

# A PROPOSED METHOD FOR SELECTING AND SCALING RECORDED SEISMIC ACCELERATIONS ACCORDING TO TCVN-9386:2012

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## **Abstract**

Accelerogram is a significant input in seismic analysis of structures, particularly for performance-based seismic designs and for advanced technologies using nonlinear energy dissipation devices. However, in seismic regions like Vietnam, earthquake data is generally scarce. Vietnam Standard TCVN-9386:2012 mentions the use of recorded accelerogram for seismic analysis, although it contains shortcomings. The paper aims to detail the procedure of selecting and scaling recorded seismic accelerations according to requirements specified by TCVN-9386:2012. The target response spectrum and the fundamental vibration period of the considered structure are critical factors for the selecting and scaling process. The proposed procedure essentially includes converting the two original horizontal accelerations to the principal directions, correcting the relative proportion between the two acceleration components, determining the period range of interest, calculating the scaling factors, and verifying the 10% matching criteria. An example is conducted on a typical set of accelerations to detail the application of the proposed procedure. The results show that the response spectra of calibrated accelerations are consistent with the target spectrum and satisfy the requirements of TCVN-9386:2012, suggesting that the proposed method can be applied to the seismic analysis of structures with high reliability.

**Keywords:** elastic response spectrum; input ground motions; recorded seismic acceleration; selecting and scaling ground motion; response spectrum matching.

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## **1. Introduction**

In the seismic-resistant design of structures, the dynamic analysis method is preferred and considered to be more accurate when taking into account the dynamic properties of the structures, which have significant impacts on the seismic response as described in the codes and standards [1–4]. This method includes the two main approaches as modal response spectrum analysis and response history analysis. The first approach is performed on the (equivalent) linear elastic model of structures, using the elastic design spectrum as the impact of earthquakes on the structures. This approach has severe limitations for the design of structural buildings that rely on ductile inelastic response under the earthquake impacts, where the inelastic response is only approximated from elastic analysis results by the ductility ratio without predicting the nonlinear behavior of material/structural components, local inelastic deformation on critical elements, etc.

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The second approach is conducted on the linear and/or nonlinear structural model and the seismic input is time-history records. For this approach, the seismic demands are obtained solving at every time step (time histories) from the equation of motion of dynamic structure. Consequently, it provides a complete seismic linear/nonlinear response history of structures. This approach, therefore, plays a major role in performance-based seismic design. Furthermore, it is also particularly effective for the analysis of structures using seismic protection systems exhibiting nonlinear responses (energy dissipating devices, seismic isolation, etc.).

In this way, an ensemble of representative time-history records of earthquakes is required for the specified site, which represents essential ground motion parameters such as the response spectra, amplitude, frequency content, and duration, etc. Further, the selected ground motions need to be compatible with the level of seismic hazard probability considered for design. That context has provided a great challenge in ensuring the appropriate ground motion data in such earthquake regions in Vietnam, which meets the requirements of appropriate accelerograms specified in the design codes and standards [1–4], to serve as input excitations for nonlinear response history analyses.

Over the years, time-history acceleration used for earthquake analysis has been divided into three main sources, including artificial records compatible with horizontal elastic response spectrum from the codes and standards, synthetic records produced from seismological models, and accelerations recorded from real earthquakes.

Artificial accelerations are made to fit the target spectra by deriving a power function of spectral density from the smoothed response spectra and then generating harmonic signals with random phase directions and amplitudes. It often has an excessive number of strong-motion cycles, resulting in an impractically high energy content [5].

Synthetic acceleration can be generated using the seismological reference model and with path and location effects are taken into account. It requires a definition suited to the magnitude, rupture mechanism, geological conditions, and site of a specific seismic scenario. It causes difficulties in the context that these parameters are commonly unavailable, especially when employing seismic-resistant design codes and standards.

Recorded earthquake accelerations provide a lot of information regarding the ground shaking and carry all the earthquake characteristics (amplitude, frequency content, energy content, duration, and phase characteristics, etc.), as well as all of the factors that drive accelerations (characteristic of the source, path, and location) [2, 6]. Despite its undeniable advantages, instructions on selection and scaling this type of accelerations is not detailed in TCVN-9386:2012 [4].

This paper investigates the issue of selecting and scaling recorded time-history ground motions as input excitations for response history analyses of structures in specific seismic regions of Vietnam. The definition of the horizontal elastic response spectrum according to the Vietnam Standard (TCVN-9386:2012 [4]) is first outlined. The application of the standard guidelines for the selecting and scaling of recorded ground motion for the seismic analysis is summarized and clarified. Several additional requirements for selecting and scaling recorded time-history ground motion are considered. An example is performed for a set of three earthquakes including six acceleration records (a pair of orthogonal acceleration for each one), adopted the target spectrum of Thanh Xuan, Hanoi with soil type B and 5% damping ratio.

