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Modified Equivalent Sinusoidal-Deformation to Evaluate Viscoelastic Damper under Long-Duration Wind Loading (Part 2: Equivalence considering Spectral Approach)

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Viscoelastic Damper Wind Loading Dynamic Response Spectral Approach
Modified Equivalent Sinusoid Frequency Sensitivity

1. INTRODUCTION

As reported in Part 1, the cumulative dissipated energy from the analysis of VE damper using the calculated equivalent-sinusoidal deformation [1] varies significantly to that of the random deformation. This was particularly observed in the along-wind direction cases only. This is because the response in this direction contains more low-frequency component than the across-wind direction response. This paper, therefore, proposes a modification of the equivalent-sinusoidal deformation by considering spectral approach used in wind engineering.

2. DYNAMIC RESPONSE TO WIND LOADING

2.1 Random Vibration or Spectral Approach

Figure 1 shows the random vibration approach to resonant dynamic response of structures against wind loadings outlined by Davenport [2]. Here, the spectral density, which primarily uses the frequency domain, is used to perform calculations (e.g., gust spectrum, wind force, and structure responses).

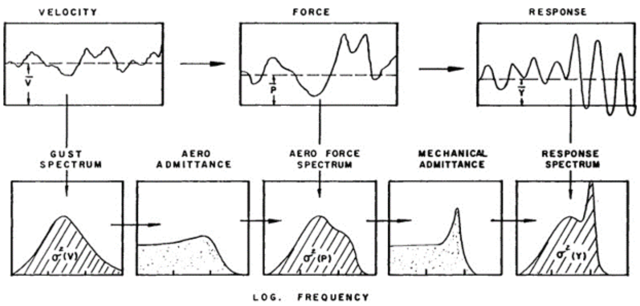

Figure 1. The random vibration (frequency domain) approach to resonant dynamic response [2].

2.2 Components of Dynamic Response of Buildings

As in Figure 2, the response spectrum determined from the random vibration approach (Figure 1) [2] has the background and resonant components. The broadband background component B represents the quasi-static response due to the wind gust lower than the natural frequency of the structure, thus, similar shape to wind force spectrum. The narrowband resonant component R represents the structure response due to resonance [3].

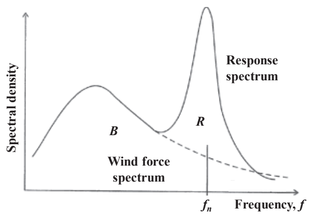

Figure 2. Background and resonant components of response [3].

2.3 Viscoelastic Damper Deformation due to Wind Loading

In principle, viscoelastic (VE) damper employed to tall buildings will deform in similarly to that of the building dynamic response. Therefore, the VE damper deformation and building response will have similarly shaped spectra.

In Figure 7 of Part 1, the power spectral density (PSD) plot of the damper deformations due wind loading are shown. The along-wind deformation contains significant amount of low-frequency background component, while the across-wind deformation has otherwise. Since VE dampers are highly sensitive to excitation frequency, the individual effects of the low-frequency broadband background component and high-frequency narrowband resonant component are considered in modifying the equivalent-sinusoidal deformation.

3. EQUIVALENCE BY SPECTRAL APPROACH

Figure 3 shows the VE damper analysis using the modified equivalent-sinusoidal deformation.

First, quasi-static frequency f_{qs} is considered. According to Ogawa et al. [4], f_{qs} is reasonably equal to 1/3 of f_n. Dynamic response lower than f_{qs} will be considered to be background component, and those higher than f_{qs} will be considered to be resonant component.

The original random damper deformation u_d will be filtered using low-pass filter and high-pass filter to determine the random damper deformation corresponding to the background and resonant components, respectively.

From these filtered random deformations, the equivalent-sinusoidal background and resonant deformations are determined using the same calculation technique by Sato et al. [1] (See Equation (1) in Part 1). Accordingly,

$$f_{r,B} = N^{+}_{0,B} / t_a \text{ , and } A_{r,B} = \sigma_{u,B}\sqrt{2} \text{ ,} \qquad \text{(1a, b)}$$

$$f_{r,R} = N^{+}_{0,R} / t_a \text{ , and } A_{r,R} = \sigma_{u,R}\sqrt{2} \text{ .} \qquad \text{(2a, b)}$$

The VE damper is then analyzed using the LD model [3] mentioned in Part 1 considering the modified equivalent-sinusoidal deformations. The same 1D heat transfer coefficients $\alpha_{c,out}$ and $\alpha_{c,in}$ from Part 1 are used.

