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STRONG MOTION ARRAYS IN INDIA

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SUMMARY

Two strong motion arrays are now in operation in the two sub regions of Himalayas, one in NE and other in NW of India. This paper briefly describes the array characteristics and salient features of one moderate event each in the two arrays which are the first to be recorded in the Himalayas. The epicentral location could be better located from strong motion data. Normalized shape of spectra based on statistical analysis has been derived. Attenuation relationship with respect to distance has been obtained.

INTRODUCTION

The Himalayan convergent zone in India is one of the potential regions of the world where major earthquakes are expected to occur in the near future. The first International Workshop (Ref.1) on Strong-Motion Earthquake Instrument Arrays held in Honolulu in May 1978 had recommended setting up of arrays in such regions for obtaining a wealth of data. In India, there are now two arrays which have now been installed and in operation. The first array is located in Kangra region of the State of Himachal Pradesh and is funded by the National Science Foundation, USA as an INDO-US collaborative project. The second array is in Shillong region of North-East India and is funded by the Department of Science and Technology, Government of India which overseas both the array projects and these are managed by the Department of Earthquake Engineering, University of Roorkee, Roorkee.

The Kangra array is a 50 element analog array and the Shillong array is a 45 element analog array. In addition one digital accelerograph is located in each of these arrays and three digital accelerograph are kept in reserve for mobile aftershock monitoring. The analog instruments are of SMA-1 with TCG card of M/s KINEMETRICS and the digital ones are of A-700 of M/s TELEDYNE.

The paper describes the planning of the arrays with respect to the peculiar topography and tectonic features of the two regions. On April 26, 1986, the Kangra array registered a Magnitude 5.7 event which triggered 9 elements. On Sept. 10, 1986, the Shillong array registered a Magnitude 5.5 event which triggered 12 elements.

Epicentral information has been derived from strong motion records in the form of first P arrivals, S-P time and resultant peak ground accelerations at various stations and compared with other postulated epicentres. It is concluded that the data of strong motion array enables a better prediction of epicentre. Some of the empirical formulae for attenuation of peak ground acceleration in the form $C(R+D)^{\alpha}$ have been compared with actual data. Statistical evaluation of mean and mean plus sigma spectra indicate high values in a narrow period range and low values elsewhere as compared to some standard spectra used in practice.

PLANNING OF THE ARRAY

Detailed description of the Seismo-tectonic setup of the region as well as particulars of the instrument stations are given in technical reports EQ-88-09 and EQ-88-11 of the author's organization. In the HP array, in view of the essentially thrust regime of the region, there is a two dimensional array trending northwest to southeast having a linear dimension of about 240 km and running parallel to the regional strike of the tectonic features. The width of the array in a direction transverse to the geological features varies from about 40 to 80 km. In total, an area of about 60 km X 240 km has been covered by this array. Fig.1 shows the pattern of the location of instruments. The interstation spacing varies between 7 to 21 km. The region has an undulating topography with hills and valleys. The elevations of the stations ranges between 470 m to 2700 m. In the Shillong array, the seismotectonic setup indicates two types of source mechanisms which may have relation to the seismicity of the region. These are strike slip mechanism along Dhubri and Dauki faults and thrust/dip mechanism of Haflong-Naga-Lushai-Disang thrust zones. The tear faults are instrumented by a comb shaped array of 23 elements and thrust faults by a two dimensional grid of 28 elements. Six elements act as common to both arrays. Fig 2. shows the pattern of the location of instruments. The interstation spacing is larger, as compared to HP array, particularly for the comb shaped array as the instruments had to be deployed to cover two sub regions. In both the arrays, the instruments are located at the plinth level of single-storeyed buildings which are owned by official agencies.

ANALYSIS OF ONE EVENT IN EACH OF THE TWO ARRAYS

Detailed information of these two events are given in technical reports EQ-88-10 and EQ-88-12 of the author's organization. Fig. 7 shows two of the stronger three component accelerograms for each of the event.

Epicentral Information

Table 1 gives information on station data and arrival times for the two events.

