to infinity represents a pure shear-beam model. The lateral deflected shapes of buildings whose lateral resisting system consists only of structural walls can usually be approximated by using the values of a between 0 and 2. Moreover, for buildings with dual lateral resisting systems consisting of a combination of moment-resisting frames and shear walls or a combination of moment-resisting frames and braced frames, the values of a are commonly between 1.5 and 6, while for buildings whose lateral resisting system consists only of moment-resisting frames the values of a are typically between 5and 20. The IDR of buildings is defined as the difference of displacements at the adjacent two floors normalized by the inter-story height. Here, the IDR at the jth story is approximated by the rotation in the beam model at the height corresponding to the middle of the story of interest as follows(Miranda and akkar, 2006; Dixiong Yang et al., 2010)

$$IDR(j,t)\approx {}^{-}(x,t)=\frac{1}{H}\sum_{i=1}^{\infty}\Gamma_i ¤_i'(x)D_i(t) \tag{3}$$

Where H is the total height of the buildings, Γ_i is the modal participation factor of the ith mode of vibration of the continuous beam model, $¤_i'(x)$ denotes the amplitude of the ith mode at non dimensional height x, $D_i(t)$ represents the relative displacement response of a single degree of freedom (SDOF) elastic system with natural period of the ith mode T_i and modal damping ratio $¸_i$ subjected to a given ground acceleration $\ddot{u}_g(t)$ .Where x is the average height of the j+1and j floors Actually, for Eq.(3) in most cases only a relatively small number of modes is sufficient to obtain good estimates of the peak rotation demand in the beam model (Miranda and akkar, 2006). Hence, the IDR at dimensionless height x can be approximated as dimensionless height x can be approximated as

$$IDR(j,t) \approx \frac{1}{H}\sum_{i=1}^{m}\Gamma_i \text{¤}_i'(x)D_i(t) \tag{4}$$

Where m denotes the number of vibration modes considered in the spectral analysis .The maximum inter-story drift spectra (MIDS) is a plot of the fundamental period T of the building versus the maximum IDR (MIDR) , and MIDR is computed as

$$MIDR = \max\left|\ulcorner(j,t)\right| \approx \max\left|\frac{1}{H}\sum_{i=1}^{m}\Gamma_i \text{¤}_i'(x)D_i(t)\right| \tag{5}$$

For a given fundamental period, the total height of the model in Eq.(4) is calculated using the relationship suggested for steel moment-resistant frame in the 1997 UBC code, namely, $T_1=0.0853H^{0.75}$ (Miranda and akkar, 2006). The fundamental period T of the building ranged from 0.04s to 5.0s with an incremental of 0.02 (i.e., 249 values of period) and viscous damping ratio ξ assumed 5%. Maximum inter-story drift spectrum compute for eight vibration modes (m = 8) and five typical values of lateral stiffness ratios (0.01, 5, 10, 25 and 650).

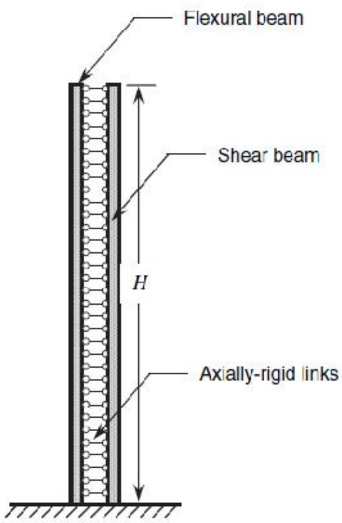

Figure 1. Simplified beam model of multi-story building (Miranda and akkar, 2006)

EFFECT OF GROUND MOTİON PARAMETERS ON MAXİMUM İNTER-STORY DRİFT SPECTRA

The dataset of recorded accelerograms employed in this study comprises 61 large velocity pulses in the fault-normal components of strong ground motion recordings of the Next Generation Attenuation (NGA) project library (www.peer.berekeley.edu), classified by Baker as pulse-like ground motions (Mollaioli and Bosi, 2012). Key properties regarding the recording stations and earthquakes characteristics are listed in Table 1 which are used as seismic excitation. Currently, the maximum inter-story drift demand is targeted as response parameter to achieve adequate structural performance of earthquake-resistant structures. For this purpose, the effects of several ground motion parameters on derived pulse-like ground motion maximum inter-story drift spectra (MIDS) are investigated herein. However, as illustrated in fig.2, the maximum inter-story drift spectra (MIDS) of total pulse-like ground motions for lateral stiffness ratios (α=0.01,650). For this purpose, the threshold value of different ground motion parameters was selected as an average of those calculated using all of ground motions. In this study, the 61 near-fault pulse-like ground motions are divided into two groups, lower and larger than these thresholds, and the corresponding ratio of the maximum inter-story drift spectra (MIDS) for each group is evaluated.