## 2. Overview the seismic action according to TCVN-9386:2012

### 2.1. Horizontal elastic response spectrum

According to TCVN-9386:2012, for the seismic action, the elastic response spectrum of the horizontal components  $S_e(T)$  is determined as the following:

$$\begin{aligned} 0 \leq T \leq T_B : S_e(T) &= a_g S [1 + (2.5\eta - 1) T/T_B] \\ T_B \leq T \leq T_C : S_e(T) &= 2.5a_g S \eta \\ T_C \leq T \leq T_D : S_e(T) &= 2.5a_g S \eta (T_C/T) \\ T_D \leq T \leq 4s : S_e(T) &= 2.5a_g S \eta (T_C T_D/T^2) \end{aligned} \quad (1)$$

where  $S_e(T)$  is the elastic response spectrum;  $T$  is the vibration period;  $T_B, T_C, T_D$  are the parameters of spectral acceleration branch;  $S$  is the scaling factor (soil factor);  $a_g$  is the design ground acceleration on type A ground;  $\eta$  is the damping factor, determined by the viscous damping ratio of structure  $\xi$  (%) with different expressions between TCVN-9386:2012 [4] and Eurocode 8 [3]. In the framework of this paper, the viscous damping ratio is taken  $\xi = 5\%$  then  $\eta = 1$ .

The elastic displacement spectrum  $S_{de}(T)$  is calculated through the elastic acceleration response spectrum as the following:

$$S_{de}(T) = S_e(T) (T/2\pi)^2 \quad (2)$$

For the periods longer than 4.0s, based on Eurocode 8 [3], the elastic acceleration response spectrum may be obtained from the elastic displacement spectrum  $S_{de}(T)$ , where  $S_{de}(T)$  is defined as the following expressions [4]:

$$\begin{aligned} T_E \leq T \leq T_F : S_{de}(T) &= 0.025a_g S T_C T_D \left[ 2.5\eta + \left( \frac{T - T_E}{T_F - T_E} \right) (1 - 2.5\eta) \right] \\ T_F \leq T : S_{de}(T) &= 0.025a_g S T_C T_D \end{aligned} \quad (3)$$

where  $T_E, T_F$  are the parameters of spectral acceleration branch.

Accordingly, the elastic acceleration response spectrum, with 5% damping ratio, for the location of Thanh Xuan - Hanoi ( $a_g = 0.1097g$ ) is determined as shown in Fig. 1.

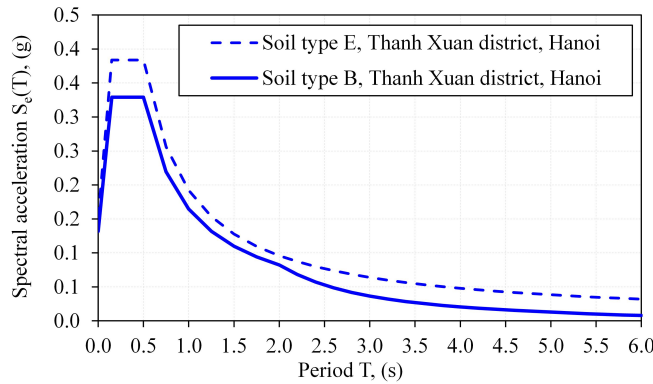


Figure 1. Horizontal elastic response spectrum according to TCVN 9386:2012

## 2.2. Selection and scaling recorded accelerograms

### a. Selection ground motion records

The standard specified that the seismic motion is also represented in terms of time-history records (acceleration, velocity, displacement). The selected records should be “adequately qualified with regard to the seismogenetic features of the sources and to the soil conditions appropriate to the site”.

A minimum of 3 accelerograms should be used for time-history analyses. For analysis of a spatial model of the structure, the seismic motion shall consist of three simultaneously acting accelerograms (including two horizontal components and a vertical component), and the same accelerogram may not be used simultaneously along with both horizontal directions. Further, the seismic wave components must be uncorrelated among themselves, as well as the two horizontal orthogonal components must be “statistically independent”.

### b. Scaling accelerations

The scaling time-history accelerations must be performed with consideration of the design spectrum over a range of periods that extends from a period of  $0.2T_1$  to  $2T_1$ , where  $T_1$  is the fundamental period of the considered building in the investigated direction. In addition, the lower bound shall be smaller the period of the highest mode required to achieve 90% mass participation ( $T_{90\%}$ ), and the upper bound need to be longer the time which most of the earthquake energy stored in such regions (the period of 1.5s is recommended [2]). In such context, the period range can be considered as:

$$T_{min} = \min(0.2T_1, T_{90\%}), \quad T_{max} = \max(2T_1, 1.5s)$$

The response spectrum values of selected accelerations are scaled to the value of  $a_g S$  for the zone under consideration and should be matched to the target spectrum. Namely, the values of mean response spectra at  $T = 0$  s ( $S_g^{(0)}$ ) should not be smaller than the value of  $a_g S$  for the site. In the considered period range, no value of the mean elastic spectrum (with 5% damping ratio) of selected accelerations ( $S_g$ ) should be less than 90% of the corresponding value of the elastic response spectrum ( $0.9S_e$ ) (10% matching criteria). The matched conditions are illustrated in Fig. 2.