Fig.3 shows the location of 9 instruments that registered the April 26,1986 event along with 4 postulated epicentres. The preliminary estimate E_1 put up by Directorate of Seismology, India (IMD) was 32.1°N,76.3°E, E_2 of USGS was 32.13°N,76.37°E, and E3 based on strong motion data was 32.18°N, 76.27°E. From an analysis of the pattern of peak ground acceleration, E_4 (32.19°N, 76.29°E) subsequently proposed by IMD taking strong motion data also into account appeared to be the most likely epicentre.

Fig.4 shows the location of 12 instruments that registered the Sept.10, 1986 even along with 3 postulated epicentres. The preliminary estimate E_1 put up by IMD was 25.2°N,91.6°E, E_2 of USGS 25.39°N,92.08°E with a focal depth 43 km and E_3 from strong motion records was 25.56°N,92.19°E with a focal depth of 20 km. From an analysis of the pattern of peak ground acceleration, E_3 appeared to be the most likely epicentre.

Peak Values

Table 1 gives the peak ground values of the corrected acceleration, velocity and displacement at the various stations. The data processing is mainly based on the CALTECH procedure described in Ref.2. It is expected that the acceleration time history would not be much influenced by the technique used for digital signal processing but the velocities and particularly displacements would very much depend on the technique adopted. It is planned to carry out analysis by different techniques.

Attenuation Relationship

Location of epicentre is the most crucial information for evaluation of attenuation relationship. In these two cases, even if the first arrivals times may not be as accurate, the S-P times and peak values of acceleration of near field strong motion records gives the best estimate of epicentral location. A relationship of the form $(R+D)^{\alpha}$ has been fitted to the resultant peak acceleration data for the two events which are as follows :-

	HORIZONTAL	VERTICAL
HP array :	$Y = e^{10.9}(R+\beta(M_1))^{-2.12}$	$e^{7.76}(R+\beta(M_1))^{-1.29}$
Shillong Array:	$Y = e^{7.985}(R+\beta(M_2))^{-1.00}$	$e^{7.25}(R+\beta(M_2))^{-0.991}$

where $\beta(M) = 0.0606\ e^{0.7M}$; $M_1 = 5.7$; $M_2 = 5.5$
Y = peak ground acceleration in cm/s^2.
R = hypocentral distance in km.

Response Spectra

Statistical analysis of the acceleration response spectrum values normalized with respect to the corresponding to peak ground acceleration has been made. Fig 5. and 6 show the mean and mean plus one standard deviation values for both horizontal and vertical components and compared with US Nuclear Regulatory commission's Blume Spectra. It is seen that these events indicate a higher magnification in a narrow short period range but has smaller values elsewhere. The rate of decay from the peak region with respect to the period is faster in case of Shillong region as compared to HP region.

ACKNOWLEDGEMENTS

The National Science Foundation, U.S.A. and DST, Government of India has fully funded the HP array and Shillong array respectively. The DST is the agency overseeing both the projects and would be funding both of them in future. Prof. Jai Krishna and Prof. D.E. Hudson, past Presidents of IAEE gave main impetus for this work. Assistance was available from the State Governments of H.P., Meghalaya and Assam as well as various central Government agencies. The Department of Earthquake Engineering has given all the help needed in the management of the project. Particular thanks are due to Mr. Vipul Prakash, Mr. J.Das, Mr.D. Chandra, Mr.A.P. Sharma and Mr.D.V. Sharma in the preparation of this paper.

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TABLE 1 : STATION INFORMATION, ARRIVAL TIMES AND SUMMARY OF STRONG MOTION DATA

