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Design Spectra Analysis of Chi-Chi Earthquakes 1999 as a Normalized Ground Motions Input of Taichung City, Taiwan

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Abstract: *Chi-Chi Earthquake is the second largest earthquake that hit Taiwan on 1999. The damages include the death, and the bridges and buildings failure. Many ground motions data that were recorded in several locations shows that Chi-Chi earthquake on 1999 is one of the near fault ground motion that have special characteristics.*

Design spectra concept is the ground motion analysis to normalize the ground motion from the original locations, considering the soil and site condition in another location to calculate the scaling factor. So that the ground motions input that applied to the building have been adapted with the existing site condition.

The number of three ground motions of Chi-Chi Earthquakes proposed from three different stations. TCU068, TCU102, and TCU05. Due to Chi-Chi earthquakes is one of strong motion input with the special characteristic. Many engineers in around the world consider Chi-Chi Earthquakes as the input of earthquake analysis of the construction modeling. Different location site will be different in their site condition, thus the design spectra analysis need to consider since this method provide the scaling factor that represent the new site construction.

Keyword: *Design Spectra, Near Fault, Chi-Chi Earthquake.*

I. INTRODUCTION

Chi-Chi earthquakes that happen in Taiwan on 1999 were considered as the near fault earthquake Chi-Chi Earthquake has been chosen due to their special behavior of the strong motion earthquakes. In the middle of the night about 1:47 am local time on September 21, 1999 there was large magnitude of earthquake in central western Taiwan, a severe earthquake that famously called Chi-Chi earthquake occur and caused thousand building collapsed, deaths, and about 20 billion USD of the total economic lost. Beside thousand building collapsed, another infrastructure such like power system, communication, water and wastewater system, gas system, railroads, dams, and tanks damaged due to Chi-Chi earthquake that happen in near Nantou City, Taiwan.

Based on tectonic map of Taiwan region that showed in figure 1, the collision of the Philippine sea plate into the Asian plate controlling the tectonics behavior of Taiwan, thus Taiwan is categorized as part of the Ryukyu-Taiwan-Philippine arc system. Chilungpu fault is known as a major thrust fault in western of Taiwan, then Chi-Chi earthquake happened due to the rupture of Chilungpu fault as describe on figure 2 that the red line is the major fault of Chilungpu, and the epicenter of Chi-Chi earthquake occur on star point, its prove that Chi-Chi earthquake happen due to the activity of Chilungpu fault.

Fig. 1. Tectonic map of Taiwan, Taiwan lies on Ryukyu trench and Manila trench (www.researchgate.net)

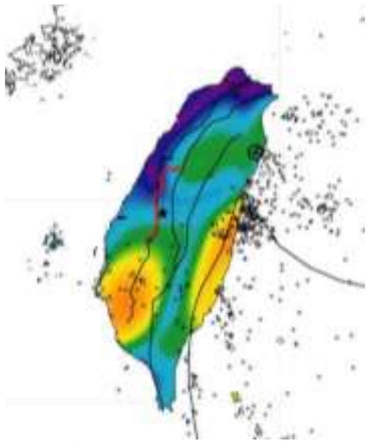

Fig. 2. Major fault in Taiwan, (www.eri.u-tokyo.ac.jp)

Taiwan government of Central Weather Bureau (CWB) predict that the epicenter of Chi-Chi earthquake was on Nantou City, and in hypocenter predict on 7 km of depth under the surface ground, because of this reason Chi-Chi earthquake is categorized as severe earthquake that estimated by the moment magnitude about M_w=7.7. Issue comes up

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toward engineering analysis about earthquake studies to consider about the estimation of ground motion in the particular location related with building construction, analysis about Chi-Chi earthquake related with the strong motion density measure about how much ground motion contribution can change as a function of the distance away from the nearest strong motion recording, (ASCE, 2000).

The previous explanation will be the reason for many engineer consider Chi-Chi Earthquakes as their input of the ground motion in order to prevent the failure and damage that caused by the near fault earthquake. Take a construction site in Taichung City of Taiwan. The soil condition will be different with Nantou City of the original epicenter of Chi-Chi earthquakes. The purpose of this research is to explain about how to analyze the ground motions input that consider the design spectrum concept, considering the site location and soil condition.