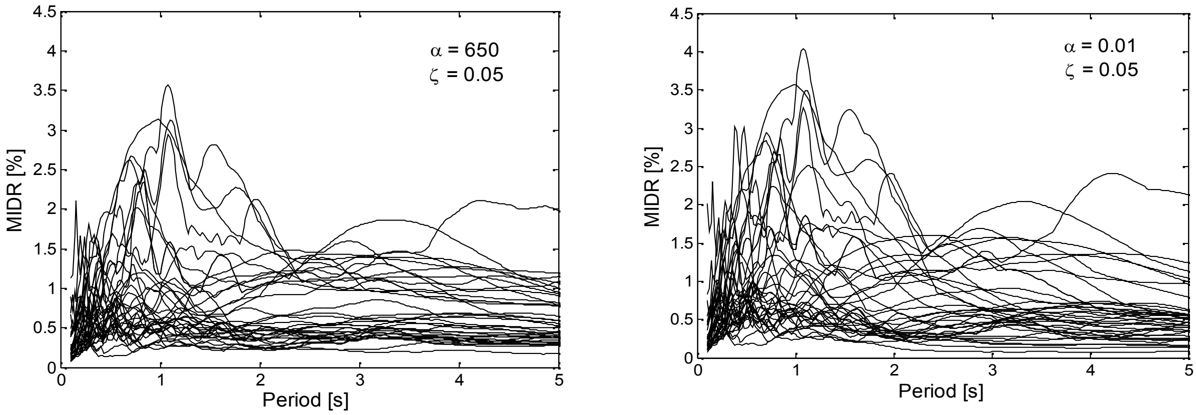

Figure 2. Maximum inter-story drift spectra of pulse-like ground motions for α=0.01, 650.

EFFECT OF PEAK GROUND VELOCITY (PGV)

Peak ground velocity (PGV) has the greatest influence on the inelastic displacement ratio spectra for pulse-like ground motions (Yaghmaei, 2012). It is necessary to investigate the effects of PGV on the MIDS. In this section, the ground motions are divided into two groups according to the different PGV ranges, and the numbers of ground motions in each PGV range summarized in table 1. The effect of this parameter on mean MIDS is presented in Fig. 3 for pulse-like ground motions as a ratio of results for PGV >65cm/s to those with PGV <65cm/s.

Table 1. Number of ground motions in each PGV, arias intensity and earthquake magnitude.

PGV (cm/s)	30- 65	21
	65-167	40
Arias intensity,(I)	0.3-2	19
	2-10	42
Earthquake magnitude,(M_w)	5.7-6.7	29
	6.7-7.6	32

Several important remarks can be made from Fig. 3, meaning that the mean MIDS for ground motions with PGV >65cm/s has been significantly amplified to those with PGV<65cm/s particularly at medium-long period regions. The maximum difference between two groups is about 3.35 respectively, and occur around 1.04 s . Also, there is a large difference with maximum value of 1.3 between the results of low lateral stiffness ratio systems (i.e., 0.01) and systems with high level of lateral stiffness ratio (i.e., 650). These phenomena mean that the (PGV) has a significant influence on MIDS for pulse-like ground motions for flexural-type buildings.

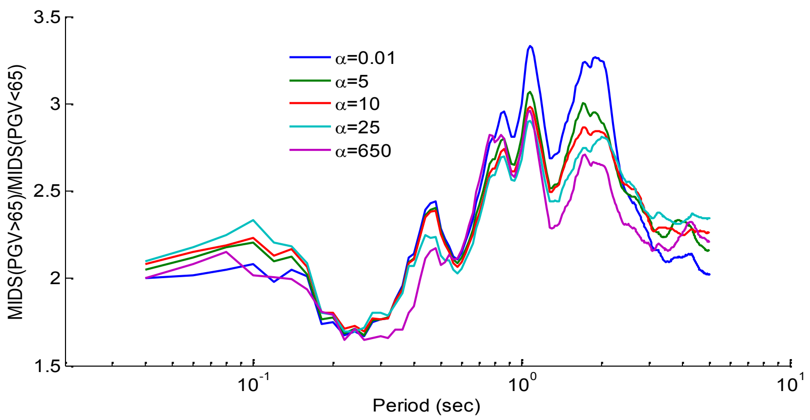

Figure 3. Ratio of MIDS for pulse-like motions with PGV>65 cm/s to those with PGV<65 cm/s.