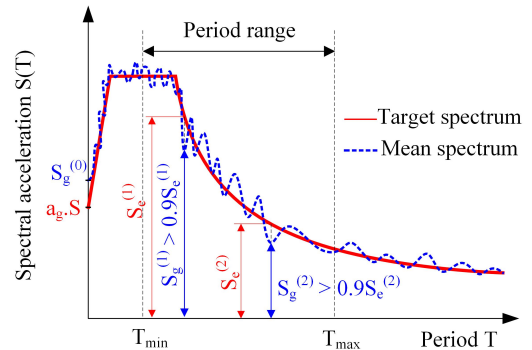


Figure 2. Illustration of 10% matching criteria of the scaling ground motion by TCVN-9386:2012

## 3. Method of transformation and scaling of ground motions

### 3.1. Transformation of ground motions

The seismic motions occur in all three directions in space simultaneously: two horizontal directions and one vertical direction. These three components of seismic motion are generally recorded in arbitrary directions [two (a pair) orthogonal horizontals and one vertical]. In the majority of cases, these records are correlated since they are records with an orientation of the “accelerograph orientation”. Thus, they must be rounded about the vertical axis in order to transform to be “statistically independent”, as required by current codes and standards [1–4].

Penzien and Watabe [7] demonstrated that there are directions (major and minor) in which seismic motion is most energetic. These directions, called principal directions, are such that the components of



the seismic motion are statistically independent. The transformation of the two horizontal components of the seismic motion in the principal directions is carried out according to a process similar to the calculation of principal stresses. Accordingly, the degree of correlation between the pair of orthogonal horizontal components ( $a_x$  and  $a_y$ ) of the selected seismic motions is determined over the entire duration  $t$  of earthquakes using the correlation coefficient  $\rho(a_x, a_y)$ , given by the following equation [8]:

$$\rho(a_x, a_y) = \frac{\int_0^t a_x \cdot a_y d\tau}{\sqrt{\int_0^t a_x^2 d\tau \int_0^t a_y^2 d\tau}}; \quad -1 \leq \rho(a_x, a_y) \leq 1 \quad (4)$$

The horizontal orthogonal axes are then rotated relative to the original axes by an angle  $\varphi$  until the correlation coefficient  $\rho(a_x, a_y)$  is zero. The angle thus found represents the orientation angle of the principal directions of the seismic motion (Fig. 3).

Once the principal directions are identified, the seismic signals are transformed using equation (5) as follows:

$$\begin{Bmatrix} a_{x,t} \\ a_{y,t} \end{Bmatrix} = \begin{bmatrix} \cos \varphi & \sin \varphi \\ -\sin \varphi & \cos \varphi \end{bmatrix} \begin{Bmatrix} a_{x,o} \\ a_{y,o} \end{Bmatrix} \quad (5)$$

where,  $a_{x,o}$  and  $a_{y,o}$  represent the original horizontal components recorded along the original orthogonal directions ( $x_o, y_o$ );  $a_{x,t}$  and  $a_{y,t}$  are the orthogonal components transformed to the principal directions ( $x_t, y_t$ ).

The procedure of transformation selected real accelerograms is illustrated in Fig. 4.

### 3.2. Scaling of ground motion

Various scaling methods have been studied such as frequency-domain and time-domain spectral matching techniques. These techniques are commonly used for artificial accelerations and synthetic accelerations [9–15]. Generally, they may be used with caution, especially in the context of nonlinear structural analysis, by carefully evaluating the behavior of the accelerations, velocity, and displacement traces, including the presence of acceleration pulses, before and after spectral matching.

For recorded ground accelerations, the relative proportion exists among the earthquake components that impose special requirements to ensure that

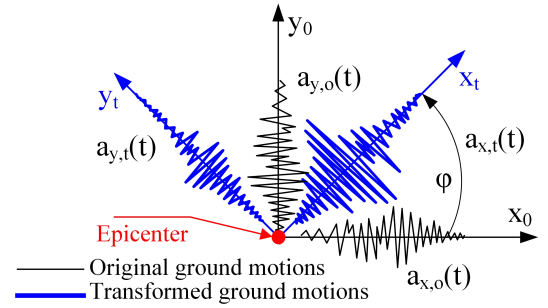


Figure 3. Principle of earthquake signal transformation into the principal directions

