SEISMIC RESPONSE OF SECONDARY SYSTEMS MOUNTED OVER TORSIONALLY COUPLED PRIMARY SYSTEM

by

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Thesis submitted
in fulfillment of the requirement for the degree of
DOCTOR OF PHILOSOPHY

Department of Civil Engineering

Indian Institute of Technology, Delhi

INDIA

April 1998

CERTIFICATE

This is to be certified that the thesis entitled, **"Seismic Response of Secondary Systems mounted over Torsionally Coupled Primary System"**, being submitted by Mr. ***Abhijit Kumar Agrawal,*** to the Indian Institute of Technology, Delhi, for the award of the degree of **'Doctor of Philosophy'** in Civil Engineering is a record of the bonafide research work carried out by him under my supervision and guidance. He has fulfilled the requirements for submission of this thesis, which to be the best of my knowledge, has reached the requisite standard.

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

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April 1998

ACKNOWLEDGEMENTS

I am greatly in debt to my research supervisor Prof. T.K. Datta, Prof, and Head Civil Engg. Deptt., for his kind helps and advices throughout the study.

I acknowledge my heartful thanks to all my friends, teaching and non-teaching staffs of the Civil Engineering Department for their co-operation and help during this work.

I am thankful to Prof. S. Karunes for her constant encouragement and moral support at various stages of my research work.

(Abhijit Kumar Agrawal)

April 1998

ABSTRACT

Dynamic behavior of secondary systems mounted over torsionally coupled linear and non-linear primary systems are investigated under random ground excitation modelled as white noise. The response quantities of interest are calculated for both *2-D* and *3-D* models of the primary system with and without considering interaction between the secondary and the primary structural systems. For the *2-D* model of the primary system, the responses are obtained under uni-directional ground excitation, and for the *3-D* model of the primary system, the responses are obtained under bi-directional ground excitations. The response behavior of the secondary system is examined under a set of important parametric variations. These parameters include the ratio between the uncoupled lateral frequencies of the primary and the secondary structural systems; the ratio of uncoupled lateral to rotational frequencies of the primary system (tuning and detuning); eccentricity ratios of the primary and the secondary structural systems; damping ratios of the primary and the secondary structural systems; the mass ratio of the two sub-systems; the hysteretic parameters for the non-linear primary system; and orientation of the secondary system with the major axis in the case of the multiple supported secondary system. Summary of the specific studies made in the thesis is given in the following:

Behavior of secondary systems mounted over torsionally coupled linear *2-D* and *3-D* primary systems is investigated under broad band seismic excitation. The response quantities of interest are the RMS values of normalized absolute acceleration of the secondary system, and the relative displacement between the secondary and the primary systems. The responses are obtained by frequency domain spectral analysis using power spectral density function of the ground acceleration as input. It is observed that for the tuned condition, the responses increase with the increase in the normalized eccentricity of the primary system. However, an opposite trend of variation is observed for the detuned condition. Also for the detuned condition, it appears that

there exists an optimum value of damping ratio for which the responses become minimum.

The response behaviors of the secondary systems mounted on non-linear *2-D* and *3-D* primary systems are studied. Two types of analysis namely, linearized spectral analysis and time domain analysis are presented. For the former, the non-linear primary system is converted into an equivalent linear primary system by modifying stiffness and damping properties by using a linearization technique. For the latter, the responses are obtained by using step-by-step time integration technique, which duly considers the non-linearity of the primary system. The effect of bi-directional interaction on the yielding of the *3-D* model of the primary system is included in the analysis with the help of the coupled differential equations (Wen's model), representing the force deformation behavior in the yielding zone. The coupling terms are neglected when the interaction effect is ignored. Some of the important conclusions of the study are: (i) as compared to the linear primary system, the responses are significantly reduced under the tuned condition and are amplified under the detuned condition, for the non-linear primary system; (ii) the maximum difference in the responses obtained by the frequency domain method of analysis and the time domain method of analysis is about 15% under the detuned condition and is insignificant under the tuned condition; (iii) for the strong torsionally coupled primary system under the tuned condition, the responses obtained by considering the bi-directional interaction are more. However, an opposite trend has been observed for the weak torsionally coupled primary system under the detuned condition.

Floor response spectra for the design of the secondary systems mounted over liner and non-linear *2-D* and *3-D* primary systems are studied by considering and ignoring the interaction between the primary system and the single-degree-of-freedom system. The floor response spectra are generated by the time domain analysis. The floor response spectra for relative displacement generally increase with the increase in the time period for both strong and weak torsionally coupled linear and non-linear *2-D* and *3-D* primary systems, for both interaction and no-interaction cases. For absolute acceleration, it is constant up to a certain value of the time period and then, the response varies with the time period, showing a definite peak. The effect of interaction between the primary and the single-degree-of-freedom systems, considerably influences the response spectra.

Response behaviors of the multi-supported secondary system mounted over *3-D* linear and non-linear primary systems have been investigated under bi-directional input excitations. Both interaction and no-interaction cases are considered in the analysis. The responses are calculated by both time domain analysis and frequency domain spectral analysis. For the non-linear primary system, responses of the secondary system under both tuned and detuned conditions are found to be more when interaction is not considered between both systems. For the detuned condition, the normalized acceleration is found to be more if interaction between both systems is not considered; however, the bending moment is found to be more if interaction is considered between both systems. The bi-directional interaction on yielding of the P-system significantly influences the responses of the S-system.

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