Paper No. 182, Bulletin, I. S. E. T. Vol. 15, No. 1 and 2 March and June, on 1978 pp. 14-19

INFLUENCE OF EARTHQUAKE PATTERNS ON MODE CONTRIBUTION

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SYNOPSIS

Results of an analytical study made on the intermodal response behaviour of four structures subject to earthquakes of five different patterns are presented.

STRUCTURES

Four structures indicated below were considered for response study.

1.1 Five Storeyed steel frame:

This is a single bay frame with joint rotations. The base is fixed to rigid foundations. The fundamental period is 1.415 secs.

1.2 Income Tax Office Building (proposed annexe), Madras:

This is a nine storeyed R.C. C. frame building proposed to be constructed at Madras, India, by the Directorate of Works, Govt. of India. In plan the building is rectangular of size 37 m x 19 m. Structurally it consists of eleven 3 span R. C. C. frames interconnected by beams in both directions at the floor levels. One of the free internal frames was chosen for study. The static loading adopted is as per I. S: 875-1964. The building is founded on a stiff foundation consisting of bearing cum friction piles driven to the rock level. For the analysis, the frame was considered fixed at the base The fundamental period is 1.292 secs.

1.3 Central Govt. Office Building, Calcutta:

This is a twenty two storeyed R. C. C. frame cum shear wall building including the basement floor and it is under construction at Calcutta, by the Directorate General of Works, Govt. of India. The building is rectangular in plan of size 46 m x 23 m. One of the open R. C. C. frames in the cross sectional direction was chosen for the study. It is a three span symmetric frame with the side spans smaller than the mid span. The static loading is as per IS: 875-1964. The building is founded on R. C. C. friction piles. For the analysis, the building is idealised to be fixed at base to a rigid foundation system. The fundamental period is 2.506 secs.

1.4 Television Tower, Madras:

This is a 176 metre high television tower at Madras, India, recently constructed by the "All India Radio". It is a selfsupporting open face lattice steel structure for supporting television and FM antennas. Static loading adopted were according to specifications laid down by "All India Radio" (A. I. R. specifications for T. V. towers at Lucknow, Madras and Kanpur). The foundation consists of 100 R. C. C. vertical piles and 112 R. C. C. raker piles 16 ' dia. driven upto hard bed rock. In the analysis, the tower

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was considered fixed at the base to a rigid foundation system. The fundamental period is 0.8412 secs.

ANALYSIS

2.1 The following five earthquakes were adopted for the analysis:

Earthquake		Max. ground accel. gals.	Duration secs
El Centro NS	1940	297	0–7.96
Koyna Longl.	1967	368	0–10.20
Koyna Trans.	1967	480	0–10.65
Hiroo NS	1970	403	0– 7.46
Hiroo EW	1970	419	0– 7.50

2.2 The Wilson—Clough method was used for numerical integration and the authors technique (1) of effective mass, effective stiffness and effective damping matrices were used for obtaining the intermodal responses.

