Proceedings of the 18th Iranian Geophysical Conference, May 2018, pages 642-645

# Simulation of Strong Ground Motion of Bam Earthquake Using Stochastic Finite Fault Method

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## ABSTRACT

In the morning of a Friday, December 26th, 2003 at 01:56 UTC (5:26 AM Iran Standard Time), the Bam Earthquake occurred with a moment magnitude of 6.5 at Bam City and surrounding areas in east of Kerman Province, Iran. In the present research, in order to estimate source parameters and rupture propagation mechanism, accelerograms resulted from the rupture were simulated using stochastic finite fault method based on dynamic corner frequency. A comparison between the simulated records and observed ones shows that, rupture propagation has occurred on the fault plane in a northward direction. By averaging over 23 recording accelerograph stations, strike and dip of the fault plane were found to be 90 and 257 degrees, respectively. Spectral decay parameters for horizontal and vertical components were estimated at 0.06 and 0.05, respectively, with stress drop and focal depth estimated to be 130 bar.

**Keywords:** Simulation of strong ground motion,Stochastic finite fault method,Bam Earthquake.

## INTRODUCTION

Strong ground motion due to earthquake is a result of a complicated physical process that is composed of three stages: seismic waves represent part of strain energy released from active fault and are related to the source effect. The waves are then propagated across the entire earth crust via a phenomenon known as wave propagation or path effect. Finally, the waves are influenced by variations in shallow layers before reaching the ground surface (site effects). The device used to record these waves also imposes some impacts on the recorded data, which can be corrected according to the device specifications. As a result, on the obtained seismogram, long-term and short-term characteristics are different. Parkfield (1996) was the first to record a near-fault seismogram. Stochastic method has been widely used for predicting ground motions. There are two variants of this method, one with a point seismic source and the other one with finite fault seismic source. The finite fault model serves as an important tool for predicting ground motions near hypocenter of significant earthquakes. In this method, time series of strong ground motion is simulated using theoretical methods; these methods include stochastic, Green's hybrid function, Green's quasi-empirical function, hybrid source model, and linked methods. Advantages of these methods rely on the fact that, the information related to seismic source, wave propagation between the source and measurement station, station conditions, and attenuations are considered in the simulation of strong ground motion, which finally end up with higher confidence in the estimation of characteristics of the strong motion in the time – frequency domain.

## BODY OF THE DOCUMENT

### Determining spectral decay parameter

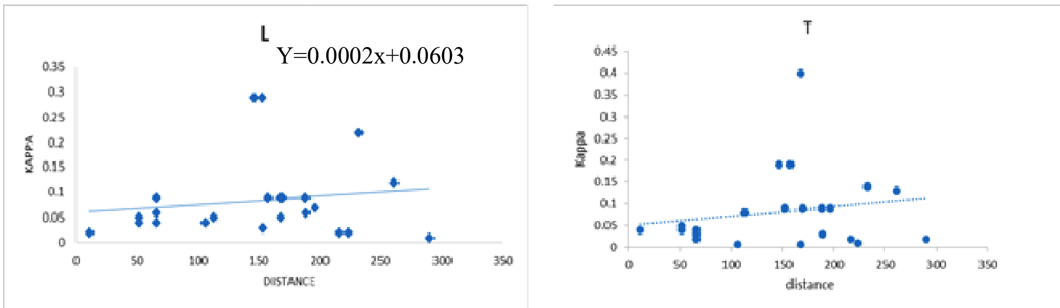
In this study, baseline-corrected accelerograms recorded at 23 accelerograph stations at Bam earthquake were used to determine the value of κ. For this purpose, some coding in MATLAB Environment was performed to determine the value of spectral decay parameter for each component of the considered accelerograms.One of the important parameters for describing strong ground motion at high frequencies (above 1 Hz) is the spectral decay parameter (κ). Kappa is a key input parameter for simulating strong ground motion via stochastic methods in areas where available strong ground motion data are less than adequate for adopting empirical relationships for predicting strong motions (Douglas *et al.*, 2009). Spectral decay parameter is a function of path effect and site. Mathematical formulation of kappa, κ (*R, S*), as a function of distance to hypocenter, *R*, and site conditions set, *S*, is as follows:

$$Ln(A(f)) = -\pi\kappa f + Ln(A_0) \quad (1)$$

In this relationship, $\kappa_0$ (*S*) takes the same value for any setting, i.e. the term required for simulating strong ground motion, via stochastic method. In general, distance-dependency is represented by the term κ (*R*).

