

**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**

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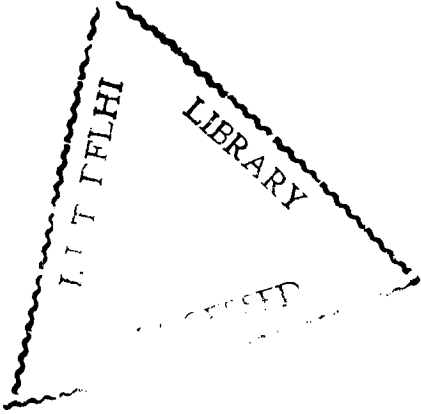


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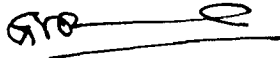
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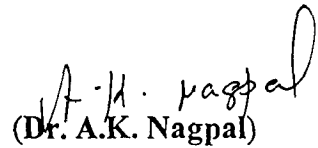
## CERTIFICATE

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

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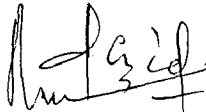
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## ABSTRACT

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:  $V_s = 350\text{m/sec}$ ,  $250\text{m/sec}$  and  $100\text{m/sec}$  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:  $20^\circ$  for firm and medium firm soils,  $10^\circ$  for firm, medium firm and soft soils and  $5^\circ$  for soft soil only. The fundamental time period  $T = 0.3\text{sec}$  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 <sup>cases</sup> these provisions are shown to be insufficient.

## TABLE OF CONTENTS

CERTIFICATE	i	
ACKNOWLEDGMENTS	ii	
ABSTRACT	iv	
TABLE OF CONTENTS	vi	
LIST OF FIGURES	x	
LIST OF TABLES	xxxi	
LIST OF NOTATIONS	xxxiv	
<b>CHAPTER 1.</b>	<b>Introduction and Literature Review</b>	<b>1</b>
1.1	Introduction	1
1.2	Literature Review	2
1.2.1	Dynamic Response of Buildings	2
1.2.1.1	<i>Response due to Translational Ground Motion</i>	2
1.2.1.2	<i>Response due to Torsional Ground Motion</i>	5
1.2.2	Methods of Response Analysis	6
1.2.3	Impedance Functions	8
1.2.4	Superstructure-Foundation Interaction Effects	10
1.2.5	Rotational Motion	11
1.3	Outline of the Present Work	12
<b>CHAPTER 2.</b>	<b>Seismic Analysis of Building-Foundation System</b>	<b>16</b>
2.1	Introduction	16
2.2	Modeling of Superstructure	17
2.2.1	Stiffness Matrix of a Stiffening Element in Local Co-ordinates	17
2.2.2	Global Stiffness Matrix of the Building:	18
2.3	Interaction Equations for Foundation-Building Systems:	20
2.3.1	Displacements of Floor Slabs in Global Co-ordinates:	21

2.3.2	Mass Matrix	23
2.3.3	Equations of Motion for the Superstructure	26
2.3.4	Equations of Motion for the Foundation	26
2.3.5	Equations of Motion in Frequency Domain:	31
2.3.6	Equilibrium Equations in Generalized Co-ordinates and Solutions:	32
2.4	Evaluation of Seismic Response	34
2.5	Power Spectral Density Function of the Ground Motion	35
2.5.1	Torsional Motion Power Spectral Density Function	36
2.5.2	Translational Motion Power Spectral Density Function	38
2.6	Simulation of Ground Motion	40
2.7	Computer Program	41
2.7.1	Generation of Ground Motion Time History	41
2.7.2	Response Evaluation of the Building	43
2.8	Conclusions	44

<b>CHAPTER 3.</b>	<b>Seismic Analysis of Symmetric Buildings</b>	
	<b>on Fixed Foundation</b>	<b>60</b>
3.1	Introduction	60
3.2	System Parameters and Result Presentation	61
3.3	Example Buildings	62
3.3.1	Buildings EBP1(0.3; 0.65, 1.0, 1.5) (3-Storey Frame Buildings)	65
3.3.2	Buildings EBP2(0.3; 0.65, 1.0) and EBP3(0.3; 1.5) (4-Storey Frame-Shear Wall Buildings)	69
3.3.3	Buildings EBP1(0.8; 0.65, 1.0, 1.5) (10-Storey Frame Buildings)	71
3.3.4	Buildings EBP2(0.8; 0.65, 1.0) and EBP3(0.8, 1.5) (12-Storey Frame-Shear Wall Buildings)	73
3.4	Codal Provisions:	76
3.5	Conclusions	77

<b>CHAPTER 4.</b>	<b>Seismic Analysis of Symmetric Buildings on Compliant Foundation</b>	<b>139</b>
4.1	Introduction	139
4.2	Impedance Functions	140
4.3	Numerical Examples	141
4.3.1	Buildings EBP1(0.3; 0.65, 1.0, 1.5) (3-Storey Frame Buildings)	142
4.3.2	Buildings EBP2(0.3; 0.65, 1.0) and EBP3(0.3; 1.5) (4-Storey Frame-Shear Wall Buildings)	145
4.3.3	Buildings EBP1(0.8; 0.65, 1.0, 1.5) (10-Storey Frame Buildings)	148
4.3.4	Buildings EBP2(0.8; 0.65, 1.0) and EBP3(0.8, 1.5) (12-Storey Frame- Shear Wall Buildings)	150
4.4	Comparison of $R_{ci, ti}$ with $R_{cf, tf}$	152
4.5	Conclusions	152
<b>CHAPTER 5.</b>	<b>Seismic Analysis of Asymmetric Buildings on Fixed Foundation</b>	<b>239</b>
5.1	Introduction	239
5.2	Numerical Examples	239
5.2.1	Buildings EBP1(0.3; 0.65, 1.0, 1.5; +0.1)	240
5.2.2	Buildings EBP1(0.3; 0.65, 1.0, 1.5; +0.2)	243
5.2.3	Buildings EBP1(0.3; 0.65, 1.0, 1.5; -0.1)	244
5.2.4	Buildings EBP1(0.3; 0.65, 1.0, 1.5; -0.2)	246
5.3	Conclusions	247
<b>CHAPTER 6.</b>	<b>Seismic Analysis of Asymmetric Buildings on Compliant Foundation</b>	<b>305</b>
6.1	Introduction	305
6.2	Numerical Examples	305
6.2.1	Buildings EBP1(0.3; 0.65, 1.0, 1.5; +0.2)	306

6.2.2	Buildings EBP1(0.3; 0.65, 1.0, 1.5; - 0.2)	309
6.3	Conclusions	311
<b>CHAPTER 7.</b>	<b>Conclusions and Scope for Future Work</b>	<b>351</b>
7.1	Conclusions	351
7.2	Recommendation for the Future Work	356