II. Fundamental Theory

A. *Earthquake Ground Motions.*

An earthquake is an impact of ground shaking caused by an energy that suddenly released in lithosphere layer, (Dowrick, 1987). Earthquake may cause by either tectonic or volcanic activity, yet the earthquake due to volcanic process only happen in specific area near the prone area and the time can be predicted in real time prediction, the damage due to this earthquake can be prevent well. An earthquake due to tectonic activity will be risky, so that the damage prevention technology extensively developed to reduce the harmful effect, especially for human beings. The energy produced due to some interaction between the crust and the earth's inner layer. Releasing energy itself involve the fracture of the surface along the plane which passes through the hypocenter. Largely of the shallower earthquake, this surface plane known as a fault.

The strength of the earthquake known in two definitions, they are intensity and magnitude. Intensity is the strength of ground shaking at any given place, and magnitude is accumulation strength of the existing ground motion. Intensity is a severity measuring of the earthquake at the certain place, intensity measured by Mercalli (MM). Yet, magnitude use to measure the size of an earthquake, associated with the energy release which is area independent, magnitude measured by Seismogram (M).

The seismic wave divide into four main types, there are:

1. Body waves: seismic waves that travel pass through inside the earth, body waves divided into two class of waves based on the wave's properties:
   a. P-Waves, vibration particle move parallel with the direction of seismic waves. Also known as primary wave, longitudinal or pressure wave.
   b. S-Waves, vibration particle that move perpendicularly through the seismic wave direction. S-waves also known as shear waves, secondary waves, or transverse wave.
2. Surface waves: different with body waves, surface waves are seismic waves pass through along the surface earth or the outer layer near the surface. Surface waves divided into two classes in general:
   a. Love waves: vibration particle on horizontal axis which is perpendicular with the seismic waves direction.
   b. Rayleigh waves: vibration particle on vertical axis which is parallel with the seismic waves direction.

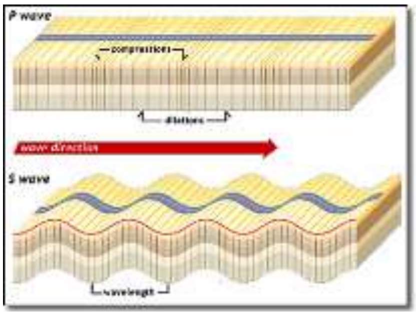

Fig. 3. P-wave and S-wave of body wave (SMS Tsunami Warning)

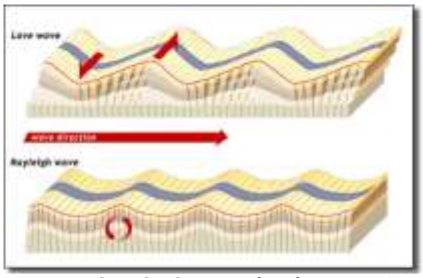

Fig. 4. Love wave and Rayleigh wave of surface wave (SMS Tsunami Warning)

B. *Near Fault Earthquakes*

Earthquakes are essentially vibrations of the earth's crust caused by subterranean ground faults. They occur several times a day in various part of the world, although only a few in a year are sufficient magnitude to cause significant damage to buildings. Major earthquakes occur most frequently in particular areas of the earth's surface that called zones of high probability. However, it is theoretically possible to have a major earthquake anywhere on the earth at some time, (Ambrose, J. &Vergun, D., 1995).

A major earthquake is usually rather in short in duration, often lasting only a few seconds and seldom more than a minute or so. During the general earthquakes, there are usually one or more major peaks of magnitude of motion. These peaks represent the maximum effect of the quake. Although the intensity of the quake is measured in terms of the energy release at the location of the ground fault, the critical effect on a given structure is determined by the ground movements at the location of the structure. The extent of these movements is affected mostly by the distance of the structure from the epicenter, but they are also influenced by the geological conditions directly beneath the structure and by the nature of the entire earth mass between the epicenter and the structure, (Ambrose, J. &Vergun, D., 1995).

Figure 5 shows an idealized distribution of intensity of the ground shaking in relation to near vertical fault rupture, such as discussed for Californian earthquakes by Housner. The traditional attenuation relationships are made to fit the mean of the data about a point source, and hence represent all the intensity contours as circle with attenuation being the same in all directions. The attenuations of near field data earthquakes allow for the effect of the line source by relating peak ground motion to distance to the fault trace, implying a contour pattern consisting of a series of straight lines parallel and equal in length to the fault trace with the ends joined by semicircles, (Dowrick, D., 1987).