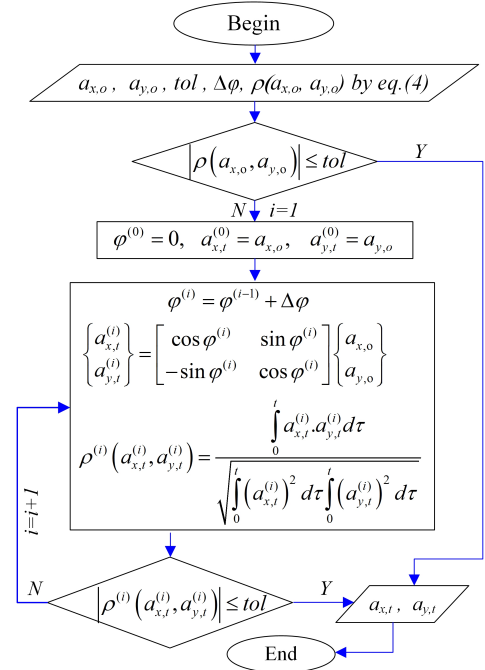


Figure 4. Block diagram of transformation of accelerations

the used acceleration reflects the significant energy content of the earthquake. According to López et al. [16], for each ground motion, the spectra are scaled by dividing by the peak acceleration of major component, that is used to build design spectra, to be consistent with the normalization criteria, which is commonly adopted in structural engineering application [17] and the design codes. Generally, the ratio of the minor and the major horizontal spectra is always less than 1, and the values that vary between 0.63 and 0.81 are recommended for use in design codes [16], namely:

$$0.63 \leq \gamma = \frac{A_{m,minor}}{A_{m,major}} \leq 0.81 \quad (6)$$

where,  $A_{m,minor}$  and  $A_{m,major}$  are the coefficient of minor component and major component that are determined as the following:

$$A_{m,minor} = \frac{1}{n} \sum_{i=1}^n \frac{S_{g,minor}^{scaled-1}}{S_{g,major}^{scaled-1}(T=0)} g; \quad A_{m,major} = \frac{1}{n} \sum_{i=1}^n \frac{S_{g,major}^{scaled-1}}{S_{g,major}^{scaled-1}(T=0)} g \quad (7)$$

$S_{g,minor}^{scaled-1}$ ,  $S_{g,major}^{scaled-1}$  are the response spectra of selected accelerogram after preliminary scale.

The methodology proposes herein considers as a linear scaling to match, evaluated by the average of the ratios between the recorded ground motion spectra and the target spectrum within the period range. In order to detail the specified requirements above, for each ground motion, a pair of accelerograms are considered for calibration. Without loss of generality, it can assume that the major component acceleration is in the x-direction, accordingly,  $A_{m,major} = A_{m,x}$  and  $A_{m,minor} = A_{m,y}$ . The procedure for scaling a pair of recorded ground motions includes two phases as follows:

*Phase I: linear scaling to match the target spectrum*

- Calculate the target spectrum ( $S_e$ ) according to TCVN-9386:2012;
- Identify the period range ( $T_{min}, T_{max}$ ) based on the fundamental period of vibration ( $T_1$ ), period step size to calculation ( $\Delta T$ ) in the period range. The numbers of period step:  $n = (T_{max} - T_{min})/\Delta T + 1$ ;
- Determine the response spectra of recorded ground motion (ground spectra,  $S_g$ );
- Calculate the difference between the target spectrum and ground spectra for each period step “ $i$ ” ( $\Delta D_{i(x|y)}^{scaled-1}$ ) as the following equation:

$$\Delta D_{i(x|y)}^{scaled-1} = S_{e,i} / S_{g(x|y),i}, \quad i = 1 \div n \quad (8)$$

Note that the index  $(x|y)$  is respectively assigned to the seismic wave components in the  $x$  and  $y$  directions.

- Determine the preliminary scaling factor  $f_p$  as the following equation:

$$f_{p(x|y)} = \left( \sum_{i=1}^n \Delta D_{i(x|y)}^{scaled-1} \right) / n \quad (9)$$

In the case of a set consisting of multiple earthquakes being considered for analysis, ground motions with the lowest  $f_{p(x|y)}$  are preferred for calibration.

- Verify the correlation between two accelerograms of each earthquake, validate the ratio of the spectrum between the minor component and the major one in order to redistribute the energy content between the two components by equation (6). In this study, the authors choose  $\gamma = 0.7$  (the mid-value of the recommended range).

- The normalized scaling factor  $f_{n(x|y)}$  is determined for such period range as the following:

$$f_{n,y} = \sqrt{\frac{0.7A_{m,x}}{A_{m,y}}}; \quad f_{n,x} = \frac{1}{f_{n,y}} \quad (10)$$

- The first scaling factor is calculated as:

$$f_{1(x|y)} = f_{p(x|y)} \times f_{n(x|y)} \quad (11)$$

*Phase II: calibrate the scaled ground motion to meet the requirements of the code*

- The original accelerogram is multiplied by scaling factor  $f_{1(x|y)}$ , determine the response spectra of normalized scaled ground motions ( $S_{g(x|y)}^{scaled-1-N}$ ) and calculate the mean spectra of each pair.

$$S_{g\_mean}^{scaled-1-N} = (S_{g,x}^{scaled-1-N} + S_{g,y}^{scaled-1-N}) / 2 \quad (12)$$

- Determined the scaling factor  $f_2$  based on the minimum value of the ratio ( $R_i$ ) of  $S_{g(x|y)}^{scaled-1-N}$  and  $S_e$  for each period step “ $i$ ”:

$$R_i = S_{g\_mean,i}^{scaled-1-N} / S_{e,i}, \text{ assume that } \delta = \min(R_i) \text{ at } i = k, k \in [1 \quad n];$$

$$\begin{cases} f_2 = 0.9 S_{e,k} / S_{g\_mean,k}^{scaled-1-N} & \text{if } \delta < 0.9; \\ f_2 = 1 & \text{if } \delta \geq 0.9. \end{cases} \quad (13)$$

The factor  $f_2$  must be satisfied that:  $f_2 S_{g\_mean}^{scaled-1-N} (T = 0) \geq a_g S$

- The final scaled accelerogram is obtained by multiplying the transformed acceleration by  $f_1$  and  $f_2$ .

