INTENSITY MEASURE PARAMETERS AND CHARACTERISTIC PERIOD OF NEAR-FAULT STRONG GROUND MOTIONS

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ABSTRACT :

This paper focuses on the effects of velocity pulse of near-fault ground motions on the structural damage potential. Two sets of near-fault ground motion records from Chi-Chi, Taiwan earthquake and Northridge earthquake with and without velocity pulse are selected as the input, and correlation analysis between 30 intensity measure parameters and maximum inelastic displacements and energy responses (input energy and hysteretic energy) of bilinear single degree of freedom (SDOF) systems are conducted. Based on the frequency characteristic of near-fault ground motions with remarkable long-period components, two intensity indices are proposed, which are the improved effective peak acceleration (*IEPA*) and improved effective peak velocity (*IEPV*). And a new characteristic period of these ground motions is defined based on *IEPA* and *IEPV*. Numerical results illustrate that the intensity measure parameters related to ground acceleration present the best correlation with the seismic responses for the rigid systems; the velocity-related and displacement-related parameters are better for medium- frequency systems and flexible systems respectively. The correlation curves of near-fault ground motions with velocity pulse differ from those of ground motions without pulse. Moreover, the improved parameters *IEPA* and *IEPV* of near-fault impulsive ground motions enhance the performance of intensity measure of corresponding conventional parameters, i.e., *EPA* and *EPV*. The new characteristic period based on *IEPA* and *IEPV* can better reflect the frequency content of the near-fault ground motions.

KEYWORDS: near-fault ground motions, velocity pulse, intensity measure parameters, characteristic period, bilinear SDOF systems, correlation analysis

1. INTRODUCTION

The near-fault ground motions have the forward rupture directivity effect, fling step effect, hanging wall effect and basin effect etc (Somerville et al 1997). Due to the former two effects, the near-fault ground motions usually show two important characteristics: a pulse-like velocity waveform and a permanent ground displacement, which had caused severe structural damage in recent major earthquakes, e.g., Northridge in 1994, Kobe in 1995 and Chi-Chi, Taiwan in 1999 and Wen-Chuan, China in 2008 etc. Especially in recent years, the study of near-fault ground motion characteristics and its effect on engineering structures is a very important topic to both the seismological and engineering communities. The intensity measure parameters of ground motions bridge between the seismic hazard analysis and structural demand parameters, and play a vital role in the seismic analysis and design of engineering structures near the fault. However, the research on the relationship between the intensity indices of near-fault ground motions and structural demand parameters is scarce, and there are no widely- accepted indices for representing the intensity of near-fault ground motions.

The near-fault pulse-like ground motions have large long-duration velocity and displacement pulse, and large peak ground acceleration (*PGA*) especially in the fault-normal direction, which mainly result from the effect of rapture directivity and hanging wall thrusting. These ground motions transmit high energy to the structure at the onset of earthquake, thus result in intensive structural damage. The intensity parameters responsible for the damage potential of near-fault ground motion have been paid close attention, which include the peak ground velocity (*PGV*), pulse duration or period, numbers of pulse cycle, and *PGV*/*PGA*, spectral acceleration (S_a) and so on (Malhotra 1999; Liao et al 2001; Manfredi et al 2003). But the correlation analysis between intensity para meters and demand parameters need to be implemented for the near-fault ground motions as an effective and systematic approach to represent structural damage potential.

Generally, the intensity indices of ground motions contain acceleration-related, velocity-related, displacement-related and compound parameters (Riddell 2007). The strength, deformation, energy and damage indices are the engineering demand parameters used frequently. To identify and determine the intensity measure parameters is significant to both the seismic hazard analysis and structural seismic design. Furthermore, it is also a key issue for the performance-based earthquake engineering. Therefore, many efforts are made for the correlation analysis between intensity parameters and structural dynamical responses based on the single degree of freedom (SDOF) model. Nevertheless, these works do not consider the distinct characteristics of rupture directivity and large velocity pulse of near-fault ground motions. This paper proposes two new intensity indices, which are the improved effective peak acceleration (*IEPA*) and improved effective peak velocity (*IEPV*) based on the frequency character of near-fault ground motions with remarkable long-period components. Then, to avoid the interference of different hypocenter mechanism to the analyzed results, 100 near-fault ground motions from Chi-Chi, Taiwan earthquake and 50 near-fault ground motions form Northridge earthquake with and without velocity pulse are selected as the input. Except the 23 intensity indices in the reference (Riddell 2007), the additional seven indices are taken as intensity measure candidates of near-fault ground motions. The correlation analysis between 30 intensity measure parameters and the maximum inelastic displacements and energy responses (input energy and hysteretic energy) of SDOF systems are performed. Our main objective is to identify appropriately intensity measure parameters for near-fault ground motions. Moreover, according to the intensity measures *IEPA* and *IEPV*, a new characteristic period of response spectrum of near-fault ground motions is suggested.

