

RESPONSE SPECTRAL MATCHING OF BI-DIRECTIONAL HORIZONTAL GROUND MOTION TO ORIENTATION-INDEPENDENT SPECTRUM

Kyoto University Student Member ○Jian Zhou
Kyoto University Regular Member Akira Igarashi

1. INTRODUCTION

Whether designing new structures or evaluating the expected performance of existing structures, the proper input ground motion for time history analysis is critical. The orientation-independent spectrum, RotDnn, is a measure of the bi-directional ground motion intensity expressed by the n th percentile of the spectral response values overall orientations. The RotD100 is becoming a widely accepted intensity measure for bi-directional ground motion of many design codes. In this paper, a new algorithm to process the bi-directional seed ground motion to be compatible with the target RotDnn response spectrum using complex discrete Fourier transform is described.

2. COMPLEX DISCRETE FOURIER TRANSFORM

The complex discrete Fourier transform (CDFT) can calculate the Fourier transform of two real-valued ground motion records of N sample points simultaneously by assigning one record $x(n)$ as the real part and the other record $y(n)$ as the imaginary part of a complex-valued record $z(n)$. In the equation form, it is given by:

$$z(n) = x(n) + iy(n) \quad n = 0, 1, \dots, N-1 \quad (1)$$

where i is the symbol of imaginary unit. CDFT of the record is given by Eq. (2):

$$Z(\omega_k) = \sum_{n=0}^{N-1} z(n) e^{-i\omega_k n} \quad k = 0, 1, \dots, N-1 \quad (2)$$

where $Z(\omega_k)$ is the result of CDFT, and $\omega_k = 2\pi k / N$. The inverse CDFT (ICDFT) is given by Eq. (3):

$$z(n) = \frac{1}{N} \sum_{k=0}^{N-1} Z(\omega_k) e^{i\omega_k n} \quad n = 0, 1, \dots, N-1 \quad (3)$$

Both CDFT and ICDFT can be computed by the standard fast Fourier transform (FFT) procedure. It is usually assumed that the first $N/2$ of the N Fourier transform samples $Z(\omega_k)$ obtained by CDFT corresponds to positive frequencies between zero and the Nyquist frequency, while the rest of samples correspond to negative frequencies, implying that $Z(-\omega_k) = Z(\omega_{N-k})$.

3. PROPOSED ALGORITHM BASED ON CDFT

The procedure of modifying ground motion records to be compatible with the target response spectrum can be stated as an optimization problem which needs iteration. In order to solve this problem, the Fourier spectrum $Z_j(\omega_k)$ at j th iteration step is modified by using Eq. (4):

$$Z_{j+1}(\omega_k) = \frac{\bar{S}_a(\omega_k)}{S_{aj}(\omega_k)} Z_j(\omega_k) \quad j = 1, 2, \dots \quad (4)$$

where \bar{S}_a is the target RotDnn response spectrum, S_{aj} is the RotDnn response spectrum estimated at the j th iteration, and $Z_{j+1}(\omega_k)$ is the updated Fourier spectrum. Then, the spectral matching can be done using the step-by-step procedure illustrated in Fig. 1.

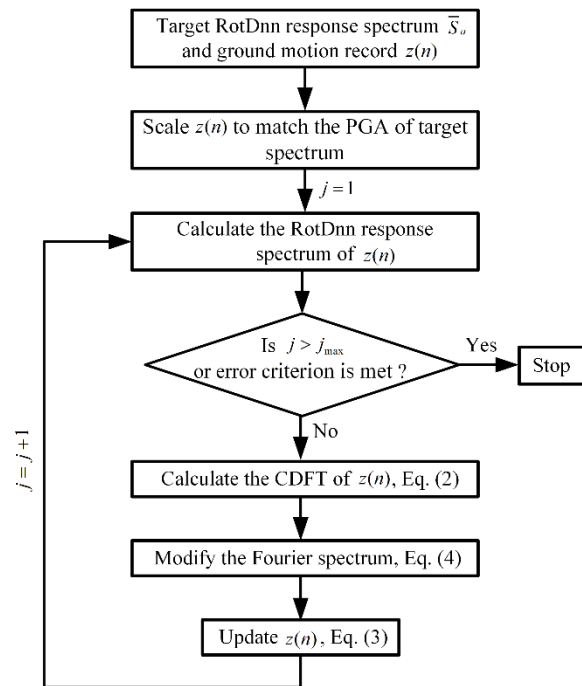


Fig. 1 The proposed algorithm.

The iterative process may be concluded when j reaches the maximum number of iteration, j_{max} , or the convergence error criterion is fulfilled. As described previously, attention should be paid that $Z(-\omega_k) = Z(\omega_{N-k})$, thus, the value of the modification factor for $Z(\omega_{N-k})$ should be the same as that of $Z(\omega_k)$ for $k = 0, 1, 2, \dots, N/2-1$.

4. TARGET SPECTRA AND SEED RECORDED GROUND MOTIONS

Two response spectra are selected as the target RotD100

Keywords: Spectral matching, RotDnn, bi-directional ground motion, seismic input
Contact address: Gokasho, Uji-shi, Kyoto, 611-0011, Japan, Tel: +080-9500-3705

response spectra for the numerical example. The first one is determined through the Chinese Code for seismic design of urban bridges (CJJ). The second target response spectrum is a standard ASCE 7-16 Risk-Targeted Maximum Considered Earthquake (MCER) response spectrum. Twenty pairs of horizontal ground motions are randomly selected from the Pacific Earthquake Engineering Research (PEER) center database. Fig. 2 shows the target CJJ and ASCE response spectrum together with the original RotD100 response spectra from the seed bi-directional ground motions.

