Response analysis of multi-storey structures on flexible foundation due to seismic excitation

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In this article, the seismic response of multi-storey buildings with soft ground floors is investigated. The floors of the buildings are assumed to rest on the flexible elastic foundation media underlain by heterogeneous elastic half-space, excited by input wave motion is studied. Analytical solutions are derived for a two-dimensional continuous building model and for the monochromatic anti-plane excitation. It has been shown that the vibration experienced by the flexible foundation of a structure during an earthquake may be substantially different from the motion that the ground perceives in its absence. It has also been observed that the presence of the flexible foundation influences the propagation of polarised shear motion to such an extent that the motion causing disturbance in the ground floor cannot make headway to the upper part of the building. One of the important consequences of this analysis is that all the above-mentioned effects may be possible in other ways as a result of the contribution of an antisymmetric mode of vibration to the overall response.

NOMENCLATURE

a_n	– fourier coefficients
b	– heterogeneous constant
c	– phase velocity
h	– thickness of the foundation soil
h_1	– sum of heights of upper floors
$_2$	– height of soft ground floor
H	– sum of height of the building and the foundation depth
$k^*_{z,n}$	– wave number in the heterogeneous medium
$k^{(i)}_{z,n}$	– wave number in the n-layer
L	– building's span
$M(x,z)$	– arbitrary point in the medium
n	– integer variable (varies from 1 to ∞)
$(Q_3)_{i,x}$	– anisotropy in the x-direction
$(Q_1)_{i,z}$	– anisotropy in the z-direction
s	– sandy parameter
T	– time period of the wave
u^*	– displacement in the heterogeneous medium
$u(x,z,t)$	– displacement of the building
$Z_n(z)$	– shape function in the z-direction
$\beta_{i,x}$	– shear wave velocity in the x-direction
$\beta_{i,z}$	– shear wave velocity in the z-direction
β^*_x	– shear wave velocity in the heterogeneous medium
$\rho^*(x,z)$	– density in the heterogeneous medium
$\mu^*(x,z)$	– shear modulus in the heterogeneous medium
λ	– inhomogeneous parameter
η	– dimensionless frequency of excitation
μ_0	– constant of the heterogeneous medium
ρ_0	– constant of the heterogeneous medium
ω	– angular frequency
θ	– incident angle with the normal
α, γ	– transmission angles

1. INTRODUCTION

An important aspect of the seismic design of a massive structure embedded at a considerable depth in a soil deposit is the evaluation of the dynamic interaction between the structure and the surrounding soil. In the soil-structure interaction analyses, energy is dissipated in the structure as structural damping and in the soil as material damping. Energy is also lost by radiation of waves from the base of the structure into the surrounding soil — a phenomenon termed the radiation or spatial damping, an extremely important parameter in foundation vibration problems.

Experience has repeatedly shown that simple structures that are planned symmetrically perform much better in earthquakes than the complex, asymmetrical ones. The force distribution in the complex, asymmetrical structures under earthquake loading is extremely difficult to predict; the torsional forces are liable to set up if the centre of mass is not coincident with the centre of resistance, and this can cause local failures.

In structural engineering, vibration methods have been the standard approach to calculate the seismic response of buildings. On the other hand, wave propagation methods are used mainly for the structures that can be modelled as a continuous medium, e.g., Clough and Penzien,[1] Todorovska and Lee,[2] Todorovska and Trifunac,[3] Hall et. al.[4] and Iwan.[5] Few references are available on the wave propagation methods applied to the half-space analysis. Numerous analytical studies, a majority of which have assumed the structure to be supported by a rigid foundation, have been conducted to investigate the seismic response of buildings. Several investigators have also directed their efforts towards the problem of analyzing the influence of the flexibility of the foundation on the response of the structure e.g., Veletsos and Meek,[6] Braja,[7] Kim et. al.,[8] Todorovska and Trifunac,[9] Wong and Luco,[10] Vaish and Chopra,[11]