Some issues on forecast of strong ground motion field

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Abstract

Conjugated with the paper of “Forecast of strong ground motion field near the fault for earthquake disaster reduction in urban area”, this paper discusses the issues in the forecast that need to be further dealt with. The first is the field must be estimated from the same source model, rather than taking the average motion at a site from more than 30 source model in the current seismic hazard assessment practice. The second is in the random synthesis, the uncertainty on envelop of motion time history from a sub source must be treated in the same way for all ground points rather than randomly varying in the current practice. The third is the uncertainty on the rupture velocity must not be changed randomly in the synthesis. The fourth is the order of the filters and the integrations of accelerations and velocities of the high and low frequency motions before being combined together. From a sensitivity analysis, the consequences of the above issues are presented and further study is suggested.

Keywords: forecast, ground motion field, source model, uncertainty, filter and integration.

1 Introduction

A set of approaches for forecasting strong ground motion at engineering site is developed in these years (Hanks and McGuire [8]; Beresenv and Atkinson [4]; Somerville et al. [16]; Atkinson and Silva [2]; Irikura [10]; Tao and Wang [18]), and are applied for disaster reduction in some engineering projects and urban areas (Boatwright and Choy [6]; Beresenv and Atkinson [5]; Liu et al. [12]). For a large city or long span structure, a ground motion field is required for seismic

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analysis. There must be some issues needed to dealt with; if the approaches are applied in the forecast of the filed, from the authors' points of view. Four of them are discussed in this paper.

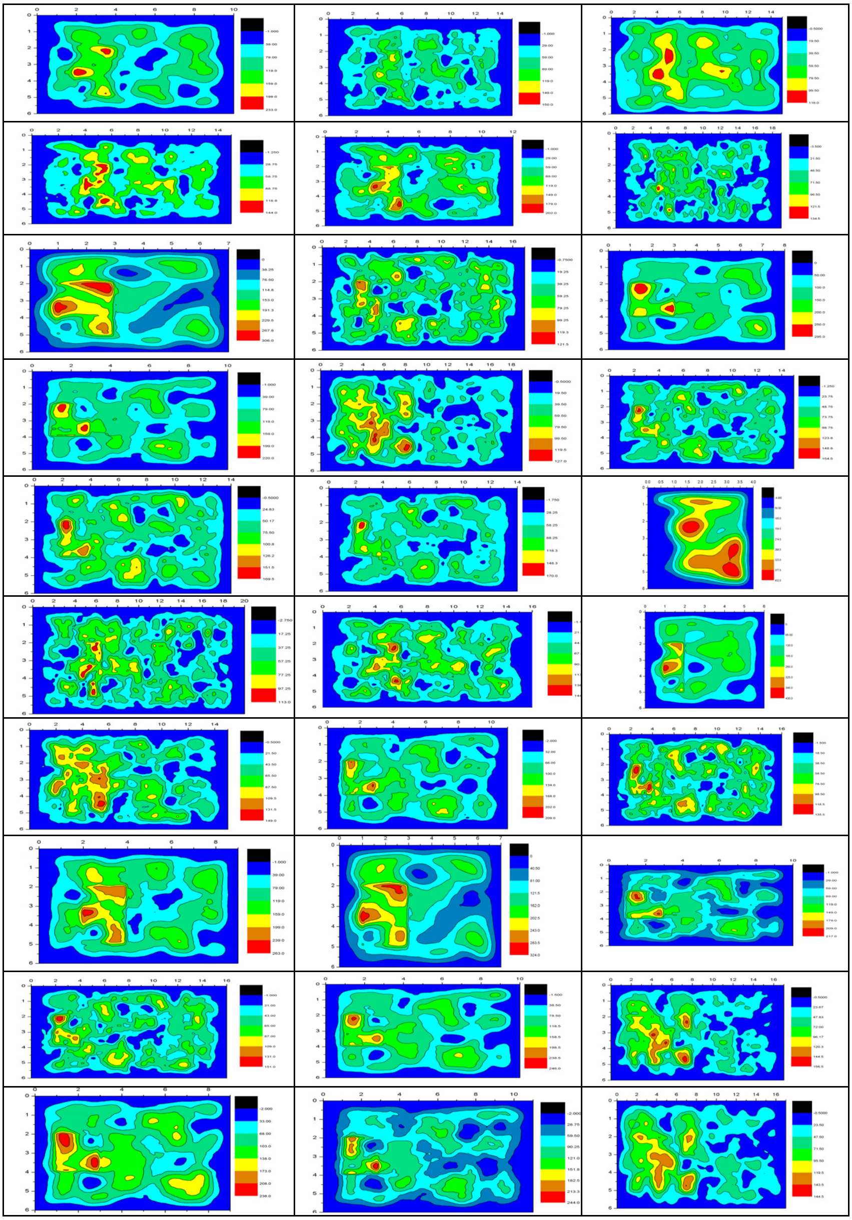

Figure 1: Source models for the earthquake with magnitude 6.0.

2 Issue with finite fault source model

A finite fault source model is needed to characterize the ground motion of a large earthquake and in the near field, otherwise the motion tends to be overestimated, and the directivity and the hanging wall effect cannot be simulated. This model allows a realistic inhomogeneous distribution of the dislocation on the rupture plane. In the model, the faulting plane is divided into many sub-sources, and the specified dislocation energy is assigned to each one of them, as point source. The most difficult issue at present is to determine the source parameters that describe the dynamics of the slip, such as stress drop and rise time, and the inhomogeneous distribution of the dislocation on the fault plane. In the hybrid finite fault source model (Tao and Wang [18]), the slip distribution on the fault plane is determined by superimposition of a long wavelength slip from an asperity model (Somerville *et al* [16]) for the physical nature and of short wave length slip from *k* square model (Herrero and Bernard [9]) for the uncertainty. In order to take this uncertainty and that on the parameter estimation of the source size and the average slip into account, 30 source models at least are required for each site in the current seismic hazard assessment practice. Figure 1 shows 30 models for an assessment of site in southeastern China, for example. One can find out that there are very big differences between each of the models. Therefore the ground motions generated from them must be different.