**Table1**: The results of the spectral decay parameterat 23 Bam earthquake recording stations.

| Station | Long | lat | Epi. Dis. (km) | Spectral Decay Parameter | | | |
|---|---|---|---|---|---|---|---|
| | | | | T.com. | L.com | Ave.(L,T) | V.com. |
| Jiroft | 28.67 | 57.74 | 65.7 | 0.03 | 0.09 | 0.06 | 0.06 |
| Mohammad | 28.9 | 57.89 | 65.74 | 0.04 | 0.06 | 0.05 | 0.05 |
| Bam | 29.09 | 58.35 | 11.1 | 0.04 | 0.02 | 0.03 | 0.01 |
| Abargh | 29.34 | 57.94 | 51.49 | 0.04 | 0.04 | 0.04 | 0.01 |
| Sirch | 30.2 | 57.69 | 145.8 | 0.19 | 0.29 | 0.24 | 0.025 |
| Andooh | 29.34 | 57.94 | 51.49 | 0.05 | 0.05 | 0.05 | 0.01 |
| Zarand | 30.81 | 56.57 | 261.3 | 0.13 | 0.12 | 0.13 | 0.12 |
| Baft | 29.23 | 56.6 | 167.1 | 0.4 | 0.09 | 0.25 | 0.02 |
| Bard sir | 29.92 | 56.57 | 196.2 | 0.09 | 0.07 | 0.08 | 0.02 |
| Bolv | 29.42 | 56.05 | 223.3 | 0.01 | 0.02 | 0.02 | 0.01 |
| Chesh | 29.42 | 56.42 | 188.3 | 0.03 | 0.06 | 0.05 | 0. 03 |
| Gale Gang | 27.52 | 57.87 | 169.3 | 0.09 | 0.09 | 0.09 | 0. 05 |
| Golb | 29.88 | 57.72 | 112.8 | 0.08 | 0.05 | 0.07 | 0. 05 |
| Hasan | 27.35 | 56.85 | 232.0 | 0.14 | 0.22 | 0.18 | 0.06 |
| Horjand | 30.67 | 57.15 | 216.3 | 0.02 | 0.02 | 0.02 | 0.02 |
| Kahnooj | 27.94 | 57.74 | 65.7 | 0.02 | 0.04 | 0.03 | 0.02 |
| Kerman | 30.28 | 57.74 | 152.2 | 0.09 | 0.29 | 0.19 | 0.05 |
| Lalezar | 29.56 | 56.81 | 157.3 | 0.19 | 0.09 | 0.14 | 0.02 |
| Mahan | 30.06 | 57.29 | 153.1 | 0.09 | 0.03 | 0.06 | 0. 03 |
| Nosrat | 29.85 | 59.98 | 188.1 | 0.09 | 0.09 | 0.09 | 0. 02 |
| Ravar | 31.26 | 56.79 | 290.2 | 0.02 | 0.01 | 0.02 | 0.05 |
| Rayan | 29.59 | 57.44 | 106.1 | 0.008 | 0.04 | 0.02 | 0.01 |
| Shah dad | 30.41 | 57.69 | 167.4 | 0.008 | 0.05 | 0.03 | 0.01 |




**(a)** **(b)**

***Figure 1.****Variations of κ with increasing the distance to hypocenter for horizontal component of Bam Earthquake:*

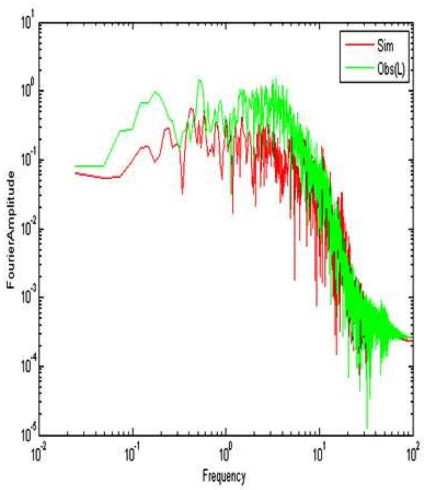



***Figure 2** : comparison between Fourier amplitude spectra of horizontal components of earthquake records (Abargh Station) to the simulated accelerograms.*

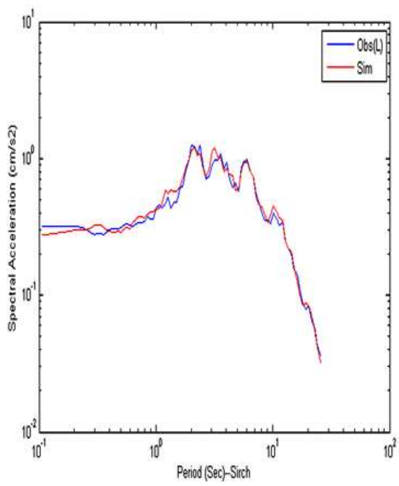



***Figure 3:** Response spectrum of horizontal components of observed accelerograms versus simulated ones of the earthquake ( Abargh Station).*

## Simulation of Bam Earthquake:

In order to determine parameters of the fault responsible for this earthquake, by the total of 23 accelerograph stations administered by the Research Center for Construction and Housing, the data from 23 stations were found to be usable. In this study, we identify the source parameters Bam earthquake 2003using stochastic finite fault method (Motazedian and Atkinson,2005). Fault plane parameters were selected in such a way that, maximum agreement between actual accelerogram and synthetic one is achieved. Table 2 represents input model parameters for simulating synthetic accelerograms using EXSIM Software. Considering the shortage of accelerograph data, initial quality factor of 90 and stress drop parameter of 130 bar gave the most agreement between the observed and calculated Fourier spectra.

