STRONG GROUND MOTION SIMULATION FOR THE 16 SEPTEMBER 1978 TABAS, IRAN EARTHQUAKE

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ABSTRACT :

Acceleration time history of horizontal earthquake ground motion has been generated to represent the motions experienced in eastern Iran from the 16 September 1978 Tabas earthquake by using of finite-fault simulation method. In this method, the finite source is represented by a rectangular plane, which is subdivided into a number of subfaults. The rupture begins from the hypocenter and spreads radially from it triggering the adjacent elements when it reaches its centre. The contribution from all the elements are lagged and summed at the receiver. The ground motion at an observation point is obtained by summing the contribution over several subfaults. Geometrical spreading, regional inelastic attenuation and site effects are included in the model. A good agreement is obtained between the simulated and the recorded data at frequencies of engineering interest which confirm the capability of this method in simulating of strong ground motions.

KEYWORDS: Ground motion, Simulation, Finite fault, Tabas earthquake, Iran

1. INTRODUCTION

The large magnitude (mb = 6.4, Mw = 7.4, $M_0 = 1.32 \times 1020$) Tabas earthquake that occurred on September 16, 1978, in the east central Iran (Figure. 1), is considered to be one of the most destructive regional events of the 20th century. The total death toll has been estimated to exceed 15,000 (Mohajer-Ashjai and Nowroozi, 1979, Berberian, 1979). The earthquake was strongly felt over an area exceeding 106 km ~, with the highest intensity of shaking (IX-X MM) observed at the town of Tabas and the adjoining villages (see Figure 2 of Berberian, 1979) near the northern limit of the rupture. It was recorded by several accelerographs, and its peak acceleration varied between 0.95 and 0.01 g in the epicentral range from 3 to 350 km.

The "stochastic modeling approach" has been extensively used in the past for the prediction of strong ground motion. Various earthquake source models such as the "ω^{-2} model" (Brune 1970, Frankel et al., 1996) have been employed for this purpose (Atkinson and Boore 1998). A discrete finite-fault model that captures the salient features of radiation from large earthquakes has been a popular seismological tool over the past two decades. In this method, the fault plane is discretized into small independently rupturing subfaults and the radiation from all subfaults is summed at the observation point.

This paper presents results of strong ground motion simulation of the "finite fault model" for 1978 Tabas earthquake in Deyhook station with 18 km hypocenter distance.

2. STOCHASTIC FINITE-FAULT SIMULATION METHOD

Even though the success of the point-source model has been pointed out repeatedly, it is also well known that it often breaks down, especially near the sources of large earthquakes [Beresnev and Atkinson, 1997, 1998a, b]. Beresnev and Atkinson [1997] have proposed a technique that overcomes the limitation posed by the hypothesis of a point source. Their technique is based on the original idea of Hartzell [1978] to model large events by the summation of smaller ones. The fault plane is discretized into a finite number of subfaults, each of which is treated as a point source with a theoretical ω^{-2}, and the rupture starts at a hypocentral point on the fault and propagates radially from it, triggering the subfaults as it passes them. The fields from all subevents are

geometrically delayed and added together at the observation point [Beresnev and Atkinson 2002].
The corner frequency (f_0) and seismic moment (m_0) of the subfaults are derived in terms of subfault size (Δl):

$$f_0 = \frac{(yz/\pi)\beta}{\Delta l} \tag{2.1}$$

$$m_0 = \Delta\sigma\Delta l^3 \tag{2.2}$$

Where $\Delta\sigma$ is the "stress parameter", β is the shear wave velocity, y is the fraction of rupture-propagation velocity to β (assumed equal to 0.8 in the present study), and z is a parameter physically linked to the maximum rate of slip. The value of z depends on the definition of the rise time and for standard conventions z=1.68 [Beresnev and Atkinson, 1997, 1998]. Due to the uncertainties involved in the definition of z, its value is allowed to vary through a parameter called sfact, which practically consists a "free" parameter during the implementation of the method.

