

## Group Velocity Dispersion Analysis of Rajshahi Earthquake for Studying the Crustal Thickness

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### Abstract

Group velocity dispersion has computed for a light earthquake of magnitude 4.1 that occurred at Rajshahi on 5 July 2008 of 16:55:53 UTC by graphical method. Subsurface layer parameters are taken for a model construction to compute the group velocity dispersion by modified Haskell matrix method. Group velocity dispersion by graphical method is then interpreted from model parameters. Sensitivity and the statistical errors of the model are studied and presented in this research. Interpreted crustal structure of the Rajshahi area shows that there are four major subsurface layers of thickness 3.0 km, 10.0 km, 7.0 km and 22.0 km.

**Keywords:** Crustal thickness, period, group velocity, earthquake data, seismic wave.

### 1. Introduction

The local earthquakes Surface wave dispersion analysis can be used to study the crustal structure of the earth using simple models of continental or oceanic crust. Ewing and Press first introduced such model for the oceanic crust using rayleigh wave dispersion. The group velocity dispersion in this research has been computed and analyzed using graphical method for the up-down component seismogram of Rajshahi earthquake event, Bangladesh [1].

There are number of direct and indirect modeling techniques, which are commonly being used in determination of the earth's interior from seismic surface wave dispersion. Direct modeling determines the crustal structure from observed surface wave dispersion. On other hand, the most widely used indirect modeling techniques deal with trial-and-error procedures. Dispersion is computed for different model parameters to see how the computed dispersion matches with observed dispersion [2].

### 2. Material and Methods

#### 2.1 Earthquake data

The earthquake data was recorded at Bangladesh Meteorological Department seismic station which is shown in Fig. 1. Table 1 lists the source parameters of the selected event.

**Table 1: Earthquake Source parameters:**

Date	Origin Time	Location	Depth (Km)	Distance of epicenter	Mw
5 <sup>th</sup> July 2008	16:55:53(UTC)	24.4 <sup>0</sup> N, 88.5 <sup>0</sup> E	29.4	205.11	4.1

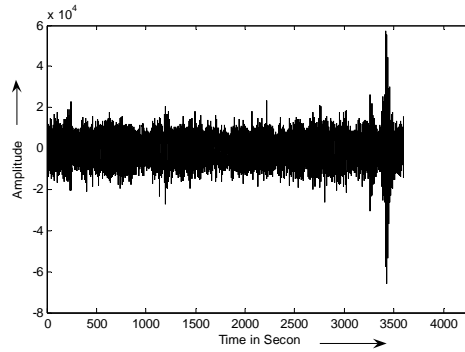


Fig.1. Up-down ground accelerated earthquake seismic wave recorded at Bangladesh Meteorological Department.

## 2.2 Methods

Group velocity from recorded earthquake wave and multilayered crustal model can be obtained respectively by graphical method and modified Haskell matrix method as explained below:

**2.2.1 Graphical Method:** Graphical method is basically a technique of group velocity dispersion determination. In this method the travel times some chosen phases along the surface wave train are measured. Usually the travel times of the wave crests and troughs are read. The group velocity,  $U_g$  of seismic surface wave can be obtained as:

$$U_g = \frac{\Delta}{t} \quad (1)$$

Where  $\Delta$  is epicentral distance and  $t$  is the travel time.

**2.2.2 Modified Haskell Matrix Method:** Modified Haskell matrix method for the case of  $n-1$  homogeneous, isotopic elastic layers over a half-space matrix can be written as [3]:

$$J = \hat{E}^n A^{n-1} \dots A^m \dots A^2 \cdot A^1 \quad (2)$$

Where  $A^m$  is the 4X4 Haskell matrix for the m'th layer and  $\hat{E}^n$  is the half-space inversion matrix.

## 3. Sensitivity of Earth Model Parameters:

Dispersion data are the function of four parameters: S-wave velocity, P-wave velocity, density, and layer thickness [4]. Using given parameters an initial earth model is constructed (Table 2). The group velocity with period is also computed and shown in Fig. 2. Four parameters are changed by 1% in the model (Table 2), an average change of group velocities for each parameter are shown in Fig. 2.