### 3.3. Main steps of proposed procedure

Based on the above describes, the proposed procedure of selecting and scaling of recorded accelerations include the following main steps:

- Determination of a design spectrum corresponding to the TCVN 9386:2012 as the target spectrum.
- Determination of a period range  $[T_{min} \quad T_{max}]$  based on the dynamic response of structures.
- Selection of appropriate accelerations, essentially based on the seismic characteristics, including the magnitude and the hypocenter distance.
- Transformation of original acceleration to the principal directions, including major and minor components.
- Determination of scaling factor 1, including preliminary scaling factor and normalized scaling factor.

Determination of scaling factor 2 based on the “10% matching criteria”.

## 4. Application examples

The reference soil classification, site class B, proposed by TCVN-9386:2012 [4] was selected as the fundamental site condition for this analysis. The horizontal elastic spectrum for the location of Thanh Xuan district, Hanoi, with seismic hazard for a probability of 10% in 50 years and 5% damping, is illustrated in Fig. 1.

Suitable ground motions should be selected considering the magnitudes and distances that control the seismic hazard at a given site. In the framework of this study, an appropriate range of magnitudes ( $M_w$  varies from 6.0 to 7.0) and distances to earthquake sources (from 10 km to 45 km) are considered for a representative analysis of Thanh Xuan, Hanoi. Magnitude and distance definitions used in this study are based on assessments of the similarity of the moderate seismic regions as the results earthquake's characterizations and seismic zoning by Nguyen and Guizani [18].

#### 4.1. Selection of ground motions

According to the above discussions, a suite of 3 earthquakes including 6 components of accelerations (a pair orthogonal acceleration for each) is considered, as shown in Table 1. The used ground motions are represented for moderate-to-large events through the peak ground accelerations (PGA) and also for near-to-far fields for such regions. Note that, due to the author's lack of suitable earthquake data, the available accelerograms are selected in order to illustrate in detail the sequence of the proposed procedure. In the case of selecting more suitable data, better results can be reached.

Table 1. Earthquake records considered for transformations

Earthquake	Station	$M_w$	Hypocenter distance (km)	PGA (g)	
				$a_x$	$a_y$
El Centro, 1940-05-19	CA - Array Sta 9; Imperial Valley Irrigation District	6.9	12.2	0.355	0.5218
Chi-Chi, 1999-09-25	TCU079, Taichung, Taiwan	6.3	20.2	0.774	0.622
North Island, 2014-01-20	Woodville Police Station, New Zealand	6.1	45.6	0.26	0.14

#### 4.2. Transformation of ground motions

For each selected pair of ground motions, the transformation of the two components to the principal directions is performed, described in section 3.1 and the block schema in Fig. 4, to ensure that their correlation is null.

Table 2 presents the results of the transformation, with a comparison of the correlation coefficient ( $\rho$ ) before and after the transformation, and the rotation angle ( $\varphi^\circ$ ) of each pair around its vertical component.

Table 2. Earthquake records selected for transformations

#	Earthquake records	$\rho_o$ (original)	$\varphi^\circ$	$\rho_t$ (transformed)
1	El Centro, 1940-05-19	-0.178	67.1	-0.00088
2	Chi-Chi, 1999-09-25	0.342	24.9	0.00025
3	North Island, 2014-01-20	-0.145	10.4	0.00014

The transformed acceleration components are therefore statistically independent. The energy content of each earthquake is then clearly distinguished for major component and minor component, as shown in Fig. 5 for a typical case of the El Centro earthquake.