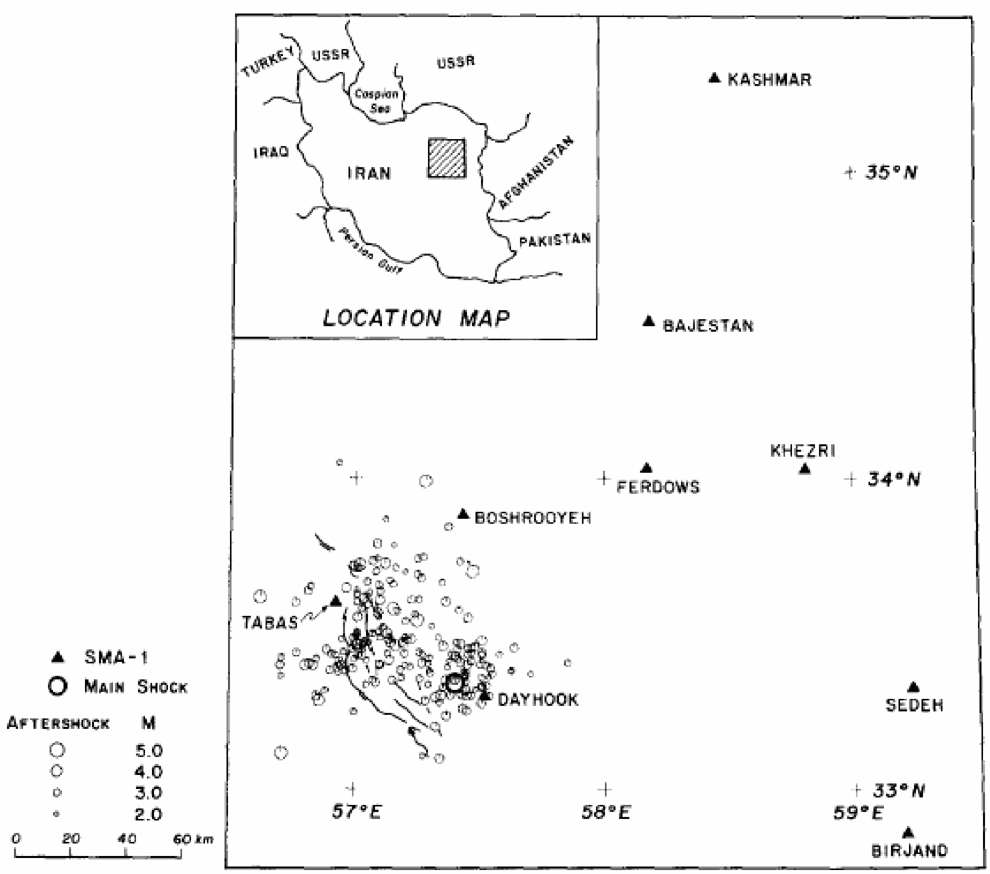


Figure 1 Map of the region adjacent to the Tabas,
Iran earthquake (Shoja-Taheri and Anderson, 1988)

Finally, a randomized time-delay for each subfult radiation to reach the observation point is calculated and the generated time series is shifted and added to total wave field in time domain as:

$$a(t) = \sum_{i=1}^{nw}\sum_{j=0}^{nl} a_{ij}(t + \Delta t_{ij}) \tag{2.3}$$

Where nl and nw are the number of subfaults along the length and width of the main fault, respectively, Δt_{ij} is the time-delay from the radiated ij subfault wave.

3. MODELING PARAMETERS

Modeling of finite source requires information of the geometry of fault plane, as well as information of the dimensions of subfaults and the location of hypocenter. The trends of epicenteral and hypocenteral distribution are in accordance with the strike and dip angle of the focal mechanism (strike, dip, slip) = (332, 31,110) of the mainshock (Berberian 1979). The source dimension is therefore roughly estimated to be 85km x 30km (Berberian 1979) and fault plane has been divided to $5km \times 5km$ subfaults. Crustal shear wave velocity and source density for this region are derived based on Global Crustal Model by Specification of 2×2 degree tiles surrounding around Tabas in CRUST 2.0.