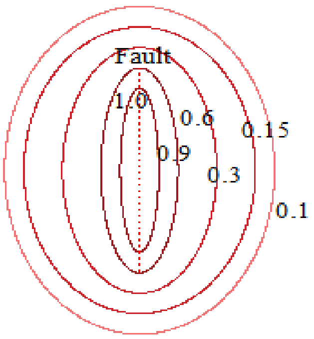

Fig. 5. Idealized contour lines of intensity of ground shaking, normalized to unit epicenterintensity, (Dowrick, D., 1987)

The symmetry about the fault trace (i.e. where the fault breaks the ground surface) of the contours in figure 5 clearly depends on the slope of the fault rupture surface, and an asymmetrical pattern, at least about the fault trace, could be expected from under-thrust faults of the main fault types, (Dowrick, D., 1987).

A common issue that comes up in the earthquakes studies is the estimation of grounf motions at particular locations for engineering analyses. The dense strong motion recordings from the Chi-Chi earthquake allow a direct measurement of how much ground motions can change as a function of the distance away from the nearest strong motion recording. The standard deviation pf the natural log of the ratio of the ground motions for sites on similar soil conditions are estimated as a function of separation distance, (ASCE, 2000).

C. Earthquakes Response on Linear System

Equation 2.1 govern the motion of a linear single degree of freedom system subjected to ground acceleration:

$$\ddot{u} + 2\zeta\omega_n\dot{u} + {\omega_n}^2 u = -\ddot{u}_g(t) \qquad \textit{Eq. 1}$$

It is clear that for a given $\ddot{u}_g(t)$ the deformation response u(t) of the system depends only on the natural frequency ω_n or natural period T_n of the system and its damping ratio ζ, writing formally, $u \equiv u(t, T_n, \zeta)$. Thus any two system having the same values of T_n and ζ will have the same deformation response u(t) even though one system may be more massive than the other or one may be stiffer than the other, (Chopra, A., 2013).

It is observed that the system with more damping respond less than lightly damped system, because the natural period of the three systems is the same, their responses display a similarity in the time required to complete a vibration cycle and in the times the maxima and minima occur. Once the deformation response history u(t) has been evaluated by the dynamic analysis of the structure, the internal forces can be determined by static analysis of the structure at each time instant, one of them is based on the equivalent static force f_s, (Chopra, A., 2013).

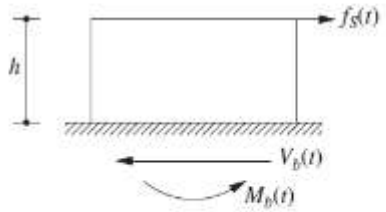

Fig. 6. Equivalent static force, (Chopra, A., 2013)

$$f_s(t) = m{\omega_n}^2 u(t) = mA(t) \qquad \textit{Eq. 2}$$
$$A(t) = {\omega_n}^2 u(t) \qquad \textit{Eq. 3}$$
$$V_b(t) = f_s(t) \qquad \textit{Eq. 4}$$
$$M_b(t) = hf_s(t) \qquad \textit{Eq. 5}$$
$$V_b(t) = mA(t) \qquad \textit{Eq. 1}$$
$$M_b(t) = hV_b(t) \qquad \textit{Eq. 2}$$

Where $f_s(t)$ is the equivalent static lateral force, m is mass, ω_n is the natural frequency, A(t) is pseudo acceleration response, $V_b(t)$ is the base shear, $M_b(t)$ is the base overturning moment, and h is the structures height. (Chopra, A., 2013)

D. Earthquakes Response on Non-Linear System

The governing equation for an inelastic system is written bellow:

$$m\ddot{u} + c\dot{u} + f_s(u) = -m\ddot{u}_g(t) \qquad \textit{Eq. 3}$$

Divided by m:

$$\ddot{u} + 2\zeta\omega_n\dot{u} + {\omega_n}^2 u_y \tilde{f}_s(u) = -\ddot{u}_g(t) \qquad \textit{Eq. 4}$$

Where:

$$\omega_n = \sqrt{\frac{k}{m}} \qquad \textit{E.q 5}$$
$$\zeta = \frac{c}{2m\omega_n} \qquad \textit{Eq. 6}$$
$$\tilde{f}_s(u) = \frac{f_s(u)}{f_y} \qquad \textit{Eq. 7}$$
$$a_y = \frac{f_y}{m} \qquad \textit{E.q 8}$$