Results from the VE damper analyses using the equivalent-sinusoidal background and resonant deformations are then combined, and compared with those from the original random deformation.

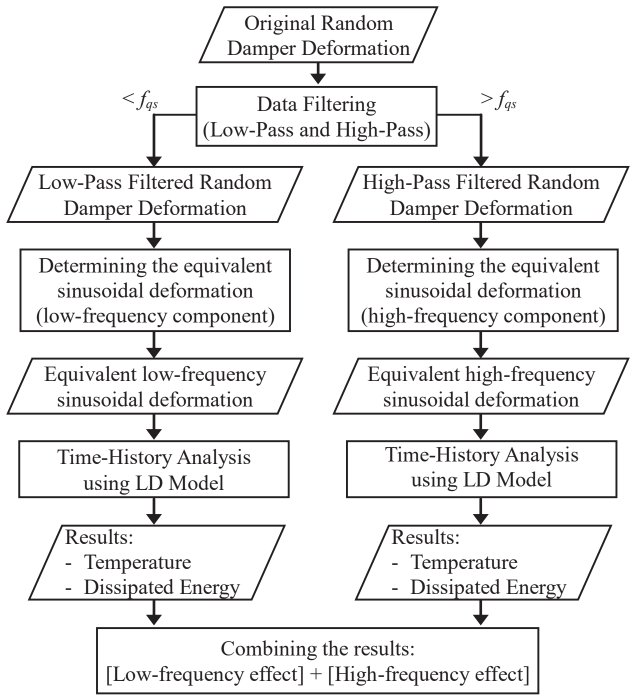

Figure 3. Flowchart of viscoelastic damper analysis using modified equivalent sinusoidal deformation.

4. IMPLEMENTATION OF THE MODIFIED EQUIVALENT-SINUSOIDAL DEFORMATION

The VE damper and random damper deformations in Part 1 are used to verify the proposed method. Figure 4 shows the results.

The built-in Butterworth filter approximation (filter order = 5) in MATLAB was used. The power spectral density (PSD) and the time-history of the thus-filtered random deformations are shown in Figure 4. Since the area of the PSD match well with the variance ($\sigma_{u,B}^2$ or $\sigma_{u,R}^2$) of their corresponding time-history deformation, the filter approximation used is accurate.

From the random deformations, it is found that $N_{0,B}^+ < N_0^+ < N_{0,R}^+$ which follows that the frequencies of the equivalent-sinusoidal deformations have the following relationship: $f_{r,B} < f_r < f_{r,R}$.

However, the standard deviations of the random deformations have the relationship: $\sigma_{u,B} < \sigma_u > \sigma_{u,R}$. As such, the amplitudes of the equivalent-sinusoidal deformations follows the same relationship: i.e., $A_{r,B} < A_r > A_{r,R}$.

The effect of the equivalent-sinusoidal background deformation is very small compared to that of the resonant deformation (Figure 4). Finally, the individual effects of the background and resonant deformations are combined, and the result matches well with those from original random deformation. This greatly improves the result from the previous method shown in Figure 8 of Part 1.

Although not shown here due to page limitation, the temperatures from the analysis using the modified equivalent-sinusoidal deformations match well with those from the original random damper deformation.

5. CONCLUSION

This paper modified equivalent-sinusoidal deformations in order to evaluate VE dampers under long-duration wind-loading based on the principle of random vibration or spectral approach. In this manner, the frequency sensitivity of VE damper is greatly considered. Results show good accuracy. However, since the individual effects of each response component are combined to evaluate the VE damper, only the damper temperature and the cumulative dissipated energy can be readily investigated by direct summation. Dynamic properties such as damping and stiffness have to be investigated using other means of combining individual effects. This will be next goal of this study.

ACKNOWLEDGEMENT

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REFERENCES:

[1] Sato, D., Tokoro, K., Kasai, K. and Kitamura, H. (2015). Properties of Viscoelastic Damper under Wind-Induced Excitation and Simplified Evaluation Method using Sinusoidal-Wave, *Journal on Structural and Construction Engineering* (Transactions of AIJ) Vol 80 No. 710, 571-581, April 2006 (In Japanese)

[2] Davenport, A.G. (1963). The buffeting of structures by gust. *Proceedings, International Conference on Wind Effects on Buildings and Structures*, Teddington, UK, 26-28 June, pp 359-391

[3] Holmes, J.D. (2007). *Wind Loadings on Structures 2nd Ed.*, Taylor and Francis Group, New York, USA.