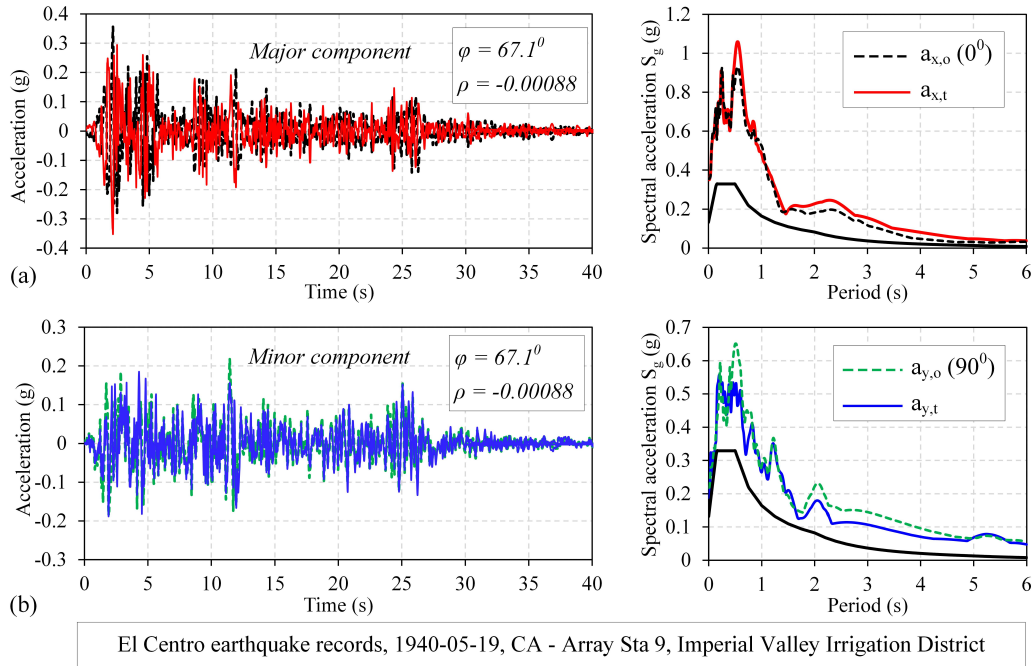


Figure 5. Transformation of ground motion accelerations (El Centro earthquake)

Accordingly, from the response spectra of each component, the peak value of the transformed major component is significantly higher than the original components. The opposite is found for the minor component (see in Fig. 5).

#### 4.3. Scaling ground motion to match the target spectrum

A multi-story reinforced concrete building (11 floors) is considered according to our previous publication [19], the essential vibration periods of structure are obtained as  $T_1 = 1.07$  s,  $T_{92\%} = T_3 = 0.13$  s [19]. The period range is determined:  $T_{\max} = 2.0$  s,  $T_{\min} = 0.13$  s. This period interval also represents for other structures [20].

Based on the criteria of scaling ground motion presented in section 3.2, the preliminary scaling factor ( $f_p$ ) is determined for each component by formula (9). The obtained results (scaled-1) of each component are plotted in Fig. 6.

From the preliminarily scaled pair of accelerations, the normalized scaling factors ( $f_n$ ) are then calculated by formula (10) in order to redistribute the energy content between the major component and the minor one. The results are plotted in Fig. 7.

As the above discussion, the mean spectra of a pair scaled acceleration must be at least 90% of the target spectrum (the 10% matching criteria) over the considered period range. In cases that this condition is not met, a second scaling factor ( $f_2$ ) needs to be taken into account where  $f_2 \geq 1$ . Accordingly, the factor  $f_2$  is determined by formula (13) for both components. Fig. 8 shows a comparison of time-history accelerations and their response spectra of original accelerogram versus the matched one

for the El Centro earthquake. It demonstrates that the response spectra of each matched acceleration are in good consistent with the target spectrum.

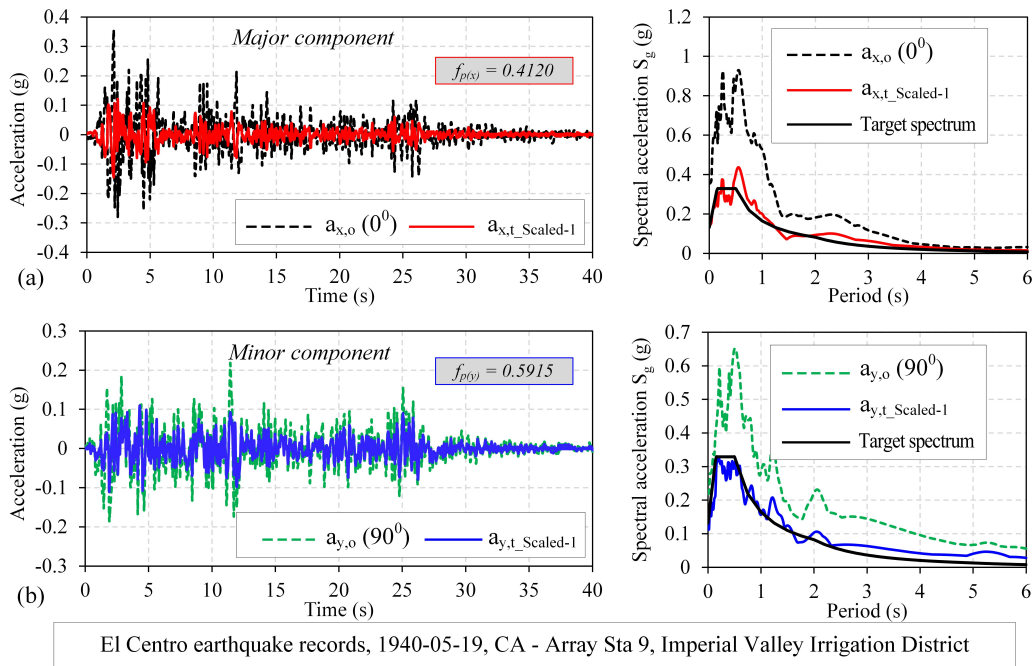


Figure 6. Comparison of original and preliminary scaled ground motion: (a) Major acceleration components, (b) Minor acceleration components