Figure 2 shows 30 acceleration response spectra at a ground point from the source models. From the figure, one can find the scattering degree of the spectra from their mean. In practice, the average spectrum and the ground motion time history corresponding to the spectrum mostly close to it are then selected as input for seismic analysis.

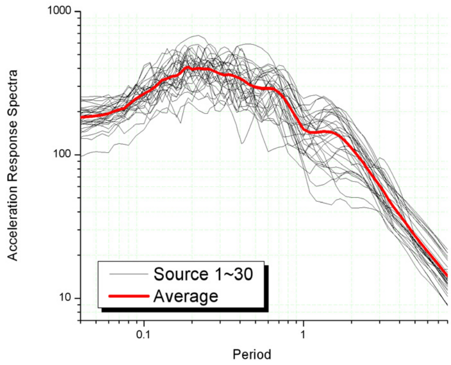

Figure 2: Response spectra at a point from 30 models and their mean.

It is obvious that the selected time histories at different points may not come from the same source model, if this approach is applied to forecast a motion field. The spatial pattern of the obtained field must be distorted by this difference. The authors like to mention the issue that just one source model must be selected for motion field forecasting, and how to do that must be dealt with carefully in the future.

3 Issues with the uncertainty in high frequency motion synthesis

In the random synthesis of high frequency motion, the acceleration time history at a site is obtained by summing those of all sub-sources, as follows.

$$a(t) = \sum_{i=1}^{N_L} \sum_{j=1}^{N_W} a_{ij}\left(t + \Delta t_{ij}\right) \tag{1}$$

Time history is inferred by inverse Fourier transform from the spectrum. The Fourier amplitude spectrum caused by each sub-source is from an equation as follows (Atkinson and Boore, 1997; Atkinson and Silva [2]).

$$FA(M_0, f, R) = S\left(M_0, f\right) \cdot G(R) \cdot D(R, f) \cdot A(f) \cdot P(f) \tag{2}$$

Afterwards, a phase spectrum is added which is generated randomly with uniform distribution in the range (0, 2π). Figure 3 shows 30 response spectra at a point from 30 phase spectra and a given source model.

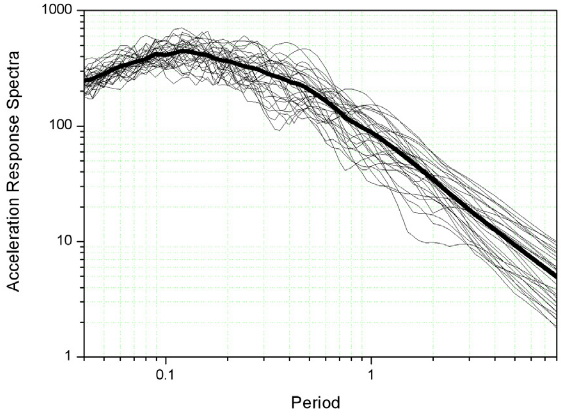

Figure 3: Response spectra at a point from 30 random phase spectra and their mean.

One can also find from the figure that there is an unneglectable scatteration of the spectra from their mean. It means that random scattering of spectra should be inferred from the randomly generated phase spectra. In engineering practice, the mean spectrum is selected. The spatial pattern of the forecasted motion field must be distorted by this uncertainty. Therefore, the issue on phase spectrum must be solved for forecast of strong ground motion field.

The Δt_{ij} in equation (1) is the time delay from the triggering time of the ijth sub-source and the travel time between the sub-source to the site. The former depends on the sub-source position on the fault plane and the rupture velocity. Some researchers suggested take into account the uncertainty on the rupture velocity by plus or minus a small random difference on the mean velocity (Beresnev and Atkinson [3]; Motazedian and Atkinson [14]). In order to see the effect of this treatment, 30 response spectra at a point are calculated from a given source model and the same phase spectrum with the changeable rupture velocity. Figure 4 shows the result.

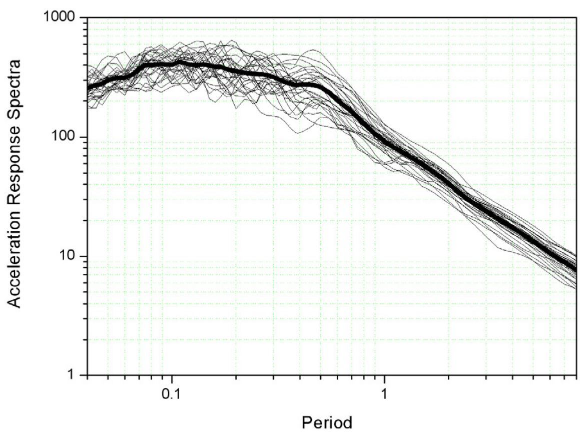

Figure 4: Response spectra at a point from a given source model and the same phase spectrum with changeable rupture velocity.

One can find from the figure that the uncertainty on rupture velocity is also un-neglectable in forecast of ground motion field. The authors suggest that it seems better to keep the same velocity than to take a randomly changeable one in the field synthesis.

4 Issue with the filtering before the superposition of the motions

In order to overcome the disadvantages at low frequency range in the 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. Usually, the synthesized motion is