***Table 2.*** *Input parameters of EXSIM Software for simulating strong ground motion of Bam Earthquake*

| Input parameters of EXSIM Software | Values |
|---|---|
| Moment magnitude | 6.5 |
| Stress drop | 130(bars) |
| Quality factor (QF) | $Q = 90\ F_0^{1.08}$ |
| Duration | T0 + 0.1 R (km) |
| Kappa | 0.06(s) |
| Fault plane dimensions | 25Km×12Km |
| Fault strike and dip | 257 °, 90 ° |
| Depth of top of the fault | 0(Km) |
| Pulsing percent | 25% |
| Window function | Saragoni-Hart |
| Shear wave velocity | 3.7(Km/sec) |
| Density | 2.8 g/cm3 |
| Damping coefficient | 5% |
| Slip distribution | Random |
| Starting rupture element | Random |

## PGA Comparison:

In order to be further ensured about proper choice of input parameters required for simulating this earthquake, simulated PGAs via stochastic finite fault method at stations administered by Iran Strong Motion Network were plotted versus Frequency. General trends of diagrams 4 resemble those of the observed PGA diagrams at each of the station versus Distance. In both cases, the values of PGA decrease with increasing the Distance.
According to Figure 4 simulated values of PGA were lower than those recorded at accelerograph stations. This could be attributed to various causes including the attenuation of wave propagation path and site conditions. Bam City is mainly located on alluvial fans, so that the effect of the alluvial fans on the characteristics of this area is dominant. And Figure 5: The location of faults and the mechanism of Bam & Area earthquakes

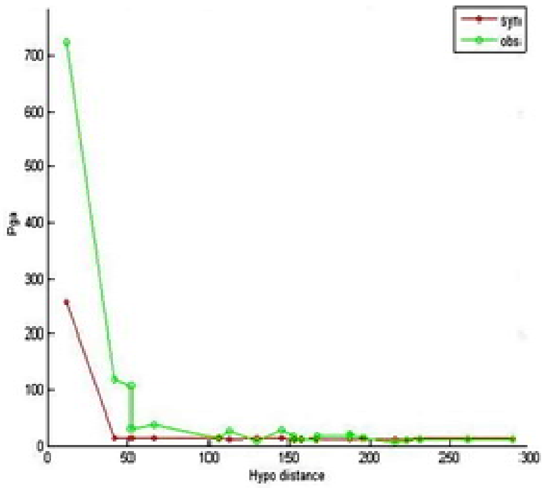



***Figure 4.***Consistency of synthetic PGAs (EXSIM) and observed ones (L) in terms of Distance at 22accelerograph stations

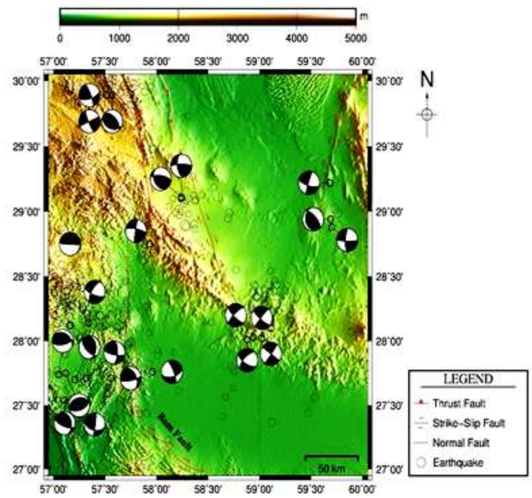



**Figure 5**: The location of faults and the mechanism of Bam & Area earthquakes

## CONCLUSION(S)

Investigations on the accelerograms recorded at Bam Earthquake shows an increase in κ with increasing the distance to hypocenter. The value of κ for horizontal and vertical components was found to be 0.06 and 0.05, respectively. The obtained fault model for this earthquake had a dimension of 25 × 12 km, with 4 and 5 subfaults along the strike and dip of the fault, respectively. Rupture velocity was considered at 0.8 β where β denotes shear wave velocity through earth crust that corresponds to 3.7 km/sec. Results of the present study are reliable within the frequency range of 0.2 – 20 Hz, so that those can be practically used in engineering structures. Calibrated parameters include key source parameters such as stress drop and pulsing percentage of the source which were found to be 130 bar and 25%, respectively. A comparison of Fourier amplitude spectra shows a good agreement between Fourier amplitude spectra of horizontal components of earthquake records (Abargh Station) to the simulated accelerograms. Fourier spectrum representations of the observed and simulated vertical components were also in agreement with one another.

## REFERENCES

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