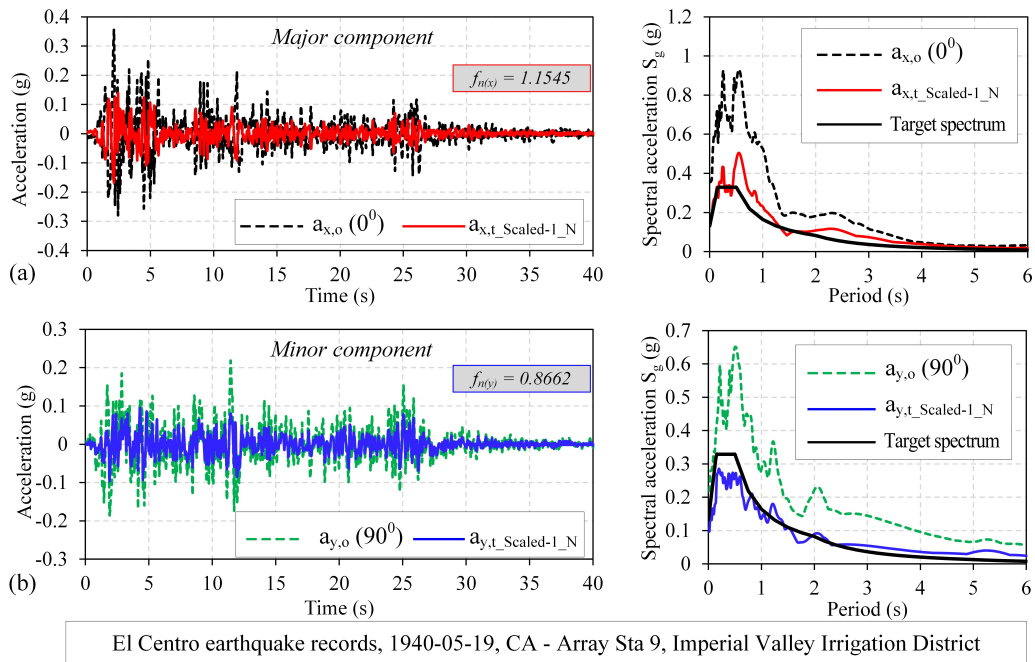


Figure 7. Comparison of original and normalized scaled ground motion: (a) Major acceleration components, (b) Minor acceleration components

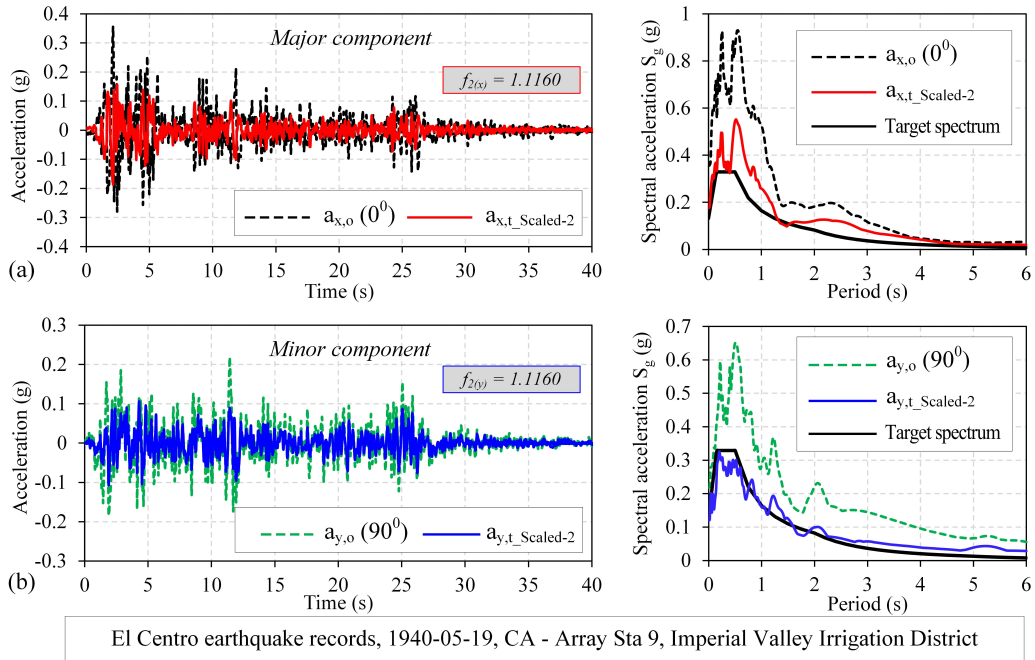


Figure 8. Comparison of original and scaled-2 (matched) ground motion adopted the target spectrum:  
(a) Major acceleration components, (b) Minor acceleration components

#### 4.4. Verification of the code requirements

The matching criteria is validated as illustrated in Fig. 9 where the mean response spectra at  $T = 0$  s of considered ground motions is higher than  $a_g S$ . Further, in the investigated period range, no value of the mean response spectra is less than 90% of the corresponding value of the elastic response spectrum.