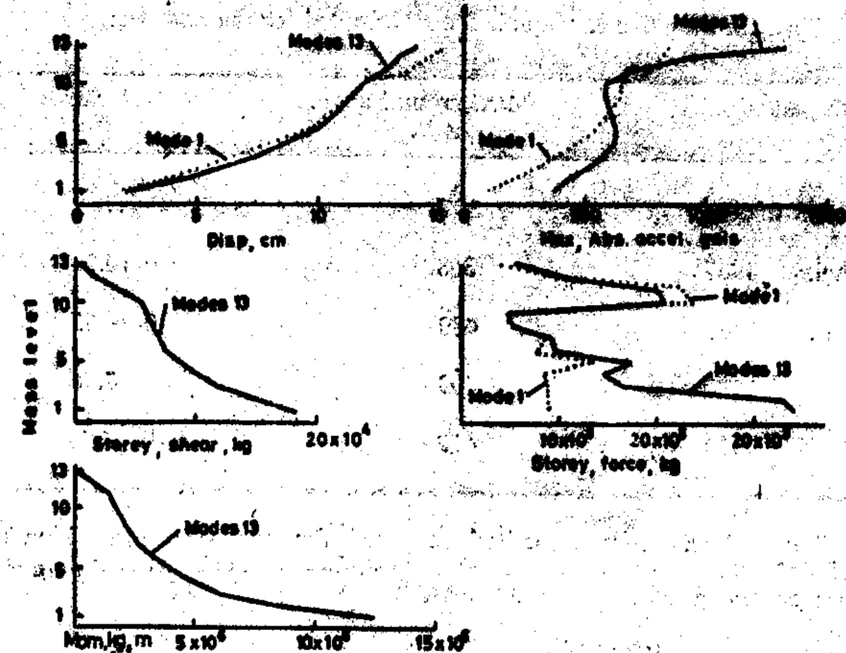
RESULTS AND DISCUSSIONS

Fig.1 reveals that for the T. V. tower, the first mode contributes most of the displacement, the contribution due to the rest of the modes being very little. However, the higher mode contributions of the absolute accelerations and storey forces are appreciable. Thus in a structure, the floor displacements are somewhat insensitive to modal contributions, whereas the accelerations and floor forces are quite sensitive. Similar is the observation with the Central Government Office Building, Calcutta, subject to Koyna Trans. earthquake vide Fig. 2.

In figs. 3 to 7 the mode contributions of the responses of the 5 storeyed building frame (Koyna Trans, Hiroo NS and El Centro NS, 1940) and the Income Tax Office Building (Koyna Trans., Koyna Longl., El Centro NS, 1940 and Hiroo NS) with time dependent damping are indicated. The damping values are shown in the figures. For the five storeyed building subject to Hiroo NS earthquake, all the modes are important for storey force responses. For a Koyna Trans. excitation, the first two modes and for an El Centro NS 1940 excitation, the first three modes reasonably represent the total storey force responses. For the Income Tax Office Building subject to Koyna Trans. and Koyna Longl. earthquakes six modes are required to be considered for a reasonable representation of the total response forces; three modes would suffice for an El Centro NS 1940 earthquake and three to four modes for Hiroo NS earthquake. The first mode alone does not represent nearly the total effects in any case.

CONCLUSIONS

From the above it can be concluded that the importance of the higher mode



T.V. Tower Madras, fixed base response to Hiroo E.W.E.Q. (damping, 0.002, 0.1205, 0.01, 1400.00)

Fig. 1. Time dependent damped response of T.V. Tower to Hiroo earthquake

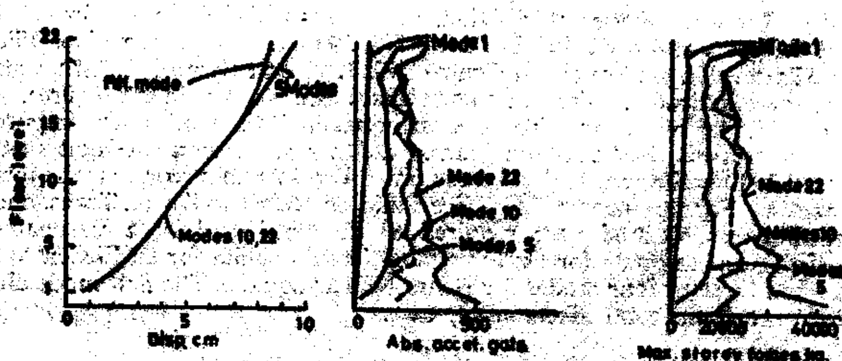


Fig. 2. C.G.O. Building, Calcutta, response to Koyna transverse, $z=0.05$.

