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Q-Factor of the Punjab Basin

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Abstract:*The present study gives the frequency dependent attenuation (Q) value which gives Quality factor (Q_0) of S-waves of the Punjab basin. For this the dataset of six earthquakes are considered which are recorded in the range of 15-100 km having earthquake magnitude of M3.1- M4.9. The frequency range has been chosen from 0.1 Hz to 20 Hz in nine frequency bands with respective their central frequencies of the lower and upper frequency of the S-wave spectrum. The Q-value of S-wave obtained as $Q(f)=257f^{0.54}$ in this region. This Q(f) value is necessary in the simulations of Ground motions. This study mostly helpful to simulate the ground motion with the help of stochastic model to know the attenuation of the small range of magnitudes where as much data is not available in the region. This study is important to develop the ground motion model for seismic hazard studies.*

Key words:*Fourier Amplitude Spectrum, Punjab Basin, Quality Factor, seismic activity*

I. Introduction: The Quality factor (Q_0) indicates the attenuation of seismic wave (amplitude) through the mediumwhich is a fundamental concept in earthquake engineering. The attenuation of seismic wave from the source tosite is mainly dependson the radiation pattern of the wave, path effect, geometrical spreading parameter, amplification factor and geological effect of site. This attenuation of the seismic wave describes in terms of frequency dependent parameter $Q=Q_0f^n$ where Q_0refers as homogeneity of soil and n as seismic activity in the region. The high $Q(f)$ (>500) value indicates there is not much change in the amplitude with distance whereas less $Q(f)$(<500) value shows there is not much change in the amplitude reduction.Normally all types of waves have their own attention properties but the attenuation of S-wave is higher in the region among others [1-3]; McNamara et al., 1996].In India there are very limited studies are available regarding Q-value because of lake of data. There are different Q-values for different regions of the India. The Quality Factor$Q(f)$ estimated for the Indo-Burma tectonic area is $431f^{0.7}$, for the Bengal basin and Shillong zone are $224f^{0.93}$, $800f^{0.42}$ for the Indian shield [4, 5]

In the present study the attenuation value (Q) has estimated for the Punjab basin by taking Punjab, Haryana and Delhi as shown in Fig.1under this basin which are under zone-IV as per IS875: part-4.

II. Seismo-tectonic setting of Punjab Basin: The name of the Punjab basin derived from the name Punjanadh which is formed due to the flow of five Indus tributaries in India and Pakistan. This basin covers Punjab, Haryana, and Delhi region in India. This basin located in between 73.75-77.5 E and 27.5- 32.5Nexcept Rajasthan.

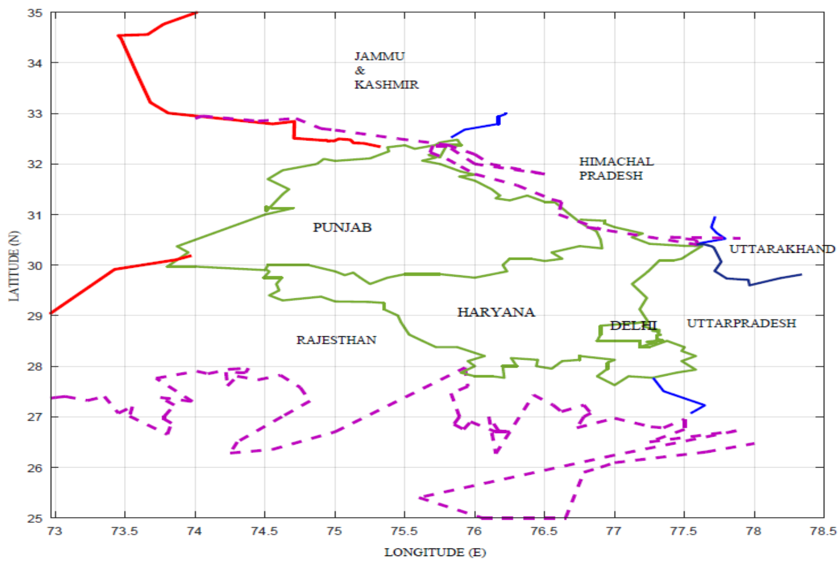

Figure 1. Geography of Indus Basin of alluvial plain (Dotted line Shows limits of Indus basin of Alluvial plain)

