I -18 Exploration of Different Smoothing Methods in Estimating Kinematic Soil-Structure Interaction Using Strong Motion Data

○	The University of Tokushima	Member of JSCE	Atsushi Mikami
	University of California, Los Angeles		Jonathan Stewart
	Tohoku Institute of Technology	Member of JSCE	Makoto Kamiyama
	The University of Tokushima	Member of JSCE	Tsutomu Sawada

1. Introduction

Deviation between foundation and free-field motions can be evaluated in two steps. The first step involves the computation of foundation input motion (FIM), which is the motion that would be experienced by the foundation if the foundation and the supported structure were massless. In the second step, foundation displacements and rocking associated with base shear and moment from the vibrating structure and the foundation inertia are added to the FIM. Differences between the free-field motion and FIM result from kinematic interaction; the effects of which are quantified by transfer functions (i.e. ratio of the FIM to the free-field motion).

The gain factor of the system can be evaluated by using input/output power spectrum relation, as eq. (1), in which it is ideally assumed that no extraneous noise exists at input or output points, and the system has no time-varying or non-linear characteristics.

$$H = \sqrt{S_{yy} / S_{xx}} \tag{1}$$

where S_{xx}, S_{yy} are power spectrum density functions of free-field and foundation motions.

Smooth estimates of power spectra are usually used to compute transfer functions that represent kinematic soil-structure interaction. Different smoothing methods yield different power spectra, resulting in different transfer functions. In this presentation, two different smoothing algorithms(1),(2) that have been used in the field of earthquake engineering to compute smooth estimates of raw spectra were taken into account, and the effects of the smoothing algorithm on the estimation of kinematic soil-structure interaction were explored.

2. Evaluation of Transfer Functions Using Different Smoothing Algorithms

Strong motion records at free-field and foundation level locations were observed at Tohoku Institute Technology, building # 6. For 2003 Off-Miyagi earthquake, the duration of the record was such that there were 10890 digital points with a sampling rate of 100 (Hz). In windowing in the time domain, the criterion was to extract nearly zero amplitude at the end of the records. Thus, a number of 8192 data points were extracted from the original data so that Fast Fourier Transform (FFT) can be efficiently applied. A high pass filter (cut-off frequency=0.1Hz) was applied to the records.

Two methods of smoothing algorithms were attempted here. In the first method, the time sequence is segmented into m sub-segments of equal length and then, FFT is applied to each segment. By taking the average of these m spectra, smoothed estimate of the original spectra is computed. The second method applies spectral window of an effective band width B_e as a weighting function to the raw spectrum, passing over the record in the frequency domain, to compute the smoothed estimate of the spectrum at the center of the smoothing window. This is the way we calculated the power spectrum density functions.

To compare the effects of two different smoothing algorithms on the transfer function estimates, the

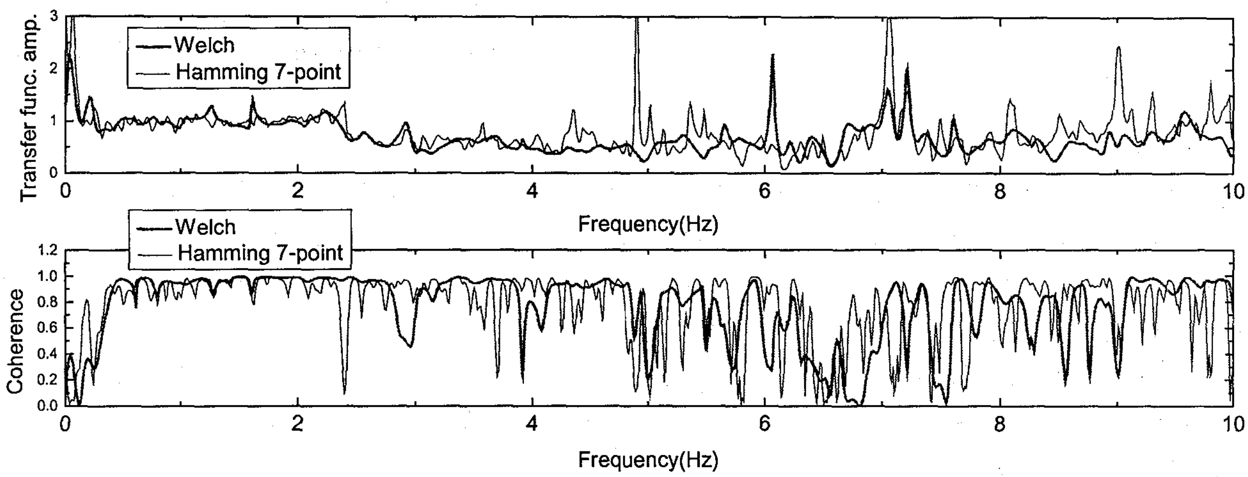

Figure 1 Transfer function and coherence

characteristics of smoothing windows need to be consistent with each other. Here, their band widths were set up so that they became statistically equivalent to each other. For the spectral estimation by averaging over time segments, the statistically equivalent band width[3] can be written as (no taper window applied to each segmentation)

$$B_e = 1/T_m \tag{2}$$

While the equivalent band width for the digital spectral window can be prescribed as

$$B_e = \frac{1}{\sum_{j=-m}^{m} p_j^2} \Delta f \tag{3}$$

As a spectral window, Hamming window that is expressed in the following form is utilized.

$$\overline{S}_k = 0.23S_{k-1} + 0.54S_k + 0.23S_{k+1} \tag{4}$$

3. Computational results

Figure 1 compares transfer functions and coherence functions computed by using 4 Kaiser taper windows ($B_e = 0.0488$ Hz) with its factor of 15.7 and by 7-point Hamming window ($B_e = 0.0517$ Hz). The 1st mode frequency of the building - flexible base system is 2.3 Hz. Both transfer functions and coherence functions agree quite well with each other in the low frequency range (< 2.5 Hz), however, some discrepancies can be seen beyond that frequency. One of the reasons might be that Kaiser taper windows are applied to time segments in the Welch method to reduce the spectral leakage effect.

References

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