For a given $\ddot{u}_g(t)$ considering the ductility factor μ as the parameter of inelastic system, define:

$$\mu(t) \equiv \frac{u(t)}{u_y} \qquad \textit{E. 9}$$

Take the consideration that $u(t) = u_y.\mu(t), \dot{u}(t) = u_y.\dot{\mu}(t), \ddot{u}(t) = u_y.\ddot{\mu}(t)$, and $\bar{f}_y = {}^{u_y}/_{u_0}$ if the equation 9 divided by u_y, then the equation will be:

$$\boldsymbol{\ddot{\mu} + 2\zeta\omega_n\dot{\mu} + {\omega_n}^2\tilde{f}_s(\mu) = -{\omega_n}^2\frac{\ddot{u}_g(t)}{a_y}} \qquad \textit{Eq. 10}$$

Where $f_s(u)$ is the resisting force for an elastoplastic system, and $\tilde{f}_s(u)$ describes the force-deformation relation in partially dimensionless form, u_y is yield deformation, and a_y interpreted as the acceleration of the mass necessary to produce the yield force f_y.

Figure 7 shows the force-deformation relation in elastoplastic system. Starting on point a when u and f_s are both zero. At this point the system is linearly elastic and remains so until point b. when the deformation reaches the yield deformation for the first time, identified as b, yielding begins. From b to c the system is yielding, the force is constant at f_y, and the system is on plastic branch b-c of the force-deformation relation. At c, a local maximum of deformation, the velocity is zero, and the deformations begin to reverse, the system begins to unload elastically along c-d and is not yielding during this time.

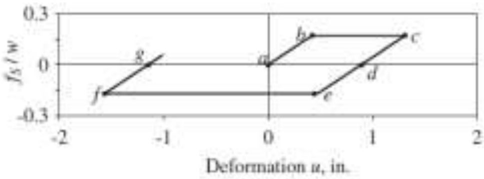

Fig. 7. Force-deformation relation (Chopra, A., 2013)

Unloading continues until point d when the resisting force reach zero. Then the system begins to deform and load in the opposite direction and this continues until point f, f_s=-f_y during this time span and the system is moving along the plastic branch e-f. At f local minimum for deformation, the velocity is zero, and the deformation begin to reverse, the system begins to reload elastically along f-g and is not yielding during this time. Reloading brings the resisting force in the system to zero at g, and it continues along this elastic branch until the resisting force reach +f_y, (Chopra, A., 2013).

III. METHODOLOGY

A. *Research Site and Bridge Model*

The target of construction site is on Taichung City in the middle part of Taiwan, Republic of China. And the bridge model shown bellow:

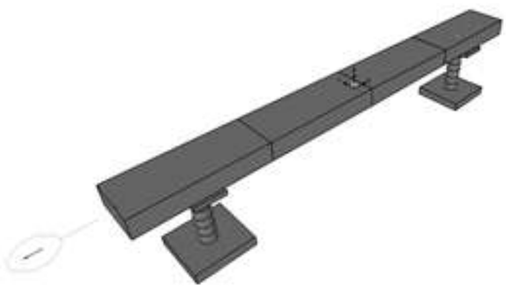

Fig. 8. Bridge Model

B. *Earthquake Response*

A plot of the peak value of a response quantity as a function of the natural vibration period T_n Of the system, or a related parameter such as circular frequency ω_n Or cyclic frequency f_n, is called the response spectrum for that quantity. Each such plot id for SDF system having a fixed damping ratio ζ, and several such plots for different values of ζ are included to cover the range of damping values encountered in actual structures whether the peak response is plotted against f_n Or T_n Is a matter of personal reference. A variety of response spectra can be defined depending on the response quantity that is plotted. Consider the following peak responses:

$$u_0(T_n, \zeta) \equiv max_t|u(t, T_n, \zeta)| \quad \textit{Eq. 11}$$

$$\dot{u}_0(T_n, \zeta) \equiv max_t|\dot{u}(t, T_n, \zeta)| \quad \textit{Eq.12}$$

$$\ddot{u}_0^t(T_n, \zeta) \equiv max_t|\ddot{u}^t(t, T_n, \zeta)| \quad \textit{Eq.13}$$

The deformation response spectrum is a plot of u_0 Against T_n For fixed ζ. A similar plot for $\dot{u}_0$ Is the relative velocity response spectrum, and $\ddot{U}_0^T$ Is the accelerations response spectrum, (Chopra, A., 2013).