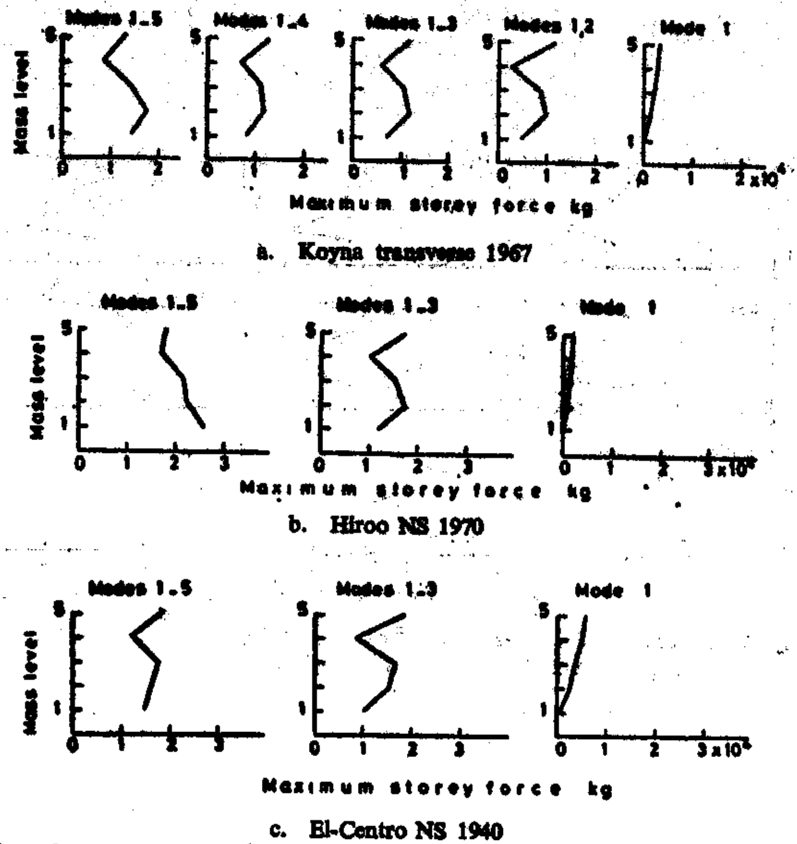


Fig. 3. Effect of modes on response of five storeyed building. Damping (0.002, 0.1205, 0.01, 1400)

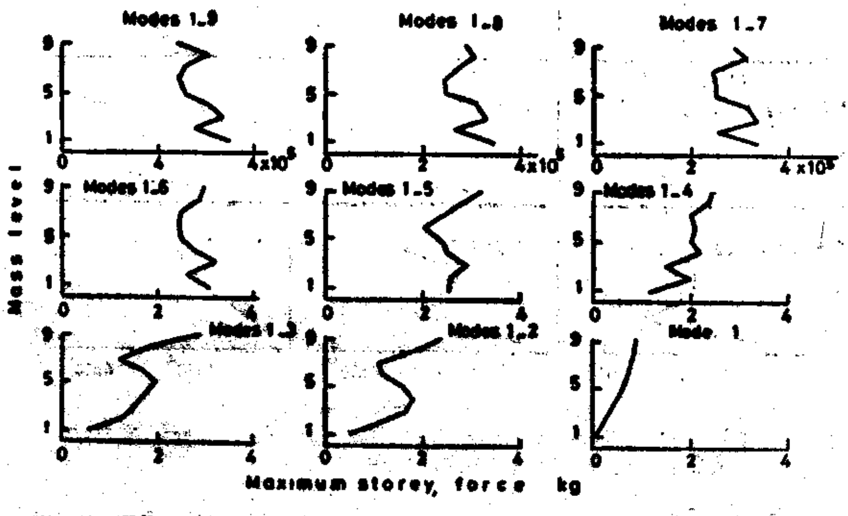


Fig. 4. Effect of modes on response of I.T. building to Koyna transverse 1967 earthquake, Damping (0.05, 0.10, 0.01, 300)