2. INTENSITY MEASURE PARAMETERS AND CHARACTERISTIC PERIOD OF NEAR-FAULT GROUND MOTIONS

Up to date, several dozens of intensity measure parameters have been suggested to describe the damage potential of strong ground motions. Some parameters are simply peak values of ground motion records, and other parameters are derived from the mathematical computation. As advised by Riddell (2007), the intensity measure parameters are divided as three classes: acceleration-related, velocity-related and displacement-related parameters.

The simplest acceleration-related intensity parameter is the peak value of the acceleration time history of ground motions (*PGA*), which is most widely applied in the earthquake engineering. Meanwhile, the intensity indices such as mean-square acceleration P_a, root-mean-square acceleration a_{rms}, squared acceleration a_{sq} and root-square acceleration a_{rs} are defined. In this study, the interval between t_1 and t_2 are taken as the significant duration t_d of motion after Trifunac and Brady, namely the interval between instants t_5 and t_{95} ($t_d = t_{95} - t_5$). Considering the effect of duration t_d, Park et al and Riddell and Garcia suggested two compound intensity parameters I_C and I_a respectively.

The simplest velocity-related intensity index is the peak value of the velocity time history of ground motions (*PGV*), which is popularly applied to characterize the damage potential of near-fault impulsive ground motions. The mean-square velocity P_v, root-mean-square velocity v_{rms}, squared velocity v_{sq} and root-square velocity v_{rs} are velocity-related intensity parameters. Araya and Saragoni advised an intensity index P_D which involves the effects of frequency content of motion. Fajfar et al proposed a compound index I_F as a measure of the ground motion capacity to damage medium-period structures. Similarly, Riddell and Garcia suggested a compound index I_v having the duration term for medium-period inelastic systems. Additionally, Housner's spectral intensity S_I is also a popular velocity-related index. It should be noted that the Housner's intensity is a posteriori index since it involves the structural properties ξ and T, less appealing as predictor variable (Riddell 2007).

The simplest displacement-related intensity index is the peak value of the displacement time history of ground motions (*PGD*). Similarly, the mean-square displacement P_d, root-mean-square displacement d_{rms}, squared displacement d_{sq} and root-square displacement d_{rs} are taken as intensity indices. Riddell and Garcia proposed a compound index I_d to minimize the dispersion of hysteretic energy dissipation spectra for long-period inelastic systems.

2.1 Improved effective peak acceleration IEPA and Improved effective peak velocity IEPV

Effective peak acceleration *EPA* and effective peak velocity *EPV* are two intensity indices specified in the ATC, FEMA documents and IBC codes (FEMA 1994). *EPA* is calculated as the mean elastic 5%-damped spectral acceleration S_a for the period range of 0.1s and 0.5s divided by an empirical factor 2.5. *EPV* is equal to the elastic 5%-damped spectral velocity S_v at the period T= 1s divided by 2.5. Therefore, in this study the two indices are respectively expressed as

$$EPA = S_a(0.1\text{s}, 0.5\text{s})/2.5 \qquad EPV = S_v(0.8\text{s}, 1.2\text{s})/2.5 \tag{1}$$

Actually, *EPA* and *EPV* are respectively calculated as the mean spectral acceleration and velocity at the dominant period which corresponds to the maximum spectral value. From Eqn.1 it can be seen that the dominant period T_{PA} of acceleration spectrum for *EPA* is taken as 0.3s, and the dominant period T_{PV} of velocity spectrum for *EPV* is taken as 1.0s. As is well known, the dominant periods of spectrum reflect the frequency property of ground motions. Because the ground motion records were mainly from the far-fault region in the past, these dominant periods of spectrum determined statistically were smaller. However, the change has happened with the increase of near-fault ground motion records in recent years. In practice, the dominant periods T_{PA} and T_{PV} of near-fault ground motions with long-period contents are generally larger than the respective periods (0.3s and 1.0s) of far-fault motions. Consequently, the intensity indices *EPA* and *EPV* in the ATC, FEMA documents and IBC codes need to be revised. Herein, for the near-fault ground motions the improved effective peak acceleration *IEPA* and improved effective peak velocity *IEPV* are proposed as