This Punjab plain having the Suleman ranges and Himalayas as boundaries in north-west and north-east respectively. Delhi-Haridwar ridge in the east which behaves like direct thrust plate and Ropar fault, some of the neotectonicfaults in this region as shown in Fig. 2. The most of the neotectonic faults are strike slip faults in this region. This basin also having the MahendraGarah –Dehradun sub surface fault. Delhi-Sargodha ridge also present in this basin. This Punjab basin in the Indus plain has covered with alluvial soils as shown in Fig. 2. The main rivers in this basin are branches or tributaries of Indus River which flows from Himalayas. The tributaries which flows in India are Raave, Beas and Sutlej.

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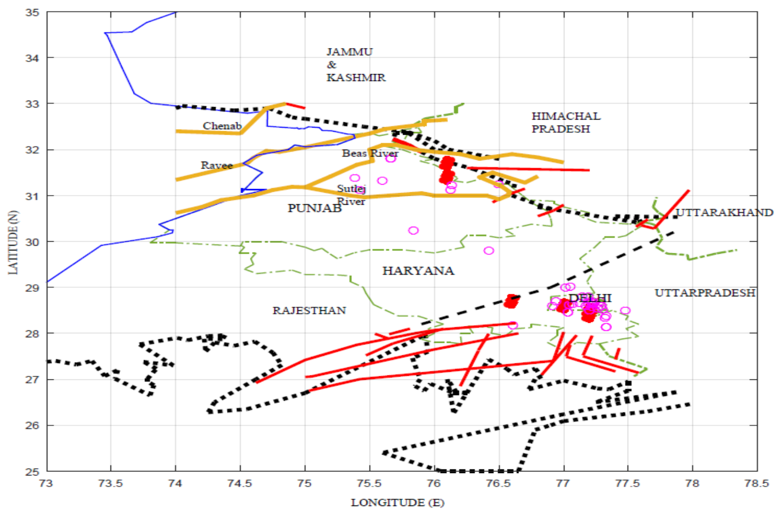

Boundaries of Indus Basin ; National Bondaries ; State Boundaries ; Earthquake Events ;
Earthquake recording Stations ; Faults ; Subsurface Fault

Figure 2 Seismo-tectonic setting of Punjab Basin which shows geological features

III. Data Selection: In the present study the earthquake data has selected from the PESMOS data base. Total 6 earthquake events are selected which occurred and recorded in Punjab, Haryana and Delhi. This all earthquake were recorded by digital strong motion accelerograms which are installed by DST and operated byIIT Roorkee. The Table 1 gives the total number of events with recorded at different stations and having depth of the events occurred and their hypocenter.This instruments records three components of earthquake in East-West, North-South and Vertical components and baseline corrected to 32 Hz [6].The map of the Punjab basins with stations are shown in Fig 2.

Table 1. Earthquake events taken for the present study

Even No	Event&Magnitude		Date	Epi-center Lat. (N)	Lon. (E)	No. of Station recorded	Depth (km)	Hypo-central (km)
1	Haryana Border	4.3	25/11/2007	28.6	77	10	20.3	23.5234
2	Punjab Himachal Border	4.6	14/03/2010	31.7	76.1	5	29	57.98435
3	Sonipat-Haryana	4.2	07/09/2011	28.6	77	10	8	31.12187
4	Bahadurgarh	4.9	05/3/2012	28.7	76.6	15	14	62.55653
5	DELHI	3.1	11/11/2013	28.5	77.2	9	10	35.42713
6	Delhi2011	3.3	11/11/2013	28.4	77.2	10	10	45.88279

IV. Methodology:

In the present study one dimensional stochastic model of Boore (1983) is used [7]. This model is useful to get the time history of earthquake.This model is used to simulate the higher frequency ground motion of earthquake. The Fourier amplitude spectra of ground motion in this model expressed as

$$A(r,f) = C.S(f).F(f).D(r,f).G \qquad 1$$

After applying the logarithm on both sides of the eq 1 the following form has obtained as linear equation.

$$\log(A(r,f)) = \log C + \log(G) - \frac{\pi fr}{Q.V_s} + \log(S(f)) + \log(F) \qquad 2$$

