SUPERPOSITION OF GROUND MOTIONS AT LOW AND HIGH FREQUENCIES IN SYNTHESIS

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ABSTRACT :

Many methods for synthesize near-field ground motions have been presented so far, those can be generally divided into deterministic and stochastic approaches. In general, ground motion at low frequency range is calculated by finite element or difference method, and that at high frequency is generated by stochastic synthesis separately. The ground motion at a site then is worked out by superposition of those two motions in time domain after high and low-pass filtering. The matching filter is overviewed firstly in this paper. Generally, the motion result of deterministic calculation is displacement time history while that of stochastic synthesis is acceleration. The sequence of filtering, integration or differentiate, and superposition of the two motions is deal with afterwards from two cases.

KEYWORDS: near-field ground motion; superposition; matching filter

1. INTRODUCTION

In order to overcome the disadvantages at low frequency range in above synthesis, the obtained motion is further superposed in time domain by motion from numerical approach, such as finite element or finite difference, after high pass and low pass filtered respectively. In this process, the matching filter is an important factor which decides the final superposed result but is easy to be neglected. The sequence of filtering, integration or differentiate, and superposition of the motions in high and low frequency range is also an important factor that can affect the final result but never be discussed before.

2. MATCHING FILTER

Many articles presented about HGF (hybrid Green's function) involve the matching filter, but few of them discuss it in detail. Most of these articles (Kamae *et.al*, 1998; Fukushima *et.al*, 2000; Pacor *et.al*, 2005; Liu *et.al*, 2006; Ameri *et.al*, 2008) chose a common matching filter of 1Hz. Pitarka *et.al* (2000) proposed a matching filter range of 0.9~1.1Hz in their work. Similarly, Roumelioti and Beresnev (2003) considered this range to be 0.5~1.0Hz. Particularly, Mena *et.al* (2006) illustrated Fourier acceleration spectra with different matching filters and finally determined a proper value of 4Hz. In our opinions, the matching filter depends on the precision of the discrete wavenumber method (DWNM). The precision of DWNM relates to the grid size of the discrete finite element and the shear wave length in the medium. In general, the shear wave length should be 6~12 times of the grid size (Zhang, 2005):

$$\Delta x = \left(\frac{1}{6} \sim \frac{1}{12} \right) \lambda \qquad (1.1)$$

Where, Δx is the minimum pace of the finite element discrete; λ is the wave length of the shear wave in the propagation medium. In addition, in order to assure the stability of DWNM, Δx should satisfies the following equation (Liao, 2002):

$$\Delta x \geq \Delta t \cdot c_{\max} \qquad (1.2)$$

Where, c_{max} is the maximum shear wave length in the working area; Δt is the maximum time step needed to keep the numerical simulation stable. In fact, with the restriction of the working capability of computer, the grid size of finite element in DWNM for a large working area always up to hundreds of meters which decides the reliable frequency range of simulated result less than about 1Hz. In addition, some research (Wang, 2004; Sun et.al, 2008) that use stochastic synthesis to calculate high-frequency ground motion show that result by stochastic synthesis agrees relatively well with records in the period less than 1sec. Therefore, we think that 1 Hz is a proper value for matching filter.

2. SEQUENCE OF SUPERPOSTION

Usually, the synthesized motion is acceleration time history, and the motion from numerical calculation is displacement. In general, the final result is required as acceleration, velocity and displacement time histories. Therefore, the displacement from numerical calculation should be differentiated to get velocity and hence acceleration. There are two ways to get filtered low frequency motion. One is to differentiate the calculated low frequency displacement, and finally to filter the three time histories. The other is to filter the displacement, and then to differentiate the result to get velocity and acceleration. Figure 1 shows velocity and acceleration time histories by two differential and filtering procedures from an arbitrary displacement time history. It is obvious from the figure that, the time histories are same in the first 7 seconds, and there is a terrible high frequency oscillation of numerical noise in the result by the second way. That means the differentiation must be done before the filter.

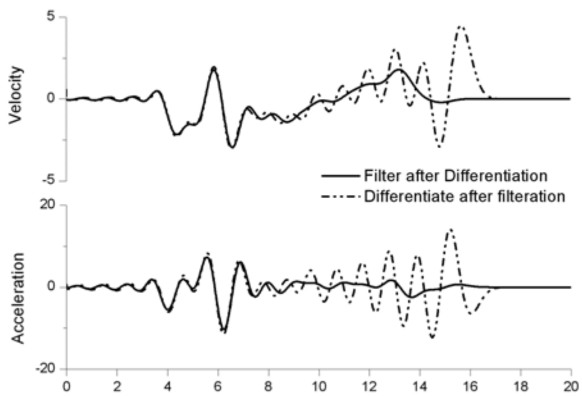

Figure 1 Velocity and acceleration by two procedures from a given displacement time history

Similarly, there are two ways to integrate and to filter the synthesized high frequency acceleration time history. One is to filter the acceleration firstly, and then to integrate to velocity and to displacement. The other is to integrate acceleration to get the velocity and displacement firstly, and then to filter these three respectively. Figure 2 shows the results of these two procedures.

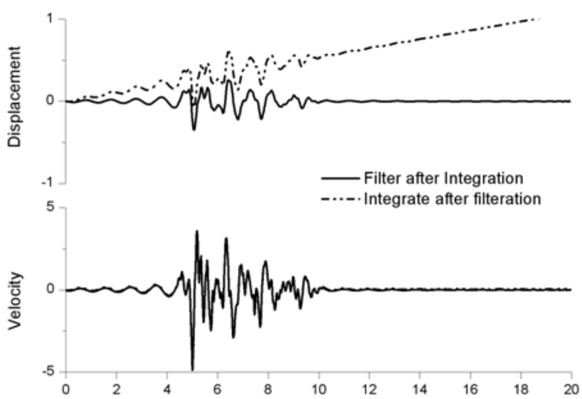

Figure 2 Velocity and displacement by two procedures from a given acceleration time history

One can find it from the figure that the velocity time histories are almost same, and there is an obvious very slow shift with time in the displacement time history by the first way. That means that the filtering must be done after integration.

CONCULUSION

In summary, ground motions in high and low frequency range by different methods should be superposed in time domain after low-cut and high-cut filtering respectively with the recommended matching filter of 1Hz. The order of integration/differentiation and filtering is also important. The filtering must be done after integration for high-frequency ground motion and differentiation for low-frequency ground motion.

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