Table 1.Modeling parameters

Parameters	**Tabas earthquake**
Fault Dimension(km)	85×30
Fault Orientation	Strike 332^0,dip 31^0
Mainshock moment magnitude(M)	7.4
Stress parameter(bar)	50
Subfault dimension(km)	5×5
Number of subfaults	102
Subfault corner frequency	0.49
Crustal shear wave velocity(km/sec)	3.5
Crustal density($\frac{g}{cm^3}$)	2.7
Geometric spreading	$1/R$
$Q(f)$	$350 f^1$
Windowing function	Saragoni-Hart
Kappa operator	0.06

The kappa parameter is average of values obtained by Shoja-Taheri and Anderson (1988) for motions recorded in number of stations in the region for occurred earthquake. The soil types of Deyhook station which selected for simulation in this paper was estimated to be of types I based on the Standard of Iran (Standard No: 2800) which is approximately equivalent with rock site in NEHRP classification. All parameters used for simulation are summarized in Table 1.

4. RESULTS AND CONCLUSION

Acceleration time history recorded during the 1978 Tabas earthquake, has been simulated using the stochastic finite-fault method proposed by Beresnev and Atkinson (1997, 1998a, 1999). The result of simulations for Deyhook station is presented by comparison of simulated and observed accelerograms and response spectra in figure 2-5.

The results show satisfactory comparable plots between simulated and observed peak ground accelerations and response spectra. Peak ground accelerations for observed record is 0.366g and 0.39g for L and T component respectively however, this value for simulated acceleration is 0.342g. The observed and simulated spectra show a good agreement within the intermediate- and high-frequency ranges. However, at low frequencies, the recorded amplitude spectra are generally larger than simulated. This can be viewed as the limitation of the homogeneous half space medium included in the simulation model to generate surface waves, which are generally observed on real accelerograms as well a Shoja-Taheri and Ghofrani (2007) have concluded about 2003 Bam earthquake simulation with finite-fault modeling.