EFFECT OF ARIAS INTENSITY (*I*)

Arias intensity (*I*), as introduced by (Arias, 1970), is defined for ground motion in the x direction as follows

$$I = \frac{®}{2g} \int_0^{T_d} (a_x(t))^2 dt, \tag{6}$$

Where I is the Arias Intensity in units of length per time, a_X is the acceleration time history in the x direction in units of g, Td is the total duration of ground motion, and g is the acceleration of gravity. It is well known that the arias intensity has significant influence on the maximum inelastic displacement demand of structures. The ground motions used in this investigation are grouped into two Arias Intensity ranges. The number of ground motions in each Arias Intensity range can be seen in Table 1. The results in Fig. 4 indicate that the ratio of MIDS for ground motions with $I \geq 2$ *m/s* is larger than those with $I < 2$ *m/s*. The largest difference of MIDS are 1.35, respectively, and occur around 0.8 s . In the short and medium period regions, the ratios of mean MIDS are more significant than the long period region. the ratios of mean MIDS in the long period region are decrease when the period increases. there is a very large difference with maximum value of 1.5 between the results of low lateral stiffness ratio systems (i.e., 0.01) and systems with high level of lateral stiffness ratio (i.e., 25, 650). These phenomena mean that the arias intensity has a significant influence on MIDS for pulse-like ground motions for flexural-type buildings (α = 0.01).

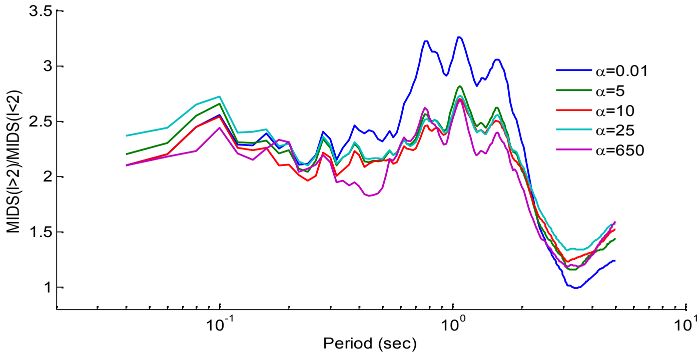

Figure 4. Ratio of MIDS for pulse-like motions with Arias intensity (I)>2 to those with Arias intensity (I)<2.

EFFECT OF EARTHQUAKE MAGNITUDE

In this section, the 61 near-fault pulse-like ground motions are divided into two groups according to the different earthquake magnitude (M) ranges. The number of ground motions in each earthquake magnitude range can be seen in table 1. The effect of this parameter on mean MIDS of pulse-like ground motions is shown in Fig. 5. The ratios of mean MIDS increase with the increase of period of vibration in medium period region, decrease when the period of vibration increases in the long period region, and are approximately independent of the period of vibration in short period region. It can be see, that the earthquake magnitude has a more significant influence on MIDS for shear -type buildings (α = 650) particularly at medium periods. In the long period region, the ratios of mean MIDS are smaller than 1.0. The results in Fig. 4 indicate that the effects of earthquake magnitude on the MIDS are moderate for near-fault pulse-like ground motions.

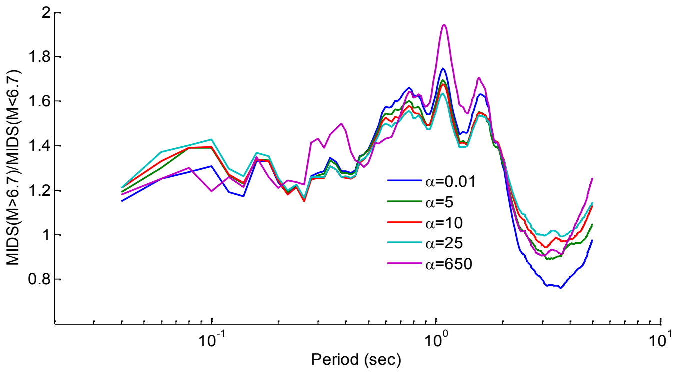

Figure 5. Ratio of MIDS for pulse-like motions with magnitude (M)>6.7 to those with magnitude (M)<6.7.

CONCLUSIONS

Currently, the maximum inter-story drift demand is targeted as response parameter to achieve adequate structural performance of earthquake-resistant structures. The effect of various pulse-like ground motion parameters on derived pulse-like ground motion maximum inter-story drift spectra was investigated herein. Multi-story buildings are modeled using an equivalent continuum model consisting of a flexural cantilever beam and a shear cantilever beam deforming in bending and shear configurations, respectively. These parameters were included as PGV, arias intensity and earthquake magnitude. The results of the study lead to following conclusions.

1. It was revealed from comparative analysis that the arias intensity and PGV has a significant effect on MIDS, therefore on the maximum inter-story drift of multi-story buildings under pulse-like motions, in particular for multi-story buildings with low lateral stiffness ratio (flexural-type buildings) and should be considered in seismic design of the structures constructed in near-field areas.
2. It can be see, that the earthquake magnitude has a more significant influence on MIDS for shear -type buildings (α = 650) particularly at medium periods.
3. It was observed that both the fundamental period of the structure and the lateral stiffness ratio can significantly effects on MIDS.

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