[4] Ogawa R., Yoshie K., Sato D., Sato T., and Kitamura H. (2016). Predictio Method for Quasi-Static Component Response of High-Rise Seismic Isolated Building under Fluctuating Wind Force, *Journal of Wind Engineering JAWE,* Vol.41, No.2(No.147), pp 41-47 (In Japanese)

[5] Kasai, K., Sato, D., and Huang, Y.H. (2006). Analytical Methods for Viscoelastic Damper considering Heat Generation, Conduction, and Transfer under Long Duration Cyclic Load, *Journal on Structural and Construction Engineering* (Transactions of AIJ) No.566, 61-69, Jan. 2006 (In Japanese)

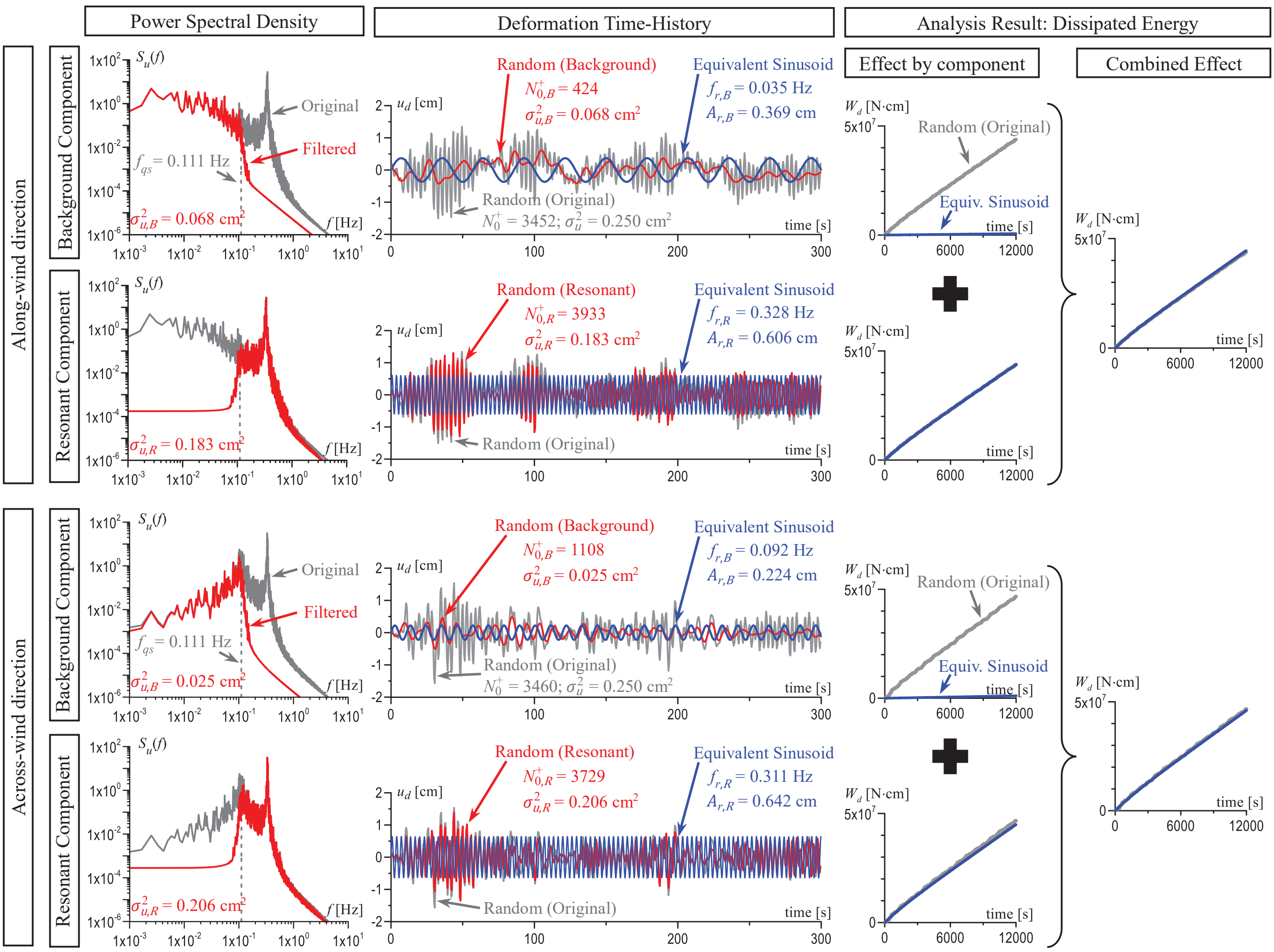

Figure 4. LD model results using the modified equivalent-sinusoidal deformations.

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