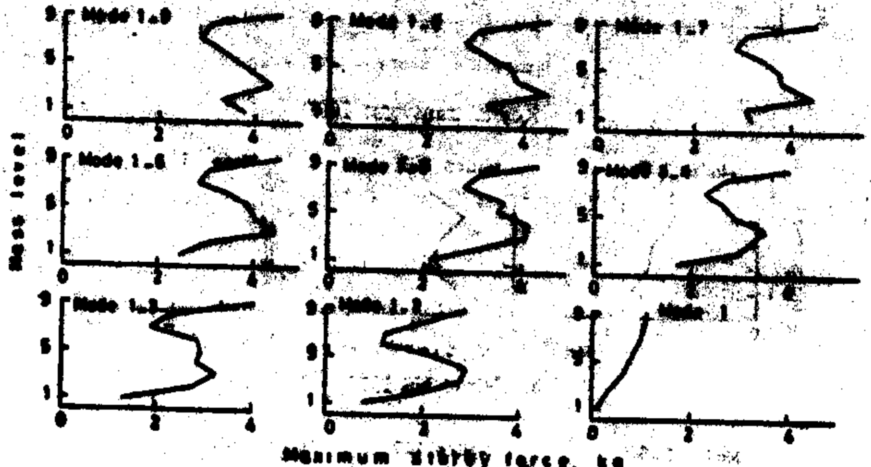


Fig. 5. Effect of modes on response of I.T. building to Koyna longitudinal 1967, earthquake; damping: (0.05, 0.10, 0.01, 300)

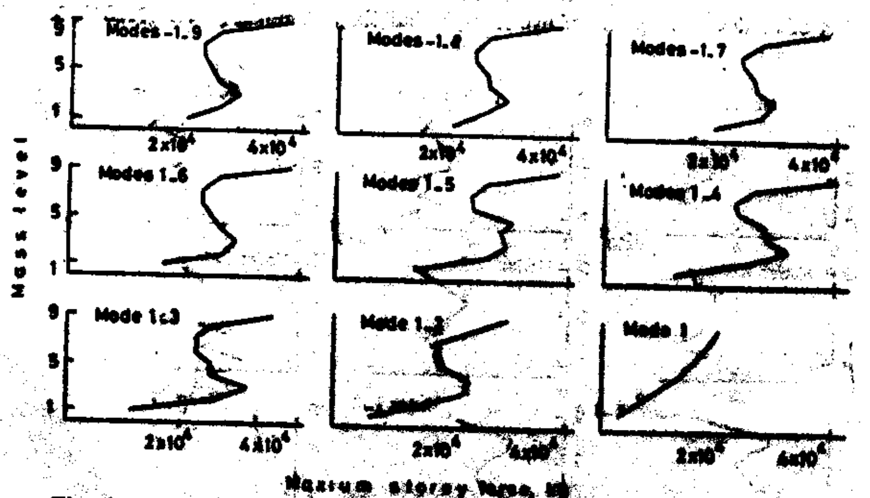


Fig. 6. Effect of modes on response of I.T. Building to El-Centro NS 1940 earthquake; Damping (0.05, 0.1, 0.01, 300)

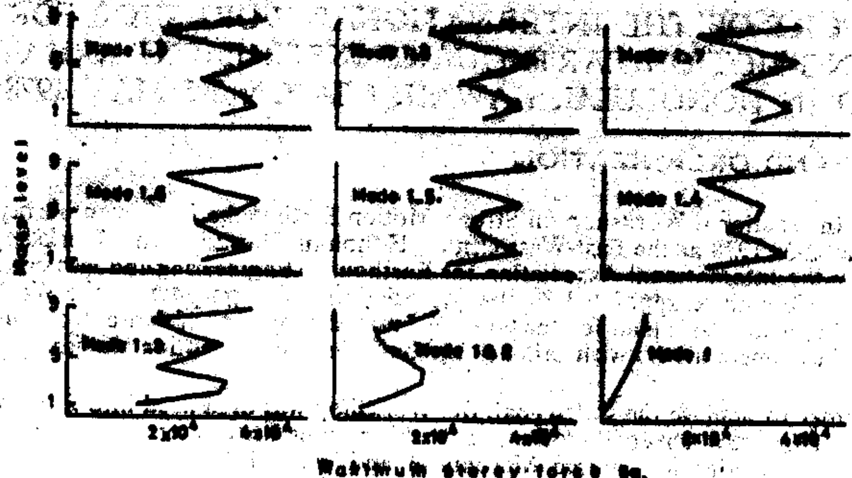


Fig. 7. Effect of modes on response of I.T. Building to Hiroo NS 1970 Earthquake, Damping, (0.05, 0.1, 0.01, 300)

contributions of a structure depends on the pattern of earthquake and that the first mode alone is a poor representation of the total effects of the storey forces. Thus in mode superposition methods adopting response spectrum techniques, a suitable parameter to account for the pattern of the earthquake should be included in the formulae for combining the spectral responses of the mode.