**Table1 2: Initial Earth model parameters.**

Layer number	Vp (km/s)	Vs (km/s)	$\rho$ (gm/cc)	h (km)
1	5.54	3.20	2.54	5.0
2	5.63	3.25	2.57	12.0
3	5.89	3.40	2.65	15.0
Half-space	6.10	3.53	2.72	Infinite

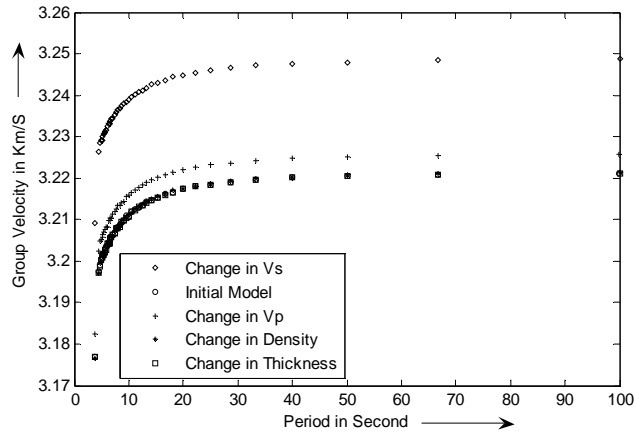


Fig.2. Sensitivity of group velocity dispersion obtained by 1% changes in each model parameter of the initial earth model as shown in Table 1.

**4. Model Error Estimation:**

The S-wave velocities ( $V_s$ ) of the layers are free to change during the inversion. Consequently, the P-wave velocities are estimated using the  $V_p/V_s$  ratio 1.732. Poisson’s ratio ( $\sigma$ ) in each layer was assumed to be .25 and the densities ( $\rho$ ) are calculated from the P-wave velocities ( $V_p$ ) using the relation  $0.32V_p+0.77$  [5]. During the inversion, a number of criteria were adapted to calculate the goodness of fit. These criteria are the standard error of estimate (SE), mean residual (MR), average absolute residual (AR), weighted root mean square error (RMS) and the percent of signal power fit (SPF) [6].

**5. Crustal Thickness Measurement:**

Group velocity dispersions are estimated in this section using graphical method (Eqn.1) and Haskell modified matrix method (Eqn. 2) as discussed below:

**5.1 Group Velocity Estimation from Earthquake data:** Group velocity is computed for the earthquake data (Fig. 1) and earthquake source parameters are shown in table 1. This dispersion relation is computed by graphical method (Eqn. 1).

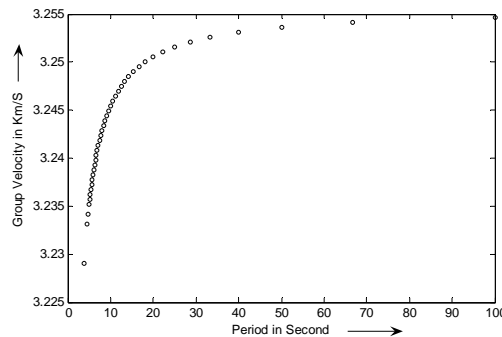


Fig.3. Group velocity dispersion curve for earthquake data

**5.2 Group Velocity Estimation from Model:** There are three models (A-C) are considered in this work. Model based group velocity is computed using modified Haskell matrix method (Eqns. 2). The computed group velocity according to model parameters are shown in Figs. 4-6 also show the group velocity computed by graphical method.

**5.3 Interpretation:** Subsurface layers are estimated from the modeling. It has seen that (Figs. 4-6) group velocity obtained from earthquake data and from models have the similar characteristics. Therefore, interpretations are made from model parameters as shown in the rectangular box in Figs. 4-6. The computed statistical errors are shown in Table 3. According to estimated statistical errors (Table 3) the model C (Fig. 6) is found more acceptable.

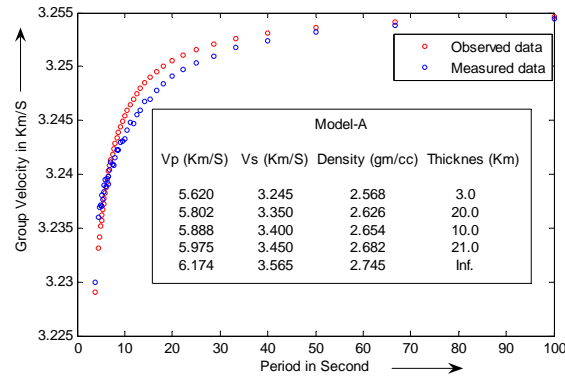


Fig.4. Group velocity dispersion obtained from earthquake data and from modeling A. Rectangular box contained the model parameters.