The deformation spectrum provides all the information necessary to compute the peak values of deformation $D \equiv u_0$ And internal force. Where E_{s0} Is the relationship between strain energy and kinetic energy, consider a quantity of peak deformation before, then the pseudo velocity response spectrum calculated by:

$$V = \omega_n D = \frac{2\pi}{T_n} D \quad \textit{Eq. 14}$$

$$E_{s0} = \frac{k u_0{}^2}{2} = \frac{kD^2}{2} = \frac{k(\frac{V}{\omega_n})^2}{2} = \frac{mV^2}{2} \quad \textit{Eq. 15}$$

And pseudo acceleration A and base shear V_{b0}Calculated by:

$$A = \omega_n{}^2 D = \left(\frac{2\pi}{T_n}\right)^2 D \quad \textit{Eq. 16}$$

$$V_{b0} = f_{s0} = mA = \frac{A}{g} w \quad \textit{Eq. 17}$$

C. *Design Spectrum Analysis*

The response spectrum for a given ground motion component $\ddot{u}_g(t)$ can be developed by implementation of these following steps:

1. Numerically define the ground motion acceleration $\ddot{u}_g(t)$. Typically, the ground motion ordinates are defines in every time step Δt.
2. Select the natural vibration period T_n and damping ratio ζ of a system.
3. Compute the deformation response u(t) of the system due to the ground motion $\ddot{u}_g(t)$ by any of the numerical methods.
4. Determine u_0, the peak value of u(t).
5. The spectral ordinates are $D = u_0,\ V = (2\pi/T_n)D,\ A = (2\pi/T_n)^2\, D.$
6. Repeat steps 2 to 5 for a range of T_n and ζ values covering all possible systems of engineering interest.

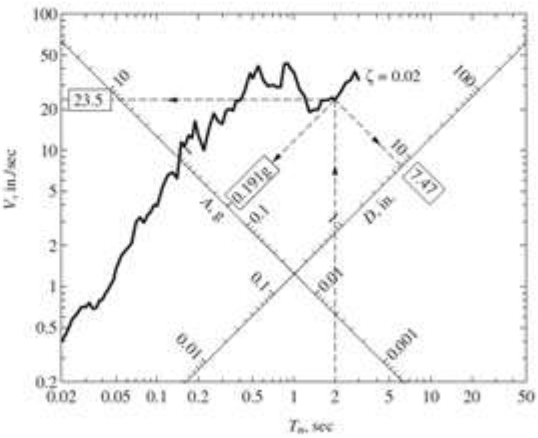

Fig. 9. Combined D-V-A response spectrum for El-Centro ground motion ζ=2%, (Chopra, A., 2013).

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Figure 8 will be an example of the combination D-V-A response spectrum for El-Centro Ground motion with damping ratio 2%.(Chopra, A., 2013)

IV. RESULT

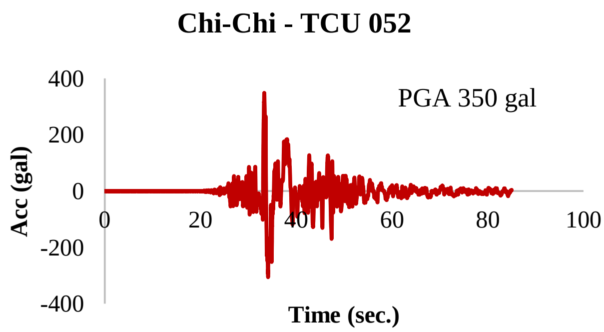
A. Original Ground Motions

Three recorded strong motion of Chi-Chi earthquake proposed in this analysis to study about the dynamic analysis of the bridge model under the near fault earthquake as shown in figure 10, there are TCU052, TCU068, and TCU102. These three ground motion have each characteristic since this ground motion recorded in different location of the earthquake. ASCE in the textbook of lifeline performance of Chi-Chi earthquake 1999 that edited by Anshel et.al mentioned that TCU068 was located at the northern end of the rupture and have large velocity pulses due to the permanent movement of the fault (fling step) and were not due to rupture directivity effects such in Northridge earthquake in 1994 and Kobe earthquake in 1995.

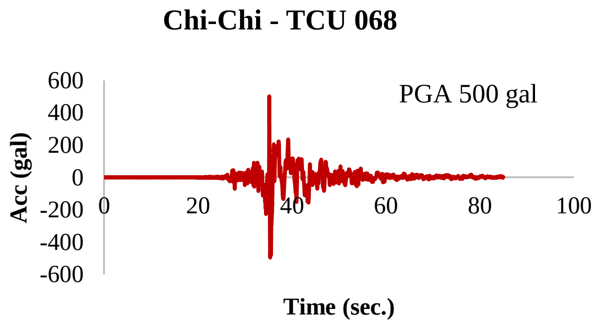
Special characteristic that showed in TCU102 need to be studied more, in case of there are two peak in this ground motion that made the structure under TCU102 is more sensitive in its peak ground acceleration (PGA). TCU052, TCU068, and TCU102 ground motions chosen due to their special characteristic of the Chi-Chi earthquake as near fault earthquake that happen, and some of them have large velocity pulses due to the fling attenuate faster with increasing distance to the fault than do large velocity pulses due to directivity effects. special characteristic that showed in TCU102 need to be studied more, in case of there are two peak in this ground motion that made the structure under TCU102 is more sensitive in its peak ground acceleration (PGA). TCU052, TCU068, and TCU102 ground motions chosen due to their special characteristic of the Chi-Chi earthquake as near fault earthquake that happen, and some of them have large velocity pulses due to the fling attenuate faster with increasing distance to the fault than do large velocity pulses due to directivity effects.