S. NO.	LOCATION	COORDINATES LAT D	M	LONG D	M	R.L. m	P sec	S-P sec	COMP L	PGA mm/s²	PGV mm/s	PGD mm	COMP V	PGA mm/s²	PGV mm/s	PGD mm	COMP T	PGA mm/s²	PGV mm/s	PGD mm
APRIL 26, 1986, 13:05 IST, DHARAMSALA EARTHQUAKE, HIMACHAL PRADESH, INDIA																				
1.	DHARAMSALA	32	13	76	19	1400	18.20	1.35	N76W	1763	71	17	VERT	833	30	25	N14E	1881	95	34
2.	SHAHPUR	32	13	76	11	700	18.70	1.70	N75E	2045	69	19	VERT	670	41	36	N15W	2448	159	27
3.	KANGRA	32	06	76	16	950	19.17	2.05	N43W	1485	49	32	VERT	734	34	26	N47E	1126	97	21
4.	N. BAGWAN	32	06	76	23	800	20.75	2.25	S85W	1469	82	32	VERT	520	31	29	N05W	806	41	30
5.	BAROH	32	00	76	19	720	22.26	3.15	N25W	588	33	11	VERT	229	15	10	N65E	570	31	12
6.	SIHUNTA	32	18	76	05	1000		3.20	N25W	509	42	30	VERT	395	38	40	N65E	359	49	31
7.	BHAWARNA	32	03	76	30	500	23.46		N82E	374	15	7	VERT	359	17	11	N08W	363	32	22
8.	BANDLAKHAS	32	08	76	32	1800	24.20		S27E	1416	66	21	VERT	233	26	18	N63E	1228	39	18
9.	JAWALI	32	09	76	01	550	27.61		S86W	159	33	32	VERT	111	37	27	N04W	167	21	16
SEPTEMBER 10, 1986, 13:20 IST, UMMULONG EARTHQUAKE, MEGHALAYA, INDIA																				
1.	UMMULONG	25	31	92	10	1300	31.48	4.50	S58E	1165	28	27	VERT	528	20	24	N32E	661	23	22
2.	DAUKI	25	12	92	02	40	35.43	5.50	S72E	887	35	13	VERT	339	31	25	N18E	909	43	25
3.	PANIMUR	25	40	92	48	150	39.02		S30E	410	28	20	VERT	238	15	14	N60E	494	30	6
4.	SAITSAMA	25	43	92	23	900	31.83	5.15	S58E	1143	42	11	VERT	633	24	21	N32E	1420	56	17
5.	KHLIEHRIAT	25	21	92	22	1180	52.22		S45E	307	12	12	VERT	172	22	21	N45E	468	33	21
6.	PYNURSLA	25	18	91	55	1300	34.58	5.10	N35E	923	32	27	VERT	326	23	28	S55E	765	23	26
7.	NONGPOH	25	55	91	53	560	38.48		N40E	542	23	9	VERT	354	12	13	S50E	612	18	14
8.	UMRONGSO	25	31	92	38	720	37.76		S63E	277	14	12	VERT	139	18	17	N27E	320	13	10
9.	BAITHLANGSO	25	58	92	36	70	34.60		S30E	464	26	18	VERT	253	11	9	N60E	424	15	8
10.	UMSNING	25	44	91	53	800	37.43	6.15	N60E	1059	37	13	VERT	520	29	26	N30W	784	29	15
11.	NONGKHLAW	25	41	91	38	900	39.22	7.30	N00E	543	74	78	VERT	353	43	43	N90E	941	57	53
12.	NONGSTOIN	25	31	91	16	1400	42.30		N85E	205	16	11	VERT	94	17	8	N05E	141	11	8

NOTES : PGA, PGV and PGD are respectively Peak Ground Acceleration, Velocity and Displacement. P indicates P-Wave arrival time after 13:05 IST in first case and after 13:20 IST in the second case.