$$IEPA = \frac{S_a(T_{PA} - 0.2,\ T_{PA} + 0.2)}{2.5} \qquad IEPV = \frac{S_v(T_{PV} - 0.2,\ T_{PV} + 0.2)}{2.5} \tag{2}$$

where $S_a(T_{PA}$-0.2, T_{PA}+0.2) denotes the mean 5%-damped spectral acceleration in the period range of T_{PA}-0.2s and T_{PA}+0.2s, $S_v(T_{PV}$-0.2, T_{PV}+0.2) represents the mean 5%-damped spectral velocity in the period range of T_{PV}-0.2s and T_{PV}+0.2s, and the period interval is 0.4s.

2.2 Other compound intensity parameters

Except the several compound parameters I_F, I_a, I_v, I_d mentioned above, the other compound intensity parameters are I_M, *PGV*/*PGA*, *PGV* T_{PV} used by some researchers. Manfredi et al (2003) advised a non-dimensional compound index I_M to account for the cumulative damage of structures. Moreover, since the dominant period of velocity spectrum T_{PV} presents good correlation with the period of velocity pulse, the product *PGV* T_{PV} can be used to describe the intensity and energy of near-fault ground motions.

3. CHARACTERISTIC PERIOD OF NEAR-FAULT GROUND MOTIONS

The characteristic period (or transition period, corner period) of elastic acceleration spectrum of ground motion reflects its frequency character, and is an important spectral parameter for structural seismic design. The characteristic period specified in the ATC is the function of *EPA* and *EPV* (Hu 2006), namely

$$T_g = 2\pi \frac{EPV}{EPA} \tag{3}$$

But considering the frequency property of near-fault ground motions, two improved intensity parameters *IEPA* and *IEPV* are proposed above. If *IEPA* and *IEPV* substitute for *EPA* and *EPV* in Eqn.3, then a new characteristic period $\overline{T}_{\mathrm{g}}$ of ground motion is written as

$$\overline{T}_{\mathrm{g}} = 2\pi \frac{IEPV}{IEPA} \tag{4}$$

Vidic et al (1994) suggested a different expression of characteristic period

$$T_{\mathrm{C}} = 2\pi \frac{c_{\mathrm{v}} \cdot PGV}{c_{\mathrm{a}} \cdot PGA} \tag{5}$$

where c_{v} and c_{a} are spectral amplification factors, which are taken as 2.0 and 2.5 herein.

4. SEISMIC RESPONSES OF BILINEAR SDOF SYSTEMS

In the seismic analysis of structure, although SDOF system is a simplest model, it is suitably applied to study the relationship between ground motion parameters and structural responses. The inelastic maximum displacement of building structures is frequently used to describe the structural damage. From the energy viewpoint, energy balance of structure is preserved during the earthquake ground motion, and the structural input energy and hysteretic energy are important damage parameters. Hence, the maximum displacement, input energy E_{I} and hysteretic energy E_{H} are taken as engineering demand parameters in the following sections. To measure the correlation between intensity parameters X and dynamic responses (demand parameters) Y of bilinear SDOF system, the curve with the same form of power function as that in Riddell (2007) is fitted for n parameter pairs. The correlation coefficient ρ between X and Y is calculated according to

$$\rho = \frac{n\sum(\ln X \ln Y) - \sum \ln X \sum \ln Y}{\sqrt{(n\sum(\ln X)^2 - (\sum \ln X)^2)(n\sum(\ln Y)^2 - (\sum \ln Y)^2)}} \tag{6}$$

5 INTENSITY MEASURE PARAMETERS AND CHARACTERISTIC PEROD OF NEAR-FAULT GROUND MOTIONS FROM CHI-CHI EARTHQUAKE

The Chi-Chi great earthquake (M_{S}=7.3, M_{W}=7.6) occurred in Chi-Chi Town, Taiwan on the 1:43 of 21 Sep., 1999. The rupture type of Chelungpu fault in Chi-Chi belongs to the reverse-dip earthquake, which almost slips from south to north. From the strong ground motions database in Pacific Earthquake Engineering Research Center, 50 pulse-like near-fault ground motions and 50 non-pulse ordinary near-fault motions are selected as the input, and the effects of velocity pulse of near-fault ground motions on the correlation between intensity indices and structural responses are examined. We list the property parameters of ground motions such as the closet distance to fault rupture d, class of site soil S, PGA, PGV, PGD, PGV/PGA, characteristic period T_{g}, improved characteristic period $\overline{T}_{\mathrm{g}}$ and 95% significant duration t_{d} (omitted here). The closet distance to rupture of these records is smaller than 20 km, PGA is larger than 0.1g except TCU057NS, and PGV is greater than 25cm/s.