REFERENCE

Joseph, M. Godwin, and Radhakrishnan, R., "A Damping Model for Response Analysis of Multistoreyed Buildings", Sixth World Conference on Earthquake Engineering, 1977, New Delhi, 3:151—3:156.

REPORT OF THE INTERNATIONAL WORKSHOP FOR STRONG-MOTION EARTHQUAKE INSTRUMENT ARRAYS HELD IN HONOLULU, HAWAII, USA ON 2-5 MAY 1978

PURPOSE AND ORGANIZATION

The International Workshop on Strong-Motion Earthquake Instrument Arrays was held on May 2-5, 1978 at the East-West Center, Honolulu, Hawaii. This Workshop was convened by the International Association for Earthquake Engineering and was organized by a Steering Committee appointed by that Association. The purpose of the Workshop was to develop a workable plan for the possible future deployment of dense strong-motion earthquake instrument arrays with primary emphasis on ground motion studies.

In order to achieve the stated goal, the Workshop was organized into five working subgroups. The areas covered by the five working subgroups were: Favourable Array Locations, Array Design for Source Mechanism and Wave Propagation Studies, Array Design for Local Effect Studies, Array Construction and Operation, and Implementation.

PARTICIPANTS

Experts in earthquake engineering and seismology were invited from all over the world to participate in the Workshop. Those individuals with expertise necessary to the success of a particular subgroup were designated as full participants and assigned to that subgroup. They were required to contribute to the work of the subgroup both before, during and following the Workshop. Their expenses were paid in full. In addition to the full participants, a number of individuals were invited as observers in order to ensure a balanced geographical and technical distribution. These individuals had no specific assignments and only their air travel expenses were paid. A list of participants is included as Annexure C.

FINANCIAL SPONSORSHIP

Financial sponsorship for the Workshop was undertaken by the United States National Science Foundation and the United Nations Educational, Scientific and Cultural Organization. Incidental financial support was provided by the Department of Architecture of the University of Hawaii and the Earthquake Engineering Research Laboratory of the California Institute of Technology.

WORKSHOP PROCEEDINGS

The reports and recommendations of the individual subgroups as well as the recommendations of the delegates made in general session will be published within the next few months by the Chairman of the Steering Committee.

The Workshop identified 28 potential sites for strong-motion instrument arrays and designated 6 of these as high priority sites. A list of the sites identified is included as Annexure B. Preliminary design for arrays which could be installed at each potential site were formulated and cost estimates were made. The details of all these items will be included in the Workshop Proceedings.

SUMMARY RESOLUTION

In the final general session, the participants of the Workshop unanimously adopted the resolution shown as Annexure A.

ANNEXURE A

RESOLUTION OF THE INTERNATIONAL WORKSHOP ON STRONG-MOTION EARTHQUAKE INSTRUMENT ARRAYS HELD IN HONOLULU, HAWAII, USA ON 2-5 MAY 1978

The protection of life and property from the devastating effects of earthquakes is an urgent worldwide problem. An understanding of the nature of strong earthquake motions is of crucial importance in solving this problem. At the present time, however, there is a scarcity of engineering data acquired near the centers of destructive earthquakes, and existing instrument arrays are inadequate to provide the necessary data. Yet there is a high probability of occurrence of destructive earthquakes in different parts of the world in the next decade. The participants in this international workshop unanimously recommend that the earthquake threatened countries and other concerned countries and organizations make a concerted effort to establish a comprehensive worldwide system of specialized strong-motion earthquake instrument arrays capable of resolving the nature of the earthquake source mechanism, wave propagation and local site effects. As a first step, the, following specific recommendations should be implemented.

1. The International Association for Earthquake Engineering in collaboration with the International Association for Seismology and Physics of the Earth's Interior form an International Strong Motion Arrays Council to facilitate the establishment of strong-motion earthquake instrument arrays.

2. Earthquake—threatened countries individually and collectively initiate the immediate installation of minimal arrays of 10–20 strong-motion instruments at least at the 28 worldwide sites identified by this workshop.

3. High priority be given to the design and installation of more elaborate source mechanism, wave propagation and local effects arrays, particularly at the 6 critical sites identified.