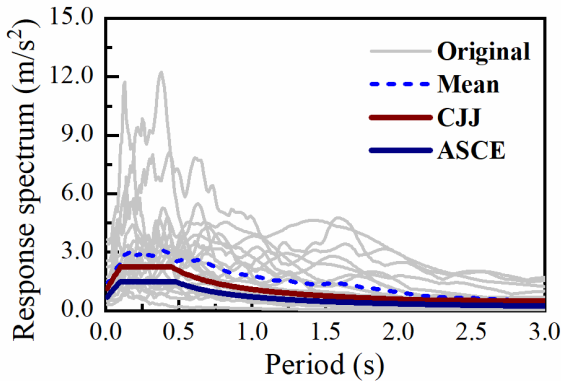


Fig. 2 RotD100 response spectra for the seed bi-directional ground motions together with their mean value and the two target spectra.

5. RESULTS

Fig. 3 presents the results for the CJJ and ASCE target RotD100 response spectra obtained using the proposed method after 10 iterations. A good coincidence between the target spectrum and the mean value of the twenty pairs of modified bi-directional accelerogram is achieved. Even though the maximum deviation is 30% between the individual and the target spectra, the error between the mean value and each target spectrum is lower. The maximum deviation between the mean value and the target spectrum for the CJJ case and that for the ASCE case are 12% and 9%, respectively.

Fig. 4 shows an example of the acceleration time history results obtained for a single record using the direct scaling (Step 2 in Fig. 1) and the proposed method. The seed ground motion corresponds to the 1984 M6.19 Morgan Hill earthquake and is matched to the CJJ target spectrum. It can be seen that the horizontal EW and NS components preserve the phase characteristics from the seed ground motions.

6. CONCLUSIONS

An algorithm for spectrally matching the bi-directional ground motion with a target RotDnn response spectrum is proposed. The algorithm is based on the complex discrete Fourier transform and iterative manipulation of the two horizontal components of the seed record. In the numerical example, two different spectra are specified as the target RotD100 spectra to demonstrate successful match results. The proposed method can be used to match any other target RotDnn response spectra, including the median spectrum (RotD50).

REFERENCES

- JRA. Design Specification for Highway Bridges, Part V, Reference materials for seismic design. JRA; 2015.
Code for seismic design of urban bridge (CJJ 166-2011). Beijing: China Architecture and Building Press; 2011.
Minimum design loads for buildings and other structures. American Society of Civil Engineers; 2013.

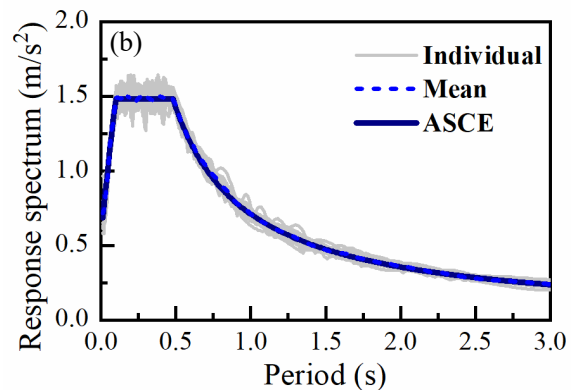
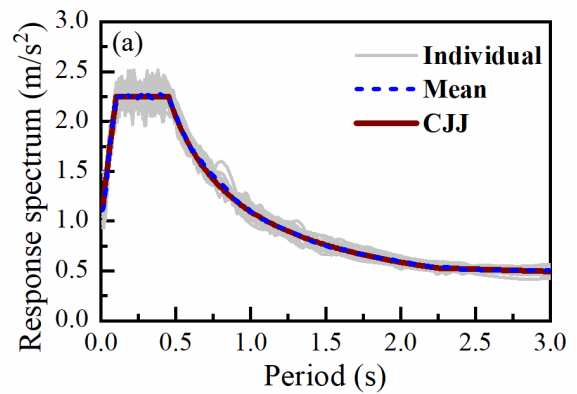


Fig. 3 Results obtained using the proposed method matching with the target RotD100 response spectra. (a) CJJ; (b) ASCE.

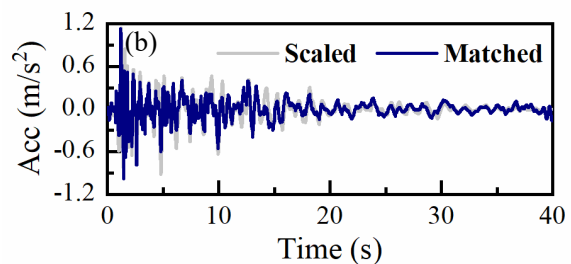
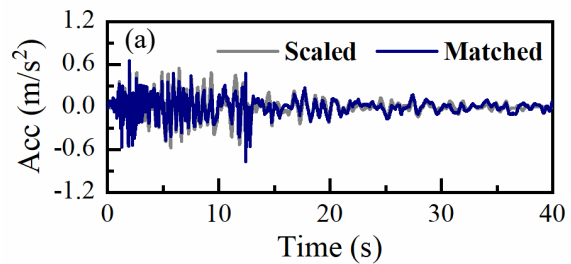


Fig. 4 Acceleration time history for the seed scaled ground motion and the RotD100 spectrally matched ground motion. (a) EW component; (b) NS component.