IMPACT OF TORSIONAL GROUND MOTION ON THE SEISMIC RESPONSE OF MULTISTOREY BUILDINGS ON COMPLIANT FOUNDATION

By

JAVEED AHMAD BHAT

DEPARTMENT OF CIVIL ENGINEERING

Submitted

in fulfilment of the requirements for the degree of Doctor of Philosophy

to the

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

INDIA

AUGUST, 2003

I. I. T. DELHI.
LIBRARY
Acc. No. TH-2987

I.I.T. DELHI
LIBRARY

TH
69.032.2:624.159.2
BHA-I

...thquake resistance
...uvendation;
...ile buildings

CERTIFICATE

This is to certify that the thesis entitled, "**Impact of Torsional Ground Motion on the Seismic Response of Multistorey Buildings on Compliant Foundation**" being submitted by **Javeed Ahmad Bhat** to the Indian Institute of Technology, Delhi for the award of the degree of **Doctor of Philosophy** is a bonafide record of research work carried out by him under our supervision and guidance. The thesis work, in our opinion, has reached the requisite standard fulfilling the requirement for the degree of **Doctor of Philosophy**.

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

(Dr. G.V. Ramana)
Assistant Professor,
Department of Civil Engineering
Indian Institute of Technology,
Delhi
Hauz Khas, New Delhi – 110016
India

(Dr. A.K. Nagpal)
Professor,
Department of Civil Engineering
Indian Institute of Technology,
Delhi
Hauz Khas, New Delhi – 110016
India

ACKNOWLEDGEMENT

All thanks to Almighty God who made me capable for carrying out this work.

It gives me a great pleasure in expressing my regards and profound sense of gratitude to Prof. A.K. Nagpal for his perspective supervision, invaluable guidance and constant encouragement throughout this work. With his magnificent understanding and in-depth knowledge of Structural Engineering and Structural Dynamics he has motivated and cultivated in me a very deep interest and ability to understand the behaviour of tall buildings under seismic loading.

I express my sincere thanks to my co-supervisor Dr. G.V. Ramana for his help, guidance and encouragement throughout the program.

I am very thankful to Prof. M.D. Trifunac (University of Southern California, CA) and Prof. V.K. Gupta (IIT Kanpur) for their valuable help and for providing related literature. I would also like to thank Prof. T.K. Dutta, Prof. A.K. Jain, Prof. A.K. Gosain and Prof. Ashok Gupta of I.I.T. Delhi for their help and cooperation.

I extend my thanks to Q.I.P. Coordinator I.I.T. Delhi and his staff for their cooperation during the program. Also I am very thankful to Govt. of India for providing me scholarship and other facilities during this course. I would also like to thank Head, Civil Engineering Department, I.I.T. Delhi and his staff for their cooperation.

I extend my sincere thanks to the authorities of my parent Institute R.E.C. Srinagar namely: Prof. A.R. Chesti, Prof. A.M. Wani, Mr. Firdous Ahmad Wani, Prof. G.Q. Dar and Mr. Abdul Rehman for processing my documents smoothly and sponsoring me for this program.

I am very much thankful to my friends Sandeep Chaudhary, Piyush Chowdhary, Pervez Ahmad and Fayaz Ahmad for their help during the thesis write up. Let me not forget my friends and colleague research scholars Dr. Mahesh, Dr. Ravi Sharma, Munish K. Bhardwaj, Dr. Amit Agarwal, Dr. Savita and A. K. Banik, for their constant encouragement and cooperation.

I also express thanks to my brothers and sisters for their consistent encouragement and moral support.

I wish to express my gratitude to my father in-law and all other family members for their concern and constant support throughout this work. I admit that most of the time I took their support for granted.

I express my indebtness to my parents and little son Bouruj, who were deprived of the privileges due to preoccupation of myself with the research work. Lastly, the work of this dimension could not have been possible without encouragement and co-operation from my wife, Mehfuza who managed most of my responsibilities on her shoulders magnificently. I am very thankful to her.

Javeed Ahmad Bhat

ABSTRACT

It is customary to assume that the input motion is the same at all points on the foundation and torsional deformations will take place only as a result of the lack of symmetry of the structural configuration or due to uneven mass distribution. The spatial variation of ground motion due to phase lag and coherency loss effect gives rise to rotational ground motions (only torsional ground motions are considered here) thereby inducing additional torsional deformations. Studies are available on buildings subjected to torsional ground motion, but most of these studies have been confined to single storey buildings on fixed foundation. No systematic studies are reported on the effect of torsional ground motion resulting from propagation of motion through different soil medium. Also studies are not available on the effect of foundation compliance, when the effect of torsional ground motion is incorporated. These studies are reported in the present work.

The studies are carried out for a series of symmetric buildings comprising of frames and frames and shear walls, and asymmetric buildings comprising of frames. The buildings are founded on the raft which rests on three different types of soils modeled as visco-elastic half space, viz: (i) Firm soil, (ii) Medium firm soil and (iii) Soft soil. The shear wave velocity V_s for these soil types have been chosen as: V_s = 350m/sec, 250m/sec and 100m/sec for firm, medium firm and soft soil respectively. Similarly on the basis of available data in the literature, a set of angles of incidence of the propagating wave have been chosen: 20^0 for firm and medium firm soils, 10^0 for firm, medium firm and soft soils and 5^0 for soft soil only. The fundamental time period T = 0.3sec for 3-storey frame and 4-storey frame-shear wall buildings and T =

0.8sec for 10-storey frame and 12-storey frame-shear wall buildings, is chosen. For all these buildings the ratio of uncoupled fundamental torsional to translational frequency varies from 0.65 to 1.5. For asymmetric buildings a set of eccentricities are considered.

A formulation based on sub-structure method is used for the analysis of buildings. For the superstructure, each floor is assumed to have 3 d. o. f., a translation along the two principal axes in the plane of floor and a rotation about a vertical axis and for the substructure, raft is assumed to have 5 d. o f., a translation along two principal axes and a rotation about each three orthogonal axes. Two cases of input motion are considered: (i) Translation ground motion only and (ii) combined translation and torsional ground motion. Equations of motion of the system incorporating foundation impedance functions are written in time domain, converted into frequency domain and the transfer functions obtained. Using Inverse Fast Fourier Transform the seismic response in time domain is then determined.

Five non-dimensional parameters have been identified to determine the individual and combined effect of torsional ground motion and compliance effects. A detailed study is reported on these parameters.

It is shown that the contribution from torsional ground motion is considerable for the soft soil case. It is also found that the increase in the response is significant for buildings, having low fundamental translational time periods and that are torsionally flexible. It is also seen that the effect of torsional ground motion reduces with the increase in the eccentricity. The codal provisions of accidental eccentricity usually give higher response but in some cases these provisions are shown to be insufficient.

TABLE OF CONTENTS