B. Response Spectrum

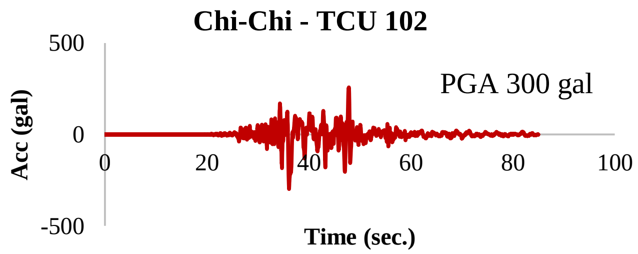
From the original ground motions, then a response spectrum diagram were plotted in order to compare with the normalized response spectrum that had been considered the soil condition of Taichung city. Figure 10 are the comparison of the original response spectrum and the normalized response spectrum.



(a)



(b)



(c)

Fig. 10. Original ground motions of (a) TCU052, (b) TCU068, and (c) TCU102.

Earthquake as a ground shaking is one of consideration in analyzing the response of structure since this is one of the most important application of the structural dynamic theory. Determining the peak response of system considering the site construction and the existing soil condition as part of response spectrum concept is the most important to determine the loading input, this chapter is further explanation of scaling method that used to determine the Peak Ground Acceleration of the near fault ground motion. Response spectrum determine as a plot of quantity response as a function of the natural frequency ω_n, natural period T_n, or cyclic frequency f_n for the fixed damping ratio ζ. Plot of response spectrum can be as deformation response spectrum u_0, relative velocity response spectrum $\dot{u}_0$, and $\ddot{u}_0{}^t$ as the acceleration response spectrum.

Based on equation of motion of single degree of freedom in eq. 3.3, gives the differential governing equation of free vibration system with damping:

$m\ddot{u} + c\dot{u} + ku = 0$ *Eq. 22*

Dividing with m as a mass and damping coefficient $c = 2m\zeta\omega_n$ and acknowledge natural frequency $\omega_n = \sqrt{k/m}$ and subjected to ground acceleration $\ddot{u}_g(t)$:

$\ddot{u} + 2\zeta\omega_n\dot{u} + \omega_n{}^2 u = -\ddot{u}_g(t)$ *Eq. 23*

Equation 3.29 shows that natural frequency $\omega_n$or natural period $T_n$of the system also damping ratio ζ contribute the deformation response u(t) for a given$\ddot{u}_g(t)$. Simply means that for two systems that have same values of ω_n and ζ shall have same deformation response u(t) although one of them is greater than the other one, also even though one system is stiffer than the other one. The system with light damping shall respond more than the system with larger damping, thus if there are several systems with the same of their natural period, their response will be similar for the time that required to complete a cycle of vibration and in peak time either maximum or minimum point, (Chopra, A., 2013).

In a structural analysis, equivalent static force preferred to choose since the building code specified the earthquake force relation, static force of f_s expressing k in terms of the mass m in the eq. 3.30:

$$f_s(t) = m\omega_n{}^2 u(t) = mA(t) \qquad \textit{Eq. 24}$$

Simply means that:

$$A(t) = \omega_n{}^2 u(t) \qquad \textit{Eq. 25}$$

This equivalent static force mentions A(t) as its pseudo-acceleration that multiply with m as mass. From the deformation response of the structure of u(t) is the basic response to calculate pseudo-acceleration A(t). Pseudo-acceleration is a plot of acceleration as a function of the natural period (Anil K. Chopra, 2014). Meanwhile the structure have the true acceleration $\ddot{u}_0{}^t$, pseudo-acceleration is undergoing acceleration of mass that associated with inertial force to calculate the base shear v_{b0}, related with eq. 3.30 then the value of base shear considered as:

$$v_{b0} = f_{s0} = mA \qquad \textit{Eq. 26}$$

With function of weight, then we get:

$$v_{b0} = {}^{A}\!/_{g} \,.\, w \qquad \textit{Eq. 27}$$

Then ${}^{A}\!/_{g}$ represented base shear coefficient and used in building codes to interpret the obtain base shear that multiplied by the weight.

