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VELOCITY DETERMINATION OF KATHMANDU COMPLEX

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ABSTRACT

Longitudinal and transverse wave velocity of the Kathmandu Complex has been determined based on the arrival times of seismic waves from Kulekhani Dam Quarry blasts, at Phulchaki, Daman and Kakani stations of the Kathmandu Tripartite seismic network by least square method.

INTRODUCTION

Precise solution of the epicentre determination problem for local seisms is not possible without the development of velocity model. In this paper an attempt has been made to determine the longitudinal and transverse seismic waves velocity on the basis of arrival times of direct seismic waves from Kulekhani Dam Quarry blasts at Phulchaki, Daman and Kakani stations of the Kathmandu seismic network.

Twelve explosions blasted out from 4th of April to 21st of May 1980 in Kulekhani Quarry have been used in this study. The precise coordinates of each blast could not be made available. However, they are all concentrated in an area of 0.1 by 0.2 km. The coordinate of the centre of this area is taken as the coordinate of the source. Its aerial distance from Phulchaki (PKI), Daman (DMN) and Kakani (KKN) station is 25.14, 5.51 and 27.89 km respectively. The location of the stations and quarry is shown in Figure 1. The corrections in traverse times of the first arrivals due to altitude variation are within the limit of arrival time reading accuracy i.e 0.1 second.

DETERMINATION

Velocity determinations based on least square criteria are widely applied in developing velocity models. The use of artificial quarry blasts reduced the number of unknown parameters i.e a) direct wave velocity V, b) Origin time H_o, c) focal depth h and d) the epicentral distance $\triangle$ are reduced to H_o and V only. Unfortunately precise timing of the explosion with an accuracy of 0.1 sec, UTC is not available due to which the number of unknowns has increased by one. The waves are considered to be direct which neglects the intraformational velocity differentiation. For direct waves the arrival time of the i^{th} explosion at the k^{th} station T_{ik} can be expressed as a linear function of the explosion–station distance D_k (Bullen, 1963)

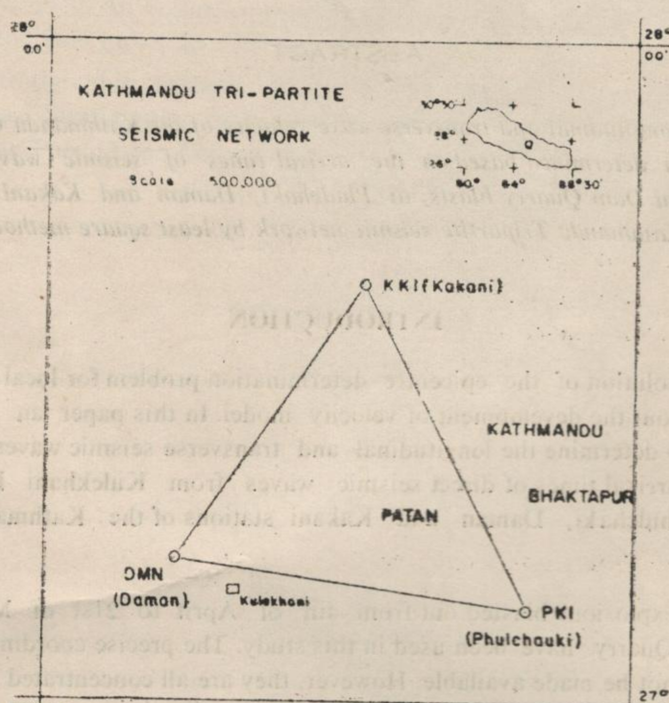

Fig. 1

$$T_{ik} = H_i^o + \frac{D_k}{V} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where K = 1,2,3 corresponding to PKI, DMN and KKN station