5.1 Characteristic period of near-fault ground motions

Table 1 demonstrates three kinds of mean characteristic period (T_{g}, $\overline{T}_{\mathrm{g}}$ and T_{C}) of near-fault ground motions with and without velocity pulse. Because EPA and EPV cannot reflect the property of near-fault ground motions with long-period components, the characteristic period T_{g} derived from them distorts the frequency character of near-fault motions, which leads to the error result of mean characteristic period T_{g} (0.84s) of impulsive ground motions smaller than that (0.93s) of non-pulse ground motions. But, the improved characteristic period $\overline{T}_{\mathrm{g}}$ can reflect the frequency character of near-fault motions reasonably. By comparison it is seen that the mean of improved characteristic period $\overline{T}_{\mathrm{g}}$ is larger than the mean of T_{g} and T_{C}. Moreover, the ratio of $\overline{T}_{\mathrm{g}}$ (1.44) between impulsive and non-pulse ground motions is close to the ratio of T_{C} (1.47). The analysis of smoothed r esponse spectrum need to be conducted to determine which characteristic period of near-fault ground motions (T_g or T_C) is better.

Table 1 Mean characteristic period of Chi-Chi earthquake near-fault ground motions (s)

Ground motions	T_g	$\overline{T}_g$	T_C
with pulse	0.84	2.04	1.53
without pulse	0.93	1.42	1.04
ratio	0.90	1.44	1.47

5.2 Correlation analysis between intensity parameters and response parameters of SDOF systems

30 intensity measure parameters of ground motions related to acceleration, velocity and displacement are considered. The correlation coefficient between 30 intensity indices and three response parameters (maximum displacement, input energy and hysteretic energy) of bilinear SDOF systems ($\mu = 4$, $\alpha = 0.05$, $\xi = 5\%$) are calculated.

5.2.1 Correlation between intensity indices and maximum displacement of SDOF systems

Table 2 demonstrates the correlation coefficients between inelastic spectral displacement and intensity parameters of impulsive and non-pulse ground motions, and the data in the bracket correspond to the case of non-pulse ground motions. The indices ranked in the top five for each control period are marked. Figure 1 shows the correlation of six representative intensity indices (*PGA, IEPA*, *PGV*, *IEPV*, *PGD*, I_d) with inelastic spectral displacement.

(1) In the short-period range (T=0.3s), the acceleration-related intensity parameters show very good correlation with inelastic spectral displacement. The indices *PGA*, *IEPA*, and I_a rank before the other parameters similar to the results of Riddell (2007). It is because the dynamic response of short-period structure is most affected by the accelerated-related ground motion parameters, but is not sensitive to the velocity-related and displacement-related parameters, which is inferred by the Newmark-Hall tripartite response spectrum.

(2) As for the medium-period systems (T=1.0s), and for the pulse-like ground motions the velocity-related parameters are fairly correlated with the spectral displacement such as I_F, I_v, *PGV* and *EPV*. Whereas, for the non-pulse ground motions the indices with strong correlation are *EPV*, *IEPA*, I_A, I_C and P_a, where the latter four parameters are related to acceleration.