From the near fault ground motion of TCU052, TCU068, and TCU102. Take place the construction site is in Taichung city meanwhile Chi-Chi earthquake is a fault activity near Nantou county. Due to the site location and soil condition reason, design spectra of the original ground motion of TCU052, TCU068, and, TCU102 must be scaled to consider the existing condition of construction site. Figure 3.32 until figure 3.34 show the plot function of the response spectra of TCU052, TCU068, and TCU102 that normalized by the standard design spectra plot function of Taichung city, as mention before that the system that even though one system is larger than another one as long as the natural period and the damping ratio is the same, they will provide the same response, this concept applied to calculate the design spectra that in further these normalized ground motion shall be used as input of the ground motion data.

Response spectrum is the plot data of the original data as a function of accelerogram that had been filtering to be time history of the ground motion data as a function of the natural frequency or natural period, yet natural period is the preferred parameter that use as a response spectrum plot function. Related with equation 28, since the response of u(t) represent as D ($D \equiv u_0$), pseudo-acceleration function of the original ground motion A calculated from this equation:

$$A = \omega_n{}^2 D = (2\pi/T_n)^2 D \qquad \textit{Eq. 28}$$

Since structure natural period is the important parameter that need to consider to normalized the ground motion using response spectrum concept, structural mass of the bridge model as shown in figure 8 associated with the stiffness equivalent of the structure as a relation of $\omega_n = \sqrt{k/m}$ and $T_n = 2\pi/\omega_n$ then the value of bridge structural natural period computed as large as 0.539 sec.

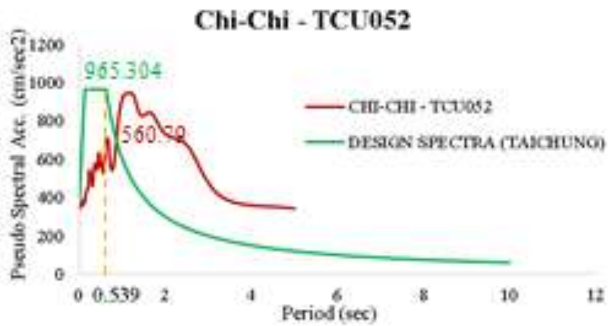


Fig. 11. Response spectrum design of TCU052

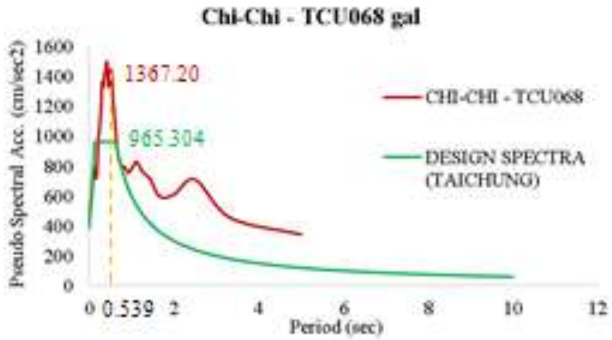


Fig. 12. Response spectrum design of TCU068

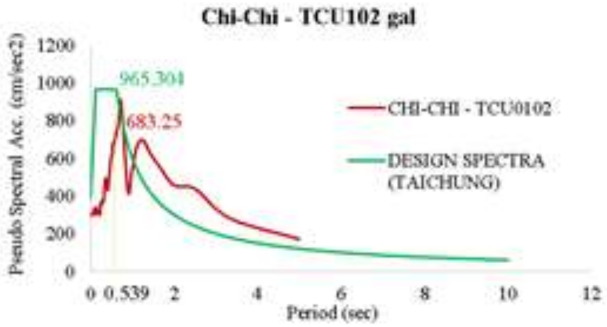
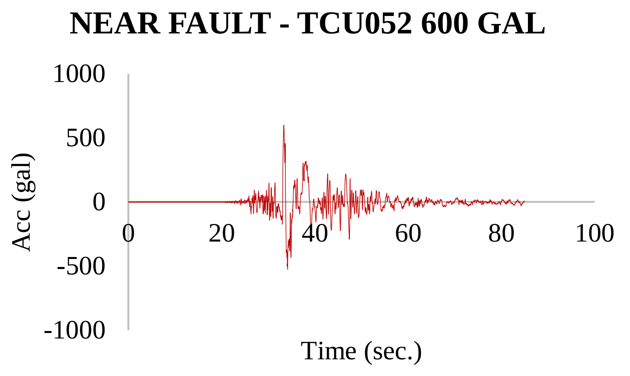


