RESPONSE OF OVER-GROUND PIPELINES AND PIPING SYSTEMS TO RANDOM GROUND MOTION

By

HANY OTHMAN SOLIMAN

Department of Civil Engineering

Thesis

Submitted in fulfilment of the requirements

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To ---------

MY PARENTS

AND THOSE WHOM I LOVE

CERTIFICATE

This is to certify that the thesis entitled, **"Response of Over-ground Pipelines and Piping Systems to Random Ground Motion"**, being submitted by **Mr. Hany Othman Soliman**, to the Indian Institute of Technology, New 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 suspervision and guidance. He has fulfilled the requirements for submission of this thesis, which to the best of my knowledge, has reached the requisite standard.

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

January 1991

(Prof. T.K. DATTA)
Civil Engineering Deptt.,
Indian Institute of Tech.,
New Delhi - 110016, INDIA.

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ABSTRACT

The present study deals with the analysis and investigation of the parametric behaviour of over-ground pipelines and piping systems for random ground motion. The study includes the following :

A method is presented for obtaining the response of over-ground pipelines to multi-component ground motion idealized as both stationary and modulated non-stationary process in frequency domain using spectral approach. The method of analysis duly considers the effect of soil-structure interaction which makes the system non-classically damped, and angle of incidence of the earthquake wave. With the help of the proposed method of analysis, an extensive parametric study is conducted. The parameters include end conditions of the pipeline, total length of pipeline to be considered for correct evaluation of internal forces, spacing of intermediate supports, slenderness ratio, radius of the pipe, the correlation coefficient, and the angles of incidence of wave propagation and of ground motion. A special attention has been paid to the determination of stresses induced at the intersections (T and L) of the pipelines and to investigate the effect of some important parameters on these stresses. The numerical investigations show that the above parameters have considerable influence on the response of the pipeline.

A time domain analysis using space state formulation

for obtaining the time history of RMS response of over-ground pipelines to non-stationary random ground motion is presented. The method of analysis duly considers the effect of soil-structure interaction, multi-component and multi-point excitation, and spatial correlation of ground motion. A comparison between frequency domain spectral analysis and the proposed time domain analysis is carried out for some specific cases. The numerical studies with the help of specific examples show that the proposed time domain analysis is computationally more efficient than the frequency domain analysis for generalized cases. However, for certain specific cases like, straight pipelines having the same modulating function for both components of ground motion, frequency domain analysis may become computationally faster. The difference between responses obtained by time and frequency domain analyses is not significant; frequency domain analysis gives always higher values.

A quasi-static analysis of over-ground pipelines for obtaining its response to random ground motion is presented. A numerical study is conducted to show the conditions under which the analysis is valid. The study shows that the proposed method provides results of sufficient accuracy for cases where the system's undamped natural frequencies are far beyond the range of frequencies for which seismic excitation has significant energy content. Such conditions may arise for many over-ground pipelines.

Both frequency and time domain analyses presented earlier are extended for piping systems subjected to multi-component, multi-support non-stationary seismic excitation. The proposed methods of analyses are also simplified for the special case of piping system with rigid supports (without soil-structure interaction/support flexibility). Using these analyses, a parametric study is conducted to investigate the effects of support conditions (stiffness and damping of supporting structures) and nature of spectrums characterizing the seismic excitations on the response. The efficiencies of the frequency and time domain analyses for piping systems to non-stationary seismic excitation are evaluated for some typical cases. The numerical study shows that the nature of input spectrum at the excitation points, the relative flexibility and damping characteristics of different supporting points have considerable influence on the response of the piping system. Time domain analysis proves to be computationally more efficient than frequency domain analysis.

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