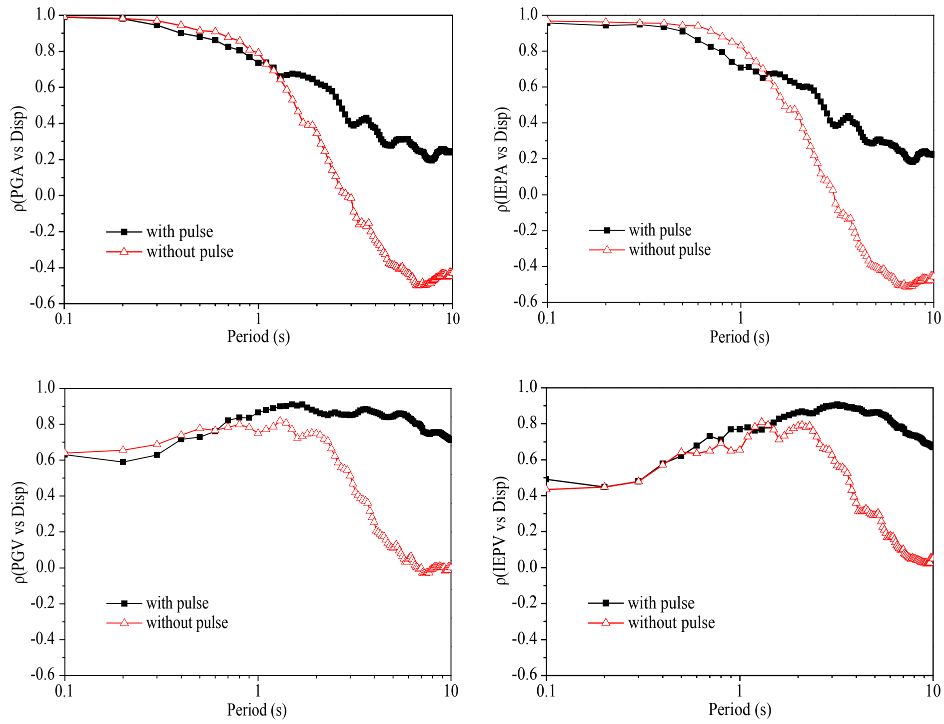
(3) For the long-period systems (T=5.0s), and for the pulse-like ground motions the best ranked intensity indices are all related to velocity such as v_{sq}, *IEPV*, *PGV*, I_F, and I_v. Whereas, for the non-pulse ground motions the indices with strong correlation are $PGV\ T_{PV}$, I_d and *PGD*. For the medium-long-period systems (T=2.0s and T=3.0s), the best ranked parameters are velocity-related indices for near-fault ground motions with and without pulse. Compound indices *PGV*/*PGA* and I_M do not correlate well with spectral displacement. The index $PGV\ T_{PV}$ correlates well with the spectral displacement only for non-pulse ground motions ($\rho = 0.79$).

(4) From Fig.1, the correlation curves of eight representative intensity indices of ground motions with pulse differ from that of ground motions without pulse. For the pulse-like ground motions, the strong correlation region of velocity-related parameters is prolonged. And in the long-period region, the correlation coefficients of velocity-related parameters (*PGV*, *IEPV*, I_F, I_v) with the spectral displacement are larger than that of displacement-related parameters (*PGD*, I_d). This phenomenon is attributed to the abundant low-frequency components of impulsive ground motions. For the non-pulse ground motions the strong correlation region of acceleration-related parameters (*PGA* and *IEPA*) is extended. It is wider than that of ground motions with pulse.

(5) The correlation coefficient of *IEPV* is improved largely compared with *EPV* in the medium and long-period region, especially for the pulse-like ground motions. The correlation coefficient of *IEPA* is also enhanced with respect to *EPA*.

Table 2 Correlation coefficient between maximum displacement of SDOF bilinear system (μ=4) and intensity p arameters of Chi-Chi ground motions with and without pulse (the data in the bracket correspond to the case of non-pulse ground motions.)