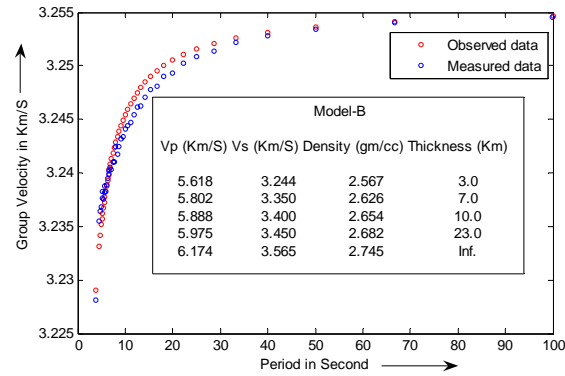


Fig.5. Group velocity dispersion obtained from earthquake data and from modeling B. Rectangular box contained the model parameters.

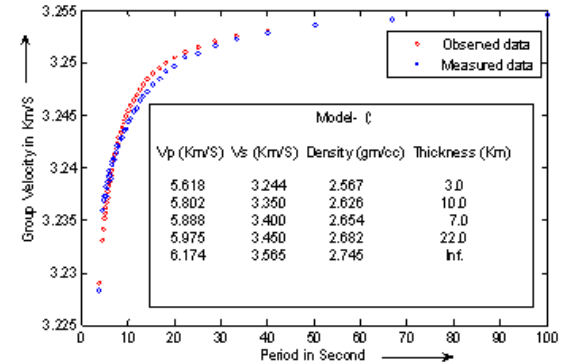


Fig.6. Group velocity dispersion obtained from earthquake data and from modeling C. Rectangular box contained the model parameters.

**Table 3: Data fit criteria:**

Model	SE	AR	RMS	SPF
A	0.0244938	0.0206183	0.0007436	99.99997940
B	0.0244938	0.0154489	0.0006551	99.99998614
C	0.0244938	0.0016291	0.0007201	99.99998725

## 6. Conclusion

There are some challenges to set up the model parameters. Most critical constraint is to consider the Poisson's ratio of 0.25. This ratio might be different for different subsurface layers in real cases. However for the computational advantages  $V_p/V_s$  ratio or Poisson's ratio were kept fixed and the value of 1.732 or 0.25 respectively. . Group velocity dispersion from the three models (A-C) (Figs. 4-6) and considering statistical error analysis (Table 3), it can be said that all the models are very nearer to an acceptable matching level though the statistical confidence level SPF should be 91.5% but our results are around 99.99998725%. Hence the interpreted subsurface layers of the studied Rajshahi earthquake data shows that there are four major subsurface layers having respectively the thickness and density of 3.0 km, 2.567 gm/cc; 10.0 km, 2.626 gm/cc; 7.0 km, 2.654 gm/cc; 22.0 km, 2.682 gm/cc.

## 7. Acknowledgement

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## 8. References

- [1] M. Ewing, and F. Press, "Crustal Structure and Surface Wave Dispersion; Part II, Solomon Islands Earthquake of July 29, 1950", *Bulletin of the Seismological Society of America*, Vol. 42, No. 4, pp. 315-325, 1952.
- [2] J. Dorman, and M. Ewing, "Numerical Inversion of Seismic Surface Wave Dispersion Data and Crust-Mantle Structure in the New York-Pennsylvania Area", *Journal of Geophysical Research*, Vol. 67, No. 13, pp. 5227-5241, 1962.
- [3] T.H. Watson, "A Note on Fast Computation of Rayleigh Wave Dispersion in the Multilayered Elastic Half-Space", *Bulletin of the Seismological Society of America*, Vol. 60, No.1, pp. 161-166, 1970.
- [4] J. Xia, R.D. Miller, and C.B. Park, "Estimation of Near-Surface Shear-Wave Velocity by Inversion of Rayleigh Waves", *Geophysics*, Vol. 64, No. 3, pp. 691-700, 1999.
- [5] C.J. Ammon, G.E.Randall, and G. Zandt "On the Nonuniqueness of Receiver Function Inversions", *Journal of Geophysical Research*, Vol. 95, No.B10, pp. 15303-15318, 1990.
- [6] K.M.A. Elenean, K.S. Aldamegh, H.M Zharan, and H.M. Hussein, "Regional Waveform Inversion of 2004 February 11 and 2007 February 09 Dead Sea Earthquakes", *Geophysical Journal International.*, Vol. 176, No. 1, pp. 185-199, 2009.