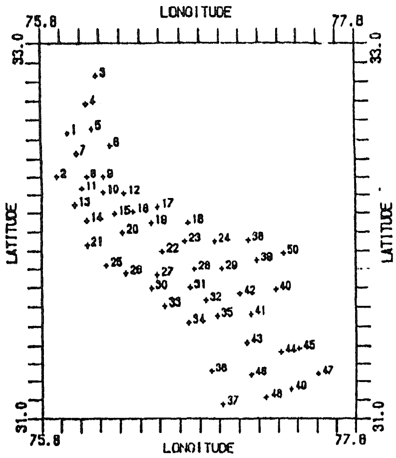

FIG. 1 S.M.A. STATIONS IN HIMACHAL PRADESH

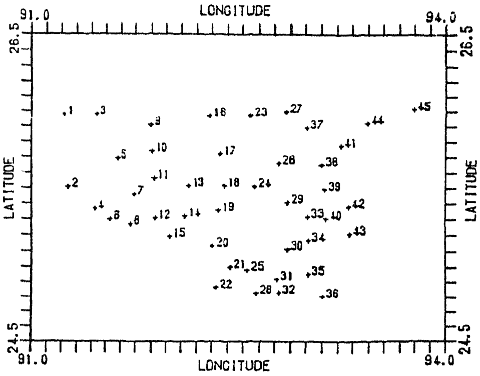

FIG. 2 S.M.A. STATIONS IN SHILLONG REGION

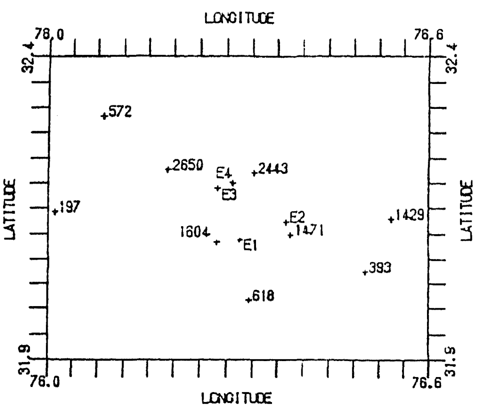

FIG. 3 PEAK HOR. ACC. (MM/S*S) AND LOCATION OF A EPICENTRE

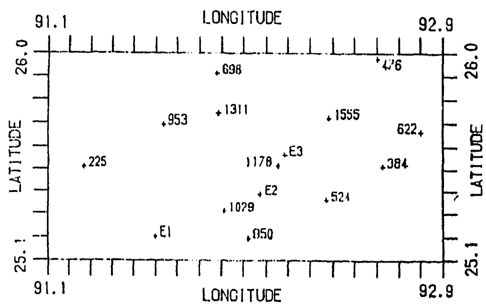

FIG. 4 PEAK HOR ACC (MM/S*S) AND LOCATION OF A EPICENTRE

FIG.5 NORMALIZED MEAN AND MEAN+SIGMA SPECTRAL SHAPES FOR DHARAMSALA EARTHQUAKE AS COMPARED TO BLUME SPECTRA

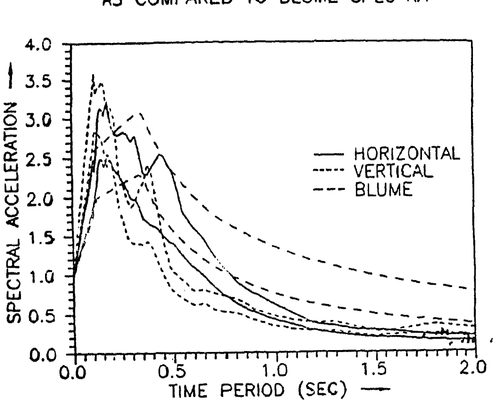

FIG.6 NORMALIZED MEAN AND MEAN+SIGMA SPECTRAL SHAPES FOR UMMULONG EARTHQUAKE AS COMPARED TO BLUME SPECTRA

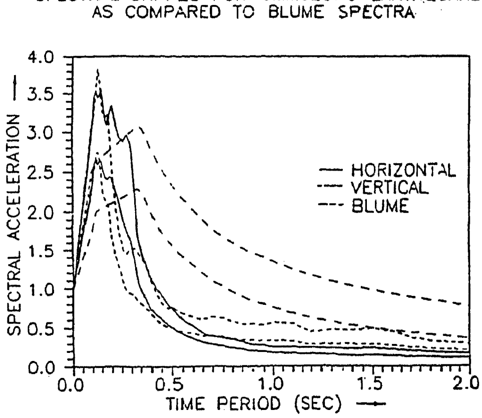

FIG. 7 TYPICAL ACCELEROGRAM TRACES FOR THE TWO EVENTS

SCALE: ACCELERATION 1 CM = 2500 MM/S*S; TIME 1 CM = 1 SEC