Where $A(r,f)$ Fourier spectralamplitude of earthquake is function of hypo-distance (r in km) and frequency (Hz). Constant C is a scaling factor, $S(f)$ is a source spectral parameter, $D(r,f)$ is used to characterize the earthquake wave propagation with in the crust of earth. $F(f)$ is the amplification factor.In the present study the single corner frequency model is used for source spectrum $S(f)$ which is give in eq 2 given by Brune(1970) [8] V_S is shear wave velocity. The scaling factor C is given as

$$C = \frac{R_{\theta\varphi}.\sqrt{2}}{4\pi\rho {V_S}^3}. \qquad 3$$

Where $R_{\theta\varphi}$ is averaged coefficient of radiation over appropriate range of azimuth and propagating angles usually it is taken as 0.55 and $\sqrt{2}$ is partitioning coefficient in orthogonal direction, ρ is the density of earth crust at the focal depth of earthquake. The diminution factor *D (r, f)* is taken fromBoore2003 [9] as

$$D(r,f) = G \exp\left[\frac{-\pi fr}{V_S Q(f)}\right] \qquad 4$$

Where $Q(f)$ attenuation factor or Quality factor of recorded earthquake, *G* is geometric attenuation and remaining denotes the anelastic attenuation which depends on hypo-central distance of earthquake and it is given as [10]

If $G < 100$; $G = 1/10\sqrt{r}$ 5

If $G > 100$; $G = 1/r$ 6

V. Results and Discursion:

In the present study the earthquakes selected from IIT Roorkee data baseis used to estimate the Q-value of the region. The time-history of the collected data has plotted for every station recorded earthquake data. The P-wave and

S-wave are separated using the 80 percent of arias intensity.The S-wave and P-waves are shown in the Fig3India(Sikkim)-Nepal-Border earthquake which occurred on 18/9/2011.The wave which has started rapid increase of arias intensity (%) is take as the arrival of S-wave and up to 80 percent of its arias intensity the recording wave has been selected as S-wave. The starting of time history has taken with reference to the arrival of S-wave.

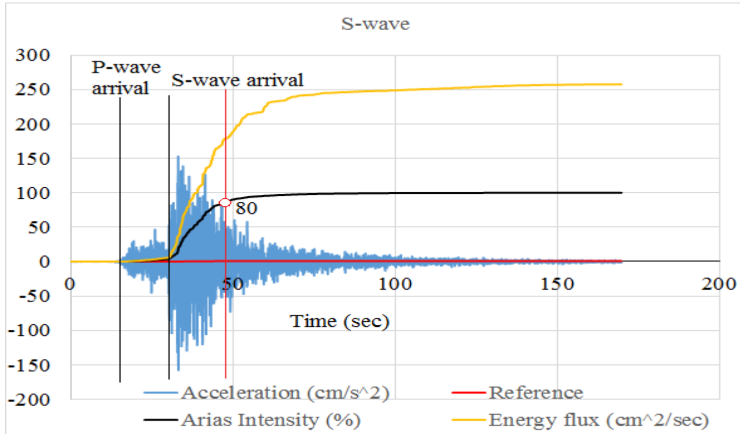

Figure 3. India(Sikkim)-Nepal-Border earthquaketime history at station SLG and Separation of P-and S-wave by using Arias intensity.

In this study the selected time history data has ban passed in ninefrequency bands by using Butterworth band pass. The ban pass frequency limits are shown in the Table 2. The lower frequency band has taken as $10^{(0.2m-0.7)}$ and higher frequency band as $10^{(0.2m-0.5)}$ and central frequency has average of both of the frequencies. Where *m* is the number of bands of the frequency.

Table 2. Different frequency bands

No. of Frequency band (*m*)	Central Freq(Hz).	Lower freq. (Hz)	Higher Freq. (Hz)
1	0.41	0.32	0.50
2	0.65	0.50	0.79
3	1.03	0.79	1.26
4	1.63	1.26	2.00
5	2.58	2.00	3.16
6	4.09	3.16	5.01
7	6.48	5.01	7.94
8	10.27	7.94	12.59
9	16.27	12.59	19.95

The selected S-wave has passed through different frequency bands as shown in Fig.4 and converted in to Fourier Amplitude Spectrum (FAS).