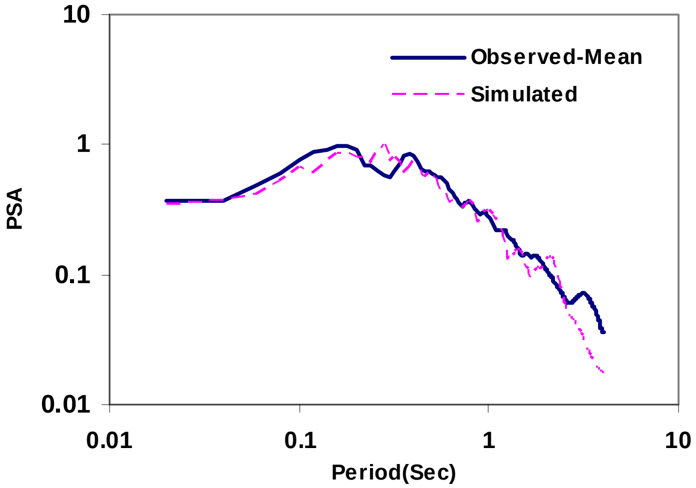


Figure 2 Simulated and observed 5٪ -damped pseudo-acceleration response spectra

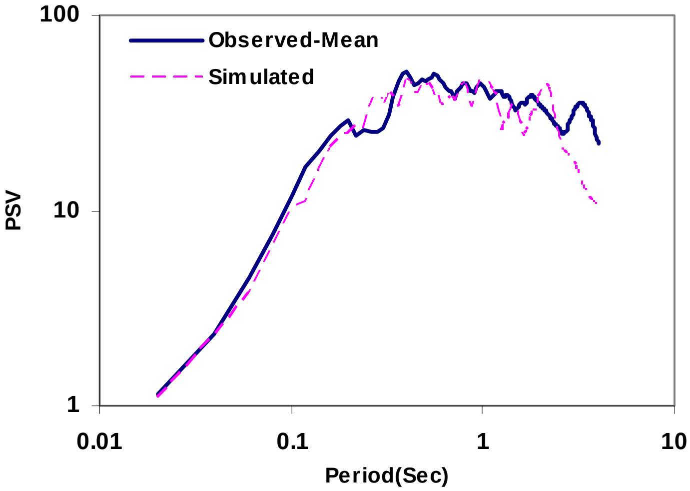


Figure 3 Simulated and observed 5٪ -damped pseudo-velocity response spectra

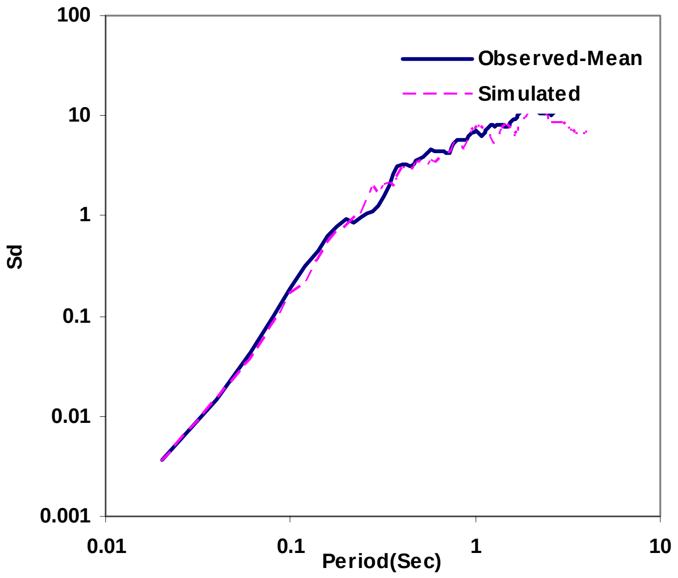
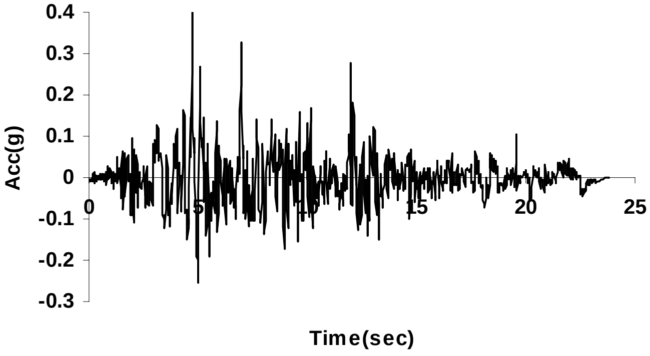
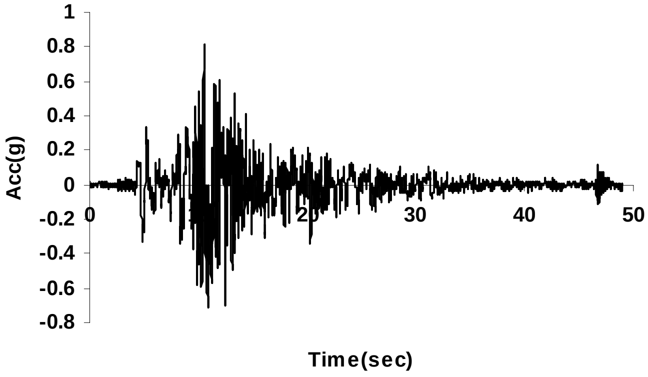


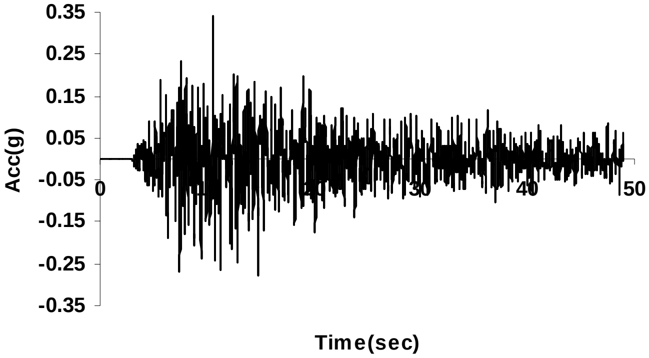
Figure 4 Simulated and observed 5% -damped displacement response spectra



a) L component



b) T component



c) Simulated

Figure 5 Observed horizontal (a, b) and Simulated (c) acceleration time history

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