i = 1,2 ....12 corresponding to 12 explosions used in this study

H_i^o = origin time of i^{th} explosion

V = velocity of corresponding longitudinal and transverse waves

Equation (1) can be written in the matrix form as

$$Y = BX \text{ .... } (2)$$

$$\begin{bmatrix} T_{11} \\ T_{12} \\ T_{13} \\ T_{21} \\ T_{22} \\ T_{23} \\ . \\ . \\ . \\ T_{121} \\ T_{122} \\ T_{123} \end{bmatrix} = \begin{bmatrix} D_1 & 1 & 0 & 0 & \ldots\ldots\ldots\ldots 0 \\ D_2 & 1 & 0 & 0 & \ldots\ldots\ldots\ldots 0 \\ D_3 & 1 & 0 & 0 & \ldots\ldots\ldots\ldots 0 \\ D_1 & 0 & 1 & 0 & \ldots\ldots\ldots\ldots 0 \\ D_2 & 0 & 1 & 0 & \ldots\ldots\ldots\ldots 0 \\ D_3 & 0 & 1 & 0 & \ldots\ldots\ldots\ldots 0 \\ . & . & . & . & \ldots\ldots\ldots\ldots \\ . & . & . & . & \ldots\ldots\ldots\ldots \\ . & . & . & . & \ldots\ldots\ldots\ldots \\ D_1 & 0 & 0 & 0 & \ldots\ldots\ldots\ldots 1 \\ D_2 & 0 & 0 & 0 & \ldots\ldots\ldots\ldots 1 \\ D_3 & 0 & 0 & 0 & \ldots\ldots\ldots\ldots 1 \end{bmatrix} \cdot \begin{bmatrix} 1/V \\ H_1^0 \\ H_2^0 \\ H_3^0 \\ . \\ . \\ . \\ H_{12}^0 \end{bmatrix}$$

36 x 1 36x 13 13x 1

An error term (principally due to seismogramme reading) should be introduced to (2) to bring it to correct form.

$$Y = B X + E$$

$$E = Y - BX$$

E is a column vector of 36 x 1 size

Then $$E^T E = \begin{bmatrix} E_1 & E_2 & \ldots\ldots\ldots\ldots E_{36} \end{bmatrix} \begin{bmatrix} E_1 \\ E_2 \\ . \\ . \\ . \\ E_{36} \end{bmatrix}$$

$$= E_1^2 + E_2^2 + \ldots\ldots\ldots E_{36}^2 = S$$

S is the sum of the squares of residuals.

Table – 1 Arrival Times of Pg and Sg at PKI, DMN, and KKN from Kulekhani Explosion

No.	Date	Station	P_g Arrival Time	P_g Amplitude 2A (mm)	P_g Period (Sec)	P_g Arrival Time	P_g Amplitude 2A (mm)	P_g Period (Sec)	$S_g - P_g$
1	4-4-1980	PKI	11 43 32.5	31K – 03.5	0.1	11 43 36.5	31K–02.0	0.1	4.0
		DMN	11 43 29.2	125K–>40.0	0.1				
		KKN	11 43 33.2	8K – 02.5	0.1	11 43 37.0	8K – 03.5	0.1	3.8
2	12–4–1980	PKI	08 26 05.3	31K–16.0	0.1	08 26 09.2	31K–11.0	0.1	3.9
		DMN	08 26 02.0	125K–>40.0	0.1				
		KKN	08 26 06.1	8K–08.0	0.1	08 26 10.6	8K – 12.0	0.1	4.5
3	21–4–1980	PKI	11 20 19.8	31K–37.0	0.1	11 20 23.6	31K–28.0	0.1	3.8
		DMN	11 20 16.4	125K–>40.0	0.1				
		KKN	11 20 20.6	8K– 20.0	0.1	11 20 24.7	8K–35.0	0.1	4 1
4	23–4–1980	PKI	08 53 47.8	31K –11.1	0.1	08 53 51.8	31K–05.0	0.1	4.0
		DMN	08 53 44.2	125K–>40.0	0.1				
		KKN	08 53 48.3	8K – 9.0	0.1	08 53 52·3	8K–10.9	0.1	4.0
5	26–4–1980	PKI	08 29 27.7	31K–03.0	0.1	08 29 31.5	31K 02.0	0.1	3.8
		DMN	08 29 24.5	125K–40 0	0.1				
		KKN	08 29 28.4	8K–02 0	0.1	08 29 32.0	8K–02.0	0.1	3.6
6	3–5–1980	PKI	11 14 35.6	31K–07.0	0.1	11 44 39.2	31K–08.0	0.1	3.6
		DMN	11 44 32.1	125K–>40.0	0.1				
		KKN	11 44 36.1	8K– 06.0	0.1	11 44 40.1	8K–05.5	0.1	4.0
7	15–5–1980	PKI	04 53 30.9	31K–05.0	0.1	04 53 34.9	31K–06.0	0.1	4.0
		DMN	04 53 27.4	125K>40.0	0.1				
		KKN	04 53 31.5	8K– 03.5	0.1	04 53 35.5	8K–07.0	0.1	4.0

Contd......