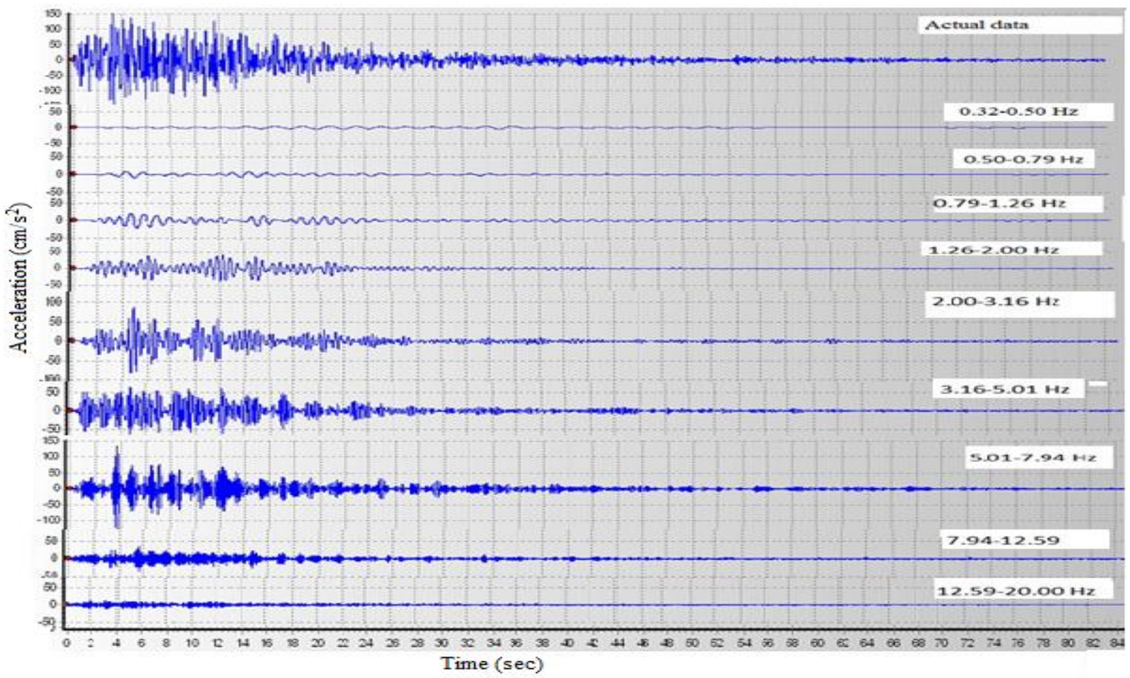

Figure 4 Time history of Himachal-Punjab-(Hoshiarpur)-Borderearthquake event recorded at NIST Delhi Station at different frequency bands.

The Q-value has estimated at ninedifferent frequency bans which has given in Table 2 by using linear regression analysis. The FAS (*A(r,f)*)of six earthquakes of 59 recording station are used in the linear equation 2, whereassource function $S(f)$ as intercept and Geometric spreading function as known parameter and the slope of the line gives the unknown parameter Q of the equation. The assumptions made in the present study $F(f)$ is taken as 1 assuming as rock type of medium. The Shear wave velocity of S-wave as 3.2km/s, density of soil as 2.9 kg/m^3. The linear regression of the data at each frequency band has given in the Fig. 5