	T=0.3s		T=1.0s		T=3.0s		T=5.0s	
	ρ	rank	ρ	rank	ρ	rank	ρ	rank
Acceleration-related								
PGA	0.945 (0.970)	2(1)	0.736 (0.792)		0.394 (-0.014)		0.294 (-0.387)	
I_A , a_{sq} and a_{rs}	0.905 (0.900)		0.770 (0.827)	(3)	0.473 (0.204)		0.353 (-0.259)	
P_a and a_{rms}	0.929 (0.926)	4(5)	0.828 (0.798)	4(5)	0.534 (0.166)		0.446 (-0.328)	
I_C	0.921 (0.918)	5	0.797 (0.823)	(4)	0.498 (0.191)		0.388 (-0.288)	
I_a	0.934 (0.948)	3(4)	0.707 (0.794)		0.363 (-0.018)		0.248 (-0.353)	
EPA	0.919 (0.956)	(3)	0.619 (0.711)		0.277 (-0.080)		0.192 (-0.460)	
IEPA	0.947 (0.957)	1(2)	0.707 (0.830)	(2)	0.390 (0.027)		0.299 (-0.402)	
Velocity-related								
PGV	0.629 (0.687)		0.865 (0.750)	3	0.849 (0.513)	5	0.841 (0.110)	3
v_{sq} and v_{rs}	0.521 (0.077)		0.797 (0.319)		0.857 (0.874)	4(1)	0.891 (0.700)	1
P_v and v_{rms}	0.472 (0.402)		0.666 (0.527)		0.693 (0.771)	(2)	0.641 (0.411)	
P_D	0.659 (0.785)		0.662 (0.795)		0.532 (0.286)		0.507 (-0.211)	
I_F	0.638 (0.570)		0.874 (0.699)	1	0.863 (0.560)	3	0.841 (0.228)	3
S_I	0.561 (0.073)		0.789 (0.341)		0.823 (0.656)	(3)	0.677 (0.439)	
I_v	0.638 (0.395)		0.872 (0.590)	2	0.864 (0.572)	2(5)	0.829 (0.345)	5
EPV	0.876 (0.925)		0.819 (0.892)	5(1)	0.525 (0.085)		0.413 (-0.382)	
IEPV	0.479 (0.479)		0.769 (0.654)		0.899 (0.625)	1(4)	0.861 (0.290)	2
Displacement-related								
PGD	0.399 (-0.391)		0.649 (-0.234)		0.650 (0.558)		0.786 (0.749)	(3)
d_{sq} and d_{rs}	0.401 (-0.560)		0.601 (-0.435)		0.578 (0.469)		0.746 (0.741)	(4)
P_d and d_{rms}	0.413 (-0.403)		0.599 (-0.318)		0.582 (0.526)		0.670 (0.700)	(5)
I_d	0.400 (-0.504)		0.655 (-0.312)		0.661 (0.502)		0.794 (0.765)	(2)
The others								
$PGV{\cdot}T_{pv}$	0.198 (-0.416)		0.409 (-0.368)		0.536 (0.494)		0.699 (0.790)	(1)
PGV/PGA	-0.050 (-0.777)		0.088 (-0.499)		0.458 (0.386)		0.477 (0.586)	
I_M	-0.497 (-0.152)		-0.502 (-0.073)		-0.647 (0.040)		-0.662 (0.075)	



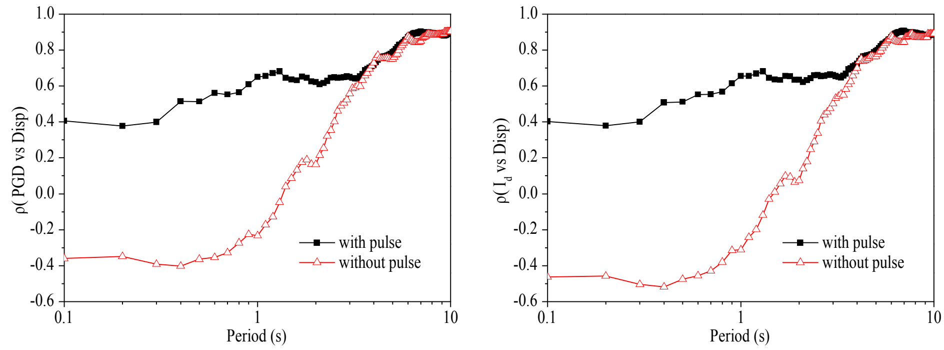


Figure 1 Correlation coefficient between intensity parameters of Chi-Chi ground motions and maximum displacement of SDOF bilinear system (μ=4) with different period

5.2.2 Correlation between intensity indices and energy responses of SDOF systems

The correlation coefficients between energy responses (input energy E_I and hysteretic energy E_h) and intensity parameters of impulsive and non-pulse ground motions are calculated. From the tendency some observation are obtained.

(1) For the rigid systems (T=0.3s), the indices with very good correlation are all acceleration-related intensity parameters, i.e. EPA, I_A, I_C, I_a and PGA. For the medium-period system (T=1.0s), the indices with strong correlation is EPV, I_A, I_C and P_a, where the latter three parameters are related to acceleration. For the medium-long-period systems (T=2.0s and 3.0s) the intensity indices with very good correlation are all velocity-related parameters, i.e. S_I, I_v, v_{sq}, I_F. For the flexible systems (T=5.0s), the best ranked indices of impulsive ground motions correlated with energy responses are almost the velocity-related parameters such as v_{sq}, I_F, PGV and I_v. Whereas, for non-pulse ground motions the indices correlated well with the hysteretic energy are almost displacement-related parameters such as d_{sq}, I_d and PGD.

