

SEISMIC ANALYSIS OF BURIED PIPELINES

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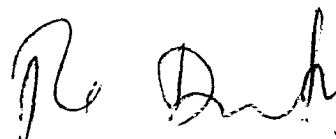
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CERTIFICATE

This is to certify that the thesis entitled, "SEISMIC ANALYSIS OF BURIED PIPELINES", being submitted by Mr. EL-SAYED AMIN MASHALT, 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 supervision 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.



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ABSTRACT

The buried pipelines are very vulnerable to damage during intense earthquakes with potentially serious adverse effect upon the regions that they serve. Therefore, a realistic evaluation of stresses induced by seismic excitation at different sections of buried pipeline system is important to satisfy the adequacy of its design and to perform a seismic risk analysis. The present study deals with the analysis of buried pipeline response to random ground motion and attempts to find the influence of various important parameters on the stresses induced by the ground motion. It also investigates the probabilities of occurrence of different damage states in the pipeline due to different levels of earthquake intensity. The study includes the following.

A method is proposed for the response analysis of straight pipeline to earthquake excitation considered as stationary random process characterized by a PSDF and a cross spectral density function to account for spatial correlation. The soil reaction to dynamic excitation along the pipelength is obtained by combining the dynamic plane strain solution with the Mindlin's static stresses within elastic half space due to uniform load. The pipeline is idealized as an assemblage of 2D beam elements. A discrete lumped mass model is employed to describe the pipe motion. Spectral analysis is performed to obtain the r.m.s pipe responses in axial direction and in lateral

direction separately (independent of each other) assuming that the ground motion is either acting along the pipe-length or perpendicular to it.

The above procedure is then modified to develop a general analysis for determining the stresses at the intersections of the pipelines due to two component earthquake incident at an angle w.r.t a set of global axes. The two (horizontal) components of ground motion are assumed to be acting in the principal directions (major and moderate) so that they may be treated as statistically independent. The pipeline system is modelled as two dimensional plane frame in a viscoelastic medium. A lumped mass model is used for describing the pipe motion; the equations of motion are developed by considering the motions of pipe along both translational degrees of freedom at a node.

Some of the important outcomes of the parametric studies conducted with the help of the above methods of analysis show that (i) consideration of cross terms of soil stiffness and damping matrices reduces the pipe stresses; (ii) for soft soil, the pipe stresses become considerably higher than those for the hard soil if the PSDF of ground motion is modified for different soil conditions; (iii) the distribution and magnitudes of the stresses near the pipe ends vary considerably with the pipe end condition, where as the stresses in the middle attain stationary values for different end conditions if certain minimum pipelengths are used in the analysis; (iv) the bending

stresses at the pipe intersections are much higher than the axial stresses; an opposite phenomenon is observed in the middle of a straight segment of pipeline; (v) the bending stresses near the pipe intersections are magnified significantly; the magnification and the extent of the pipelength over which it appears depend on the type of intersection and the diameter ratio of the intersecting pipes; and (vi) the angle of incidence of two component earthquake has considerable influence on the pipe stresses.

Finally, a methodology is described for the seismic risk analysis of buried pipeline, in which an analytical procedure is developed to estimate the annual probabilities of occurrence of different damage states (damage indices) for a component segment of the general network system of pipelines. The earthquake is considered as a stationary Gaussian random process. The PSDF of ground acceleration characterizing the earthquake motion is related to the earthquake intensities measured in MMI scale. The stresses induced in the component pipe segment due to each earthquake intensity are determined using the methods of analysis described before. The damage index (DI) for each damage state is obtained by combining a damage probability matrix (DPM) for the pipe segment with the annual probabilities of occurrence of different levels of earthquake intensity. The parametric study shows that the damage probabilities at the pipe intersections (T and + Types) or near the restrained ends (fixed or pinned)

are quite high. Also high probability of major damage is indicated for the middle of straight pipe segment if it is buried in soft soil medium.

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