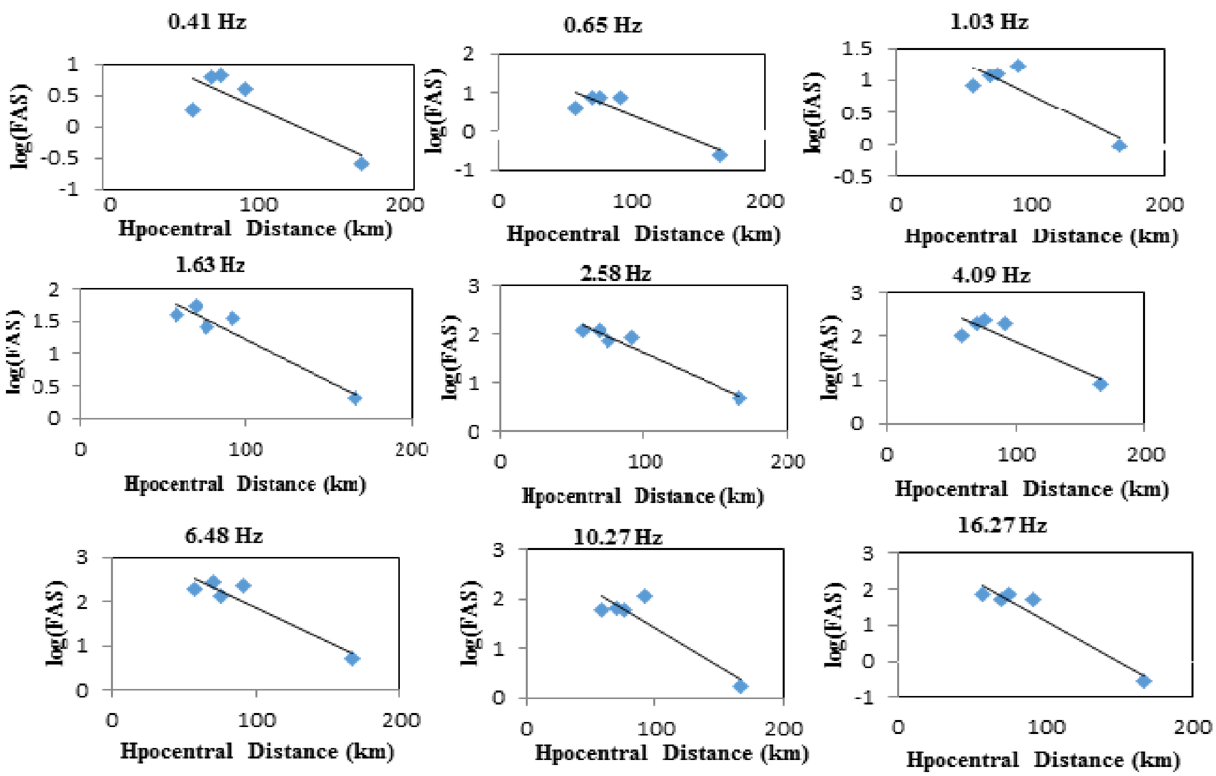

Figure 5 linear regression by using linear curve fitting of Delhi-Haryana earthquake plotted between Hypo-central distances versus logarithmic of FAS at different frequency bands.

The slope of the linear curve fit is used to find the Q-factor as given in the following eq 7.

$$slope = -\frac{\pi f}{V_s Q} \qquad (7)$$

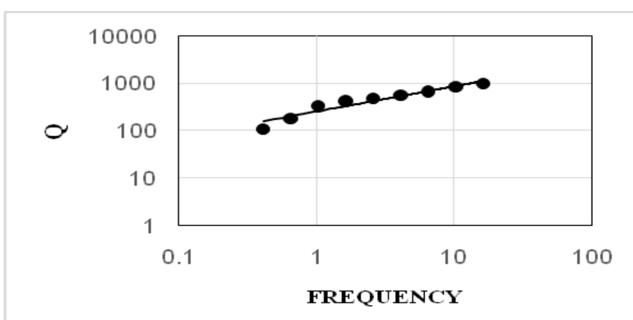

Figure 6: Q value of the Punjabbasin with respect to frequency.

This equation gives Q-values at different frequencies. The linear curve fit of logarithmic *Q*with respect to the logarithmic frequency as shown in Fig 6. The Q-factor obtained for this region is$Q(f)=257f^{0.54}$. The scaling constant is $Q_0=257$which indicates the homogeneity of soil in the region and the seismic activity of the region is$n=0.54$ for the smallermagnitudes of rang Mw3.1 – Mw4.9.

VI. Conclusion:

The frequency depended attenuation value (Q value) for S-waves estimated for this region is $Q(f)=257f^{0.54}$ for the different frequency bands, where the Quality factor (Q_0) is 257 which is less than 500 shows very less changes in amplitudes of the seismic waves in this region and the seismic activity of the region is 0.54 for the smaller earthquakes of Mw3.1 –Mw4.9 is indicate moderate seismic activity in the region.

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