(2) Because the influence of duration of ground motions on the energy responses is remarkable, this effect is examined here. It is found that the compound indices considering the duration effect present better correlation with the energy response than those without the duration term t_d, which verifies the partial statement in Riddell (2007). For instance, in the short-period region, I_C is better than a_{rms}, and I_a is better than PGA. In the medium-period and medium-long-period region (T=1.0s-3.0s), for the impulsive ground motions I_F and I_v are better than PGV. However, for the non-pulse ground motions I_F and I_v are not better than PGV for the medium system (T=1.0s). Moreover, for the long-period system I_d is averagely better than PGD. Similarly, the correlation of root-square indices (a_{sq}-a_{rs}, v_{sq}-v_{rs}, d_{sq}-d_{rs}) with energy responses is generally better than that that of root-mean-square indices (P_a-a_{rms}, P_v-v_{rms}, P_d-d_{rms}), respectively.

(3) The correlation curves of representative intensity indices of ground motions with pulse differ from that of ground motions without pulse. For the pulse-like ground motions, the strong correlation region of velocity-related parameters is prolonged. And in the long-period region, the correlation coefficients of velocity-related parameters (v_{sq}, I_F, PGV and I_v) are larger than that of displacement-related parameters (I_d and PGD). For the non-pulse ground motions the strong correlation region of acceleration-related parameters (EPA, I_C, I_A and PGA) is extended. It is wider than that of ground motions with pulse.

6. CONCLUSIONS

This paper emphasizes on the influences of velocity pulse of near-fault ground motions on the intensity measure parameters. To avoid the interference of different epicenter mechanism to the analyzed results, 100 near-fault ground motions from Chi-Chi, Taiwan earthquake and 50 near-fault ground motions from Northridge earthquake (the detailed results are omitted here) are respectively selected to compute the correlation coefficients between the intensity indices and three response quantities (maximum displacement, input energy and hysteretic energy) of bilinear SDOF system. Some conclusions are drawn below from the numerical computation and comparison.

(1) The correlation of intensity parameters of near-fault ground motions with structural response parameters depends on the fundamental period of system. There is no parameter with strong correlation in the whole period range of SDOF systems. Therefore, for different structures with different periods, it is necessary to choose different intensity parameters to characterize the structural damage and destructive degree. Averagely the acceleration-related indices (I_C, I_A and P_a) are correlated well with demand parameters in the short-period region. The velocity-related indices (*IEPV*, I_F, and *PGV*) have good correlation in the medium-period and medium-long-period regions (T=1s-3s). The displacement- related indices (I_d, d_{sq} and P_d,) have good correlation in the long-period regions.
(2) The difference between the correlation curves of near-fault ground motions with and without pulse is significant. The pulse character of near-fault ground motions prolongs the strong acceleration region of intensity parameters. The velocity-related intensity indices are affected most remarkably by the velocity pulse of motions.
(3) The improved parameters *IEPA* and *IEPV* of the pulse-like near-fault ground motions enhance the performance of intensity measure of conventional parameters *EPA* and *EPV*, respectively. But for the mixed near-fault ground motions, *IEPA* and *IEPV* could not be superior to *EPA* and *EPV* respectively as intensity indices. The new characteristic period based on *IEPA* and *IEPV* can better reflect the frequency content of the near-fault ground motions.
(4) Compared with the correlation analysis of intensity indices of near-fault ground motions from Northridge earthquake, the long-period property of near-fault round motions from Chi-Chi earthquake is more remarkable. Moreover, in the medium and long-period regions, the velocity-related and displacement-related indices are better correlated with the seismic responses of SDOF systems.
(5) The peak ground motion parameters have been widely accepted as the intensity parameters on the basis of seismic hazard assessment. Meanwhile according to the systematic correlation analysis on intensity indices of near-fault ground motions in this paper, for the sake of simplification, the intensity measure parameter of near-fault ground motions suitable for short-period structural system can be taken as *PGA*. For medium-period and long-period systems *PGV* and *PGD* are the respective intensity index of near-fault ground motions.

ACKNOWLEDGMENTS
The support of the National Natural Science Foundation of China (Grant nos. 10421002, 10672030) and the National Basic Research Program of China (Grant nos. 2006CB601205) is much appreciated.

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