Contd. Table - 1

8	15-5-1980	PKI	11 37 41.4	31K- 10.0	0.1	11 37 45.5	31K-03.0	0.1	4.1
		DMN	11 37 38.1	125K->40.0	0.1				
		KKN	11 37 42.1	8K 06.0	0.1	11 37 45.0	8K-05.0	0.1	3.7
9	18-5-1980	PKI	11 22 32.9	31K-09.0	0.1	11 22 36.8	31K-04.5	0.1	3.9
		DMN	11 22 29.4	125K->40.0	0.1			0.1	
		KKN	11 22 33.5	8K-07.0	0.1	11 22 37.4	8K-08.0	0.1	3.9
10	20-5-1980	PKI	06 17 15.0	31K-03.5	0.1	06 17 19.0	31K-03.5	0.1	4.0
		DMN	06 17 11.3	125K->40.0	0.1			0.1	
		KKN	06 17 15.9	8K-03.5	0.1	06 17 19.6	8K-05.5	0.1	3.7
11	20-5-1980	PKI	09 02 07.0	31K-10.0	0.1	09 02 11.2	31K-09.0	0.1	4.2
		DMN	09 02 04.0	125K->40.0	0.1			0.1	
		KKN	09 02 07.9	8K-05.0	0.1	09 02 11.8	8K-05.0	0.1	3.9
12	21-5-1980	PKI	11 47 50.6	31K-05.0	0.1	11 47 54.6	31K- 5.0	0.1	4.0
		DMN	11 47 47.2	125K->40.0	0.1			0.1	
		KKN	11 47 51.3	8K-03.0	0.1	11 47 55.3	8K- 03.0	0.1	4.0

The problem is to determine vector X so that S becomes minimum (least square method). After simple operations it can be shown that

$X = (B^T B)^{-1} B^T Y$ when $E^T E = (Y - B X)^T (Y-BX)$ is minimum. In our case matrix B is relatively simple and the inversion of $B^T B$ is possible without the help of computor. $B^T Y$ is a row vector of size 13×1 and $(B^T B)^{-1}$ is a symmetric matrix of 13×13 size.

Now $X = (B^T B)^{-1} B^T Y$ yields a row vector of 13×1 size. The element (1,1) of the X row vector gives the value of 1/V; H_1^o is given by element (2,1); H_2^o by element (3,1) and so on.

The detail matrix operations are not shown here and the final results are given as follows:

$$V = \frac{N\left[D_1^2 + D_2^2 + D_3^2 - \frac{(D_1+D_2+D_3)^2}{3}\right]}{\sum_{i=1}^{N} T_{i1}\frac{(2D_1-D_2-D_3)}{3} + \sum_{i=1}^{N} T_{i2}\frac{(2D_2-D_1-D_3)}{3} + \sum_{i=1}^{N} T_{i3}\frac{(2D_3-D_1-D_2)}{3}} \quad \ldots(3)$$

$$H_i^o = \frac{T_{i1} + T_{i2} + T_{i3}}{3} - \frac{D_1 + D_2 + D_3}{3} \cdot \frac{1}{V} \quad \ldots\ldots(4)$$

The r.m.s. of $\frac{1}{V}$ value is given by the element (1,1) of the matrix $\sigma^2 (B^T B)^{-1}$ where σ is the standard error of seismogramme reading.
The arrival times of phase P_g and S_g at PKI, DMN and KKN are given in Table 1. Computation of the velocities from formula (3) gives the following results:

$V_{pg} = 5.583 \pm 0.1$ Km/sec

$V_{sg} = 3.0545 \pm 0.4$ Km/sec

$V_{pg}/V_{sg} = 1.827$

CONCLUSION

All the three stations including the quarry are located within the Kathmandu Complex of Stocklin and Bhattarai (1977). The underlying Nawakot Complex is represented by low grade metamorphic rocks. The obtained velocity for longitudinal and transverse waves is recommended to be assigned to the Kathmandu Complex within the vicinity of Kathmandu. The velocity characteristic of the Nuwakot is not evident directly from this study. However, the preliminary determination of epicentres of local seisms within P_g direct arrival distances may be carried out with the obtained velocity for the events located within the sedimentary wedge.

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