

**ELASTIC AND INELASTIC BEHAVIOUR OF
TORSIONALLY COUPLED SYSTEM UNDER
RANDOM GROUND MOTION**

By

HAMZEH SHAKIB

Department of Applied Mechanics

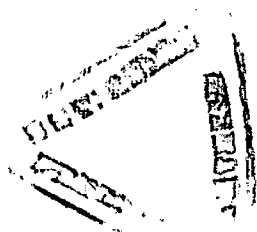
*THESIS SUBMITTED
IN FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY*



**TO THE
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
INDIA**

FEBRUARY, 1991

TO MY BROTHER
MOHAMMAD



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CERTIFICATE

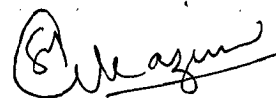
This is to certify that the thesis entitled "Elastic and Inelastic Behaviour of Torsionally Coupled System Under Random Ground Motion", being submitted by Hamzeh Shakib, to the Indian Institute of Technology, New Delhi, for award of the Degree of "Doctor of Philosophy" in Department of Applied Mechanics is a record of the bonafide research work carried out by him under our supervision and guidance. He has fulfilled the requirement for submission of this thesis, which to the best of our knowledge, has reached the requisite standard.

The material contained in this thesis has not been submitted in part or full to any other Institute or University for the award of any degree or diploma.



(Dr. T.K. Datta)

Professor
Civil Engg. Depart.
Indian Institute of Tech.
New Delhi-110016, India



(Dr. S.M.A. Kazimi)

Professor
Applied Mech. Depart.
Indian Institute of Tech.
New Delhi-110016, India

February, 1991.

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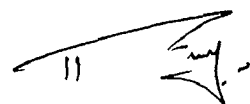
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Hamzeh Shakib

ABSTRACT

Asymmetric buildings with centre of storey resistance different than centre of floor mass respond to earthquake excitations in coupled modes producing both lateral and torsional motions. Both elastic and inelastic responses of such idealized torsionally coupled systems to earthquake excitations have been a topic of considerable interest in the past. However, results of previous studies lead to conflicting results mainly because of the different types of models used in the study. Also, some important factors, which make the findings more general, were not considered in the previous studies. Chief amongst them is the randomness of ground motion. Other important factors include, two way eccentric system, multi-component ground motions incident at an angle, and soil-structure interaction. Therefore, elastic and inelastic responses of torsionally coupled system to seismic excitation are re-examined here keeping in view the importance of the above factors.

The torsionally coupled system consists of an idealized one storey 3-D structure with a rigid square deck supported on weightless columns and walls. For elastic analysis, base of the structure is assumed as fixed, while for inelastic analysis both flexible and rigid base conditions are considered. Seismic excitation is modelled as both stationary and non-stationary

process. Time histories of random ground motions are artificially generated from specified Power Spectral Density Function (PSDF) of ground motion. Non-stationarity is incorporated by modulating the stationary process using different forms of envelope functions. An ensemble of 30 time histories of ground motions is used. Summary of various studies carried out in the present work is given below:

1. Elastic response of the torsionally coupled system to both stationary and non-stationary random ground motions is obtained by integrating the equations of motion using Newmark's β -method. From the ensemble of response time histories, the mean peak responses are obtained. The parametric investigation is carried out in terms of system parameters which identify the dynamic characteristics of the system. They include uncoupled natural frequency (lateral) in one direction (W_x), ratio of two lateral uncoupled natural frequencies (W_x/W_y), ratio of uncoupled torsional to lateral frequency (W_θ/W_x) and eccentricities in the two directions (E_x and E_y). The variations of the mean peak response with the above parameters are investigated under different conditions (namely, one and two component ground motions incident at an angle).

2. Inelastic response of the torsionally coupled system to stationary random ground motion is obtained for investigating primarily its ductility demand. The response is obtained in time domain by solving the incremental form of equations of

motion with the help of a suitable numerical integration algorithm. The yielding of individual elements of the model is checked at any instant of time with and without considering the interaction between shear forces in two principal directions. Mean peak inelastic responses (ductility ratio and mean peak torque) are determined from the ensemble of time histories of response. Also, statistical characteristics of the various response quantities are derived from the same ensemble. The parametric study is conducted under the same set of system parameters and conditions mentioned before.

3. The same study is carried out for non-stationary seismic excitation in order to investigate the effect of non-stationarity on the parametric behaviour of the system. The study is, however, confined to two way eccentric system subjected to two component earthquake only. Rest of the parametric variations remains same as those for the case of stationary excitation. Further, the response of mass-eccentric, stiffness-eccentric and stiffness and strength-eccentric systems to non-stationary random ground motions are compared to study their characteristic differences in so far as their inelastic behaviours are concerned.

4. Inelastic response of flexible base torsionally coupled system is obtained for random ground motion modelled as both stationary and non-stationary process and investigated for a parametric study. The stiffness and damping coefficients of soil representing the dynamic resistance for soil structure

interaction are considered for two horizontal directions and three rotations about the principal axes (i.e x, y, and z). The study is conducted for two way eccentric system subjected to two component earthquake. The base flexibility is varied by changing shear wave velocity V_s from a very low value to a high value depicting nearly the rigid base condition. Parametric study is conducted primarily to study the effect of base flexibility on the ductility demand of torsionally coupled system. Also, it is aimed at finding out how the inelastic behaviour of such system varies with important parametric variations.

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