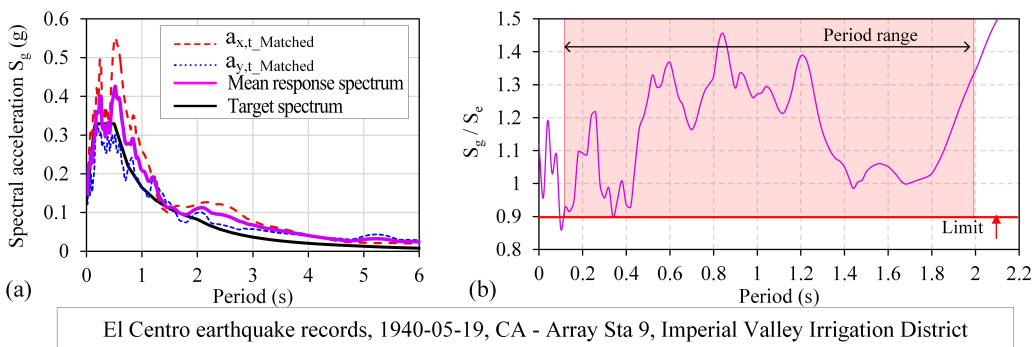


Figure 9. Response spectra for matched El Centro earthquake records: (a) Spectral acceleration, (b) differences between the mean spectra of selected records and the target spectrum of Thanh Xuan, Hanoi, soil class B, 5% damping

Similarly for remaining earthquakes, the obtained values of scaling factor for each accelerograms are presented in Table 3. The mean spectra of each pair and target spectrum are plotted in Fig. 10(a). The differences between these response spectra and the target spectrum are shown in Fig. 10(b).



Table 3. Scaled factors of selected ground motions

#	Earthquake records	Component	Scaling factor	
			(Eq. (11))	(Eq. (13))
1	El Centro, 1940-05-19 transformed	$a_{x,t}$	0.476	1.116
		$a_{y,t}$	0.5124	
2	Chi-Chi, 1999-09-25, transformed	$a_{x,t}$	0.490	1.693
		$a_{y,t}$	0.511	
3	North Island, 2014-01-20, transformed	$a_{x,t}$	1.624	1.321
		$a_{y,t}$	1.355	

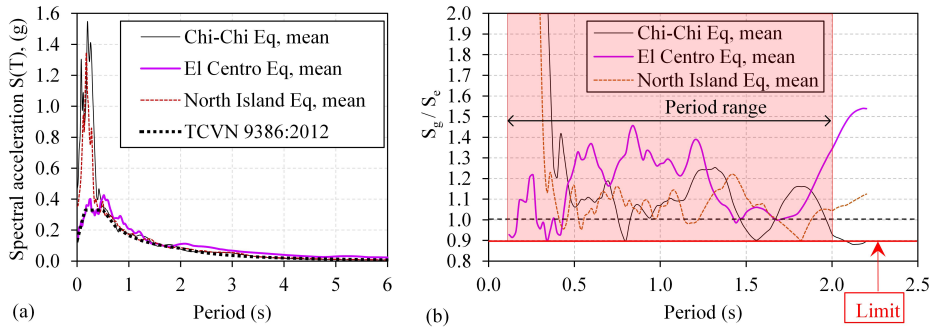


Figure 10. (a) Spectra of the selected and scaled ground motions, and (b) differences between the mean spectra of selected records, adopted the target spectrum

#### 4.5. Discussion

The methodology for selecting and scaling the recorded accelerations is applied for a suite of earthquake data to match their response spectra with the target spectrum and responds to the 10% matching criteria according to TCVN-9386:2012. For this process, the response spectral values over the period range (even for longer periods) are satisfied the matching condition. However, for very short periods, the obtained results present significantly higher values than the target spectrum, which tends to increase the conservative analysis results, especially for Chi-Chi earthquake and North Island earthquake. However, these differences can be resolved if the ground motions are scaled for multiple scenarios with shorter period range. Further, these large differences mostly correspond to high-order frequency response, which are located far from the fundamental period of the structure, have small impacts on the results. On the other hand, the mean response spectra of each pair seem to be higher (about 10% to 20%) than the target spectrum, suggesting that the using these scaled accelerations for response history analysis, the seismic response of structure tends to be conservative.

#### 5. Conclusions

In this paper, a summary of the methodology and criteria for selecting and scaling historical ground motion is presented according to the Vietnam Standard TCVN-9386:2012. A proposed procedure of selection and scaling of accelerograms, where some specific techniques are particularly applied for the recorded accelerations to match the target spectrum, is detailed. The application of the proposed procedure for TCVN 9386:2012 was illustrated by a typical example of three earthquake events that are matched to the horizontal elastic response spectrum of Thanh Xuan, soil class B, and 5% damping. The results show that the proposed procedure is highly effective, providing an effective solution in calibrating the ground accelerations for seismic time-history analysis.

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