4. A mobile strong-motion instrument array capable of making source mechanism, wave propagation and local effects measurements be established and maintained for deployment immediately following the occurrence of a major earthquake for the recording of aftershocks.

ANNEXURE B

FAVOURABLE SITES FOR STRONG-MOTION ARRAYS

Area	Fault
Vancouver, Canada	Queen Charlotte
*Palmdale, California	San Andreas
Utah	Wasatch
Yakutat, Alaska	Fairweather
*Oaxaca, Mexico	
Antigua, Guatemala	
Ica, Peru	
Arica, Chile	
San Juan, Argentina	San Juan
*Suruga Bay,Izu, Japan	(nearby)
E. Tohoku, Japan	(nearby)
W. Chubu, Japan	Neodani
Shantung, China	
*Taiwan, Chiai	Meitzekeng
Quezon, Philippines	Luzon
W. Java, Indonesia	Sumatra
Wellington, New Zealand	Wellington
*Shillong, India	Dauki-Haflong
Conabad, Iran	Dasht-e-Bayaz
*Varto, Turkey	North Anatolian
Adapazari, Turkey	North Anatolian
Patras, Greece	(nearby)
Struma, Bulgaria/Yugoslavia	
Garm, USSR	(nearby)
S. Kamchatka, USSR	
S. W. Calabria, Italy	
Granada, Spain	(nearby)
Cordillera, Peru	

*Indicates high priority sites,

ANNEXURE C

LIST OF PARTICIPANTS

Chairman, Steering Committee—W.D. Iwan

Administrative Assistant —S.A. Vedrode

Steering Committee:

A.S. Arya	Y. Osawa
G.W. Housner	J. Petrovski*
J. Krishna	J. Prince*
R.B. Matthiesen	R.I. Skinner*

Group 1. Array Locations

Chairman:	B.A. Bolt	U.S.A.
Vice Chairman:	A. Udias	Spain
	L.S. Cluff	U.S.A.
	V. Karnik	Czechoslovakia
	T. Mikumo	Japan
	M. Niazi	Iran
	S.I. Sacks	U.S.A.
	L.S. Srivastava	India

Group 2. Array Design for Source Mechanism and Wave Propagation Studies

Chairman:	T-L. Teng	U.S.A.
Vice Chairman:	K. Aki	U.S.A.
	D. Boore	U.S.A.
	J.E. Luco	U.S.A.
	B. Tucker	U.S.A.
	F. Wu	U.S.A.

Group 3. Array Design for Local Effects

Chairman:	R.V. Whitman	U.S.A.
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	G.N. Bycroft	U.S.A.
	E. Faccioli	Italy
	W.J. Hall	U.S.A.
	L.W. Heller	U.S.A.
	Y. Ohsaki	Japan
	H. Shibata	Japan
	J. Christian	U.S.A.

Group 4. Array Construction and Operation

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	M. Erdik	**Turkey**
	J. Prince*	**Mexico**
	W. Stephenson	**New Zealand**
	H. Tsuchida	**Japan**

Group 5. Implementation

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Vice Chairman:	**Y. Osawa**	**Japan**
	A.S. Arya	**India**
	J. Evernden	**U.S.A.**
	J. Krishna	**India**
	T. Okubo	**Japan**
	J. Penzien	**U.S.A.**

Official Observers

K.L. Benuska	**U.S.A.**
T. Boen	**Indonesia**
S. Cherry	**Canada**
J. Lander	**U.S.A.**
S.C. Liu	**U.S.A.**
R. Maley	**U.S.A.**
D. Mayer-Rosa	**Switzerland**
W. Minoza	**Philippines**
A. Moinfar	**Iran**
J.O'Connel	**U.S.A.**
S. Okamoto	**Japan**
E. Shima	**Japan**
C. Thiel	**U.S.A.**
Y. Tsai	**Taiwan**
T. Wooton	**U.S.A.**
R. Yarar	**Turkey**

*Did not attend Workshop.

University of Hawaii Observers

- W. Adams
- A. Fujimoto
- H. Lagunio
- N. Nielsen
- G. Tanka

Sponsoring Agency Observers

- M. Gaus
- W. Hukkala