Fig. 13. Response spectrum design of TCU102

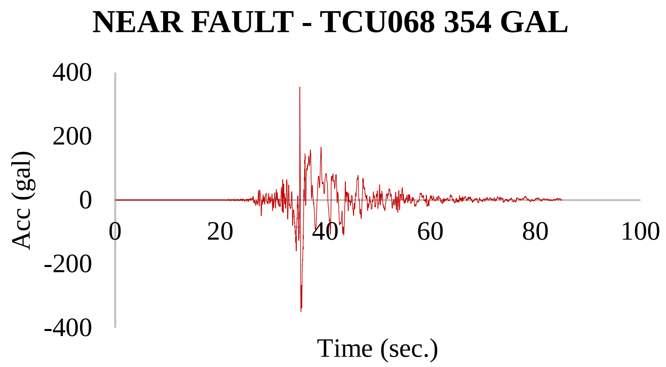
Standard design spectra that considering Taichung city as a site location, calculated using software of earthquake standard design that published by National Center Research of Earthquake and Engineering (NCREE) considering Taiwan building code. Response spectrum of the original ground motion TCU052, TCU068, and TCU102 plot merged with the standard design spectra based on Taiwan building code to find out how much scaling number that need to multiplied in original ground motion to calibrate based on the construction site condition. In a diagram of comparison between response spectrum design and standard design spectra, in a same value of structural period that computed as amount 0.539 sec, then the different value of pseudo-acceleration of both spectra can be found. Furthermore, the different value of pseudo-acceleration between response spectrum design and standard design spectra is the value of scaling that here in after used to scale the original ground motion to be normalized ground motion, then it can be calculated that the scaling factor of TCU052 is 1.721, TCU068 is 0.706, and TCU102 is 1.413.

Alfinna Mahya Ummati, Wang Chung-Yue, and Wisnumurti, “Design Spectra Analysis of Chi-Chi Earthquakes 1999 as a Normalized Ground Motions Input of Taichung City, Taiwan,” *International Research Journal of Advanced Engineering and Science*, volume 3, issue 3, pp. 157-163, 2018.

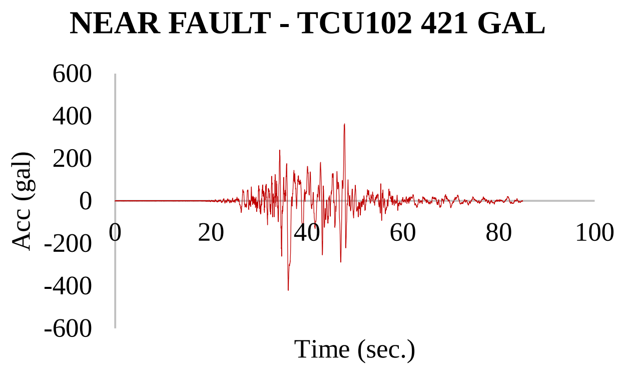
C. Normalized Ground Motions



(a)



(b)



(c)

Fig. 14. Normalized ground motions of (a) TCU052 (600 gal), (b) TCU068 (354 gal), and (c) TCU102 (421 gal).

Normalization means consider the site condition to find the scaling factor of the original ground motions. Figure 14 is the final ground motions after scaling. After these normalization procedure was done, then these will be the best loading input that applied to the model.

V. SUMMARY

Chi-Chi earthquake is the typical of the near fault ground motions that mostly considerable for earthquake engineer to analyze their building. Mostly engineer prefer to use directly of the original ground motion instead doing the normalization. Whereas these normalization of the ground motions input is the important procedure that should be done before the earthquake input applied to the model.

In this research, TCU052 (350 gal), TCU068 (500 gal), and TCU102 (300 gal) were proposed as the input of the ground motion. Considering the site condition of Taichung City, the response spectrum normalization had been done in order to find out the scaling factor of the original ground motion that was taken from Nantou City.

For the seismic record that had been proposed, the scaling factor of TCU052 is 1.721, TCU068 is 0.706, and TCU102 is 1.413. These scaling factor had been multiplied with the original ground motions, then the normalized ground motion that ready to input in the system will be 600 gal for TCU052, 354 gal for TCU068, and 421 gal for TCU102.

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