第Ⅲ部門　THEORETICAL STUDY ON THE HORIZONTAL VIBRATIONS INDUCED BY SURFACE WAVES

Research Center for Urban Safety and Security, Kobe University　Member　○Koji UENISHI
Matsushita Electric Works, Ltd.　Takayuki SAITOH

1. Introduction

In this contribution, by obtaining the relationship between the stress and the particle velocity associated with a Love wave, we investigate the mechanical characteristics of horizontal motions generated by surface waves in layered media.

2. Linear elastic wave analysis

Consider an isotropic, linear elastic half-space with an overlying layer of thickness T, bonded to the semi-infinite media at the interface $y = 0$ (see e.g., Graff, 1975; Aki and Richards, 2002). Assume that a Love wave propagates in the x-direction, with particle motions in the z-direction. The situation is shown in Fig. 1. We use the prime notation to refer to the semi-infinite medium having properties ρ' (mass density), c'_2 (shear wave speed) and unprimed notation for the layer, having properties ρ, c_2. Let u_z (u_z') be the displacement in the z-direction. Then, we can obtain the shear stress-particle velocity relations for a Love wave: $\tau_{xz} = -\rho c_2 Q \dot{u}_z$ and $\tau'_{xz} = -\rho' c'_2 S \dot{u}'_z$. Here, $Q(c'_2/c_2, \rho'/\rho, fT/c_2) \equiv c_2/c$ and $S(c'_2/c_2, \rho'/\rho, fT/c_2) \equiv c'_2/c$, with f and c being frequency and speed of the Love wave. By comparing the obtained formulae with the conventional relations for shear (SH) waves ($\tau_{xz} = -\rho c_2 \dot{u}_z$, $\tau'_{xz} = -\rho' c'_2 \dot{u}'_z$) and for Rayleigh waves ($\sigma_x = -\rho c_2 G\, \dot{u}_x$ on the free surface; horizontal normal stress σ_x is induced; u_x is the displacement in the x-direction) (Uenishi and Rossmanith, 1998; Uenishi *et al.*, 1999), we can quantitatively evaluate the effect of each wave at specific depths in the media. Here, $G(\nu^*) \equiv 4\,(1 - c_2^2/c_1^2)\, c_2/c_R$, with c_1 being longitudinal (P) wave speed, c_R Rayleigh wave speed, and ν^* generalized Poisson's ratio [$\nu^* = \nu$ (Poisson's ratio) for plane strain; and $\nu/(1 + \nu)$ for plane stress conditions]. The coefficients under several different conditions are shown in Figs. 2-4.

3. Discussion and conclusions

We show that (1) In the surface layer, Love waves will induce smaller dynamic shear stresses than those obtained by the conventional simplified analysis based on the formulae for body (shear) waves; (2) On the contrary, in the semi-infinite medium, the induced stresses will be larger than those of the conventional simplified analysis; and (3) On the free surface, Rayleigh waves may induce larger stresses than Love waves, given the same particle velocities. The overall results suggest the importance of analyzing stresses (besides particle velocities) in designing earthquake-resistant structures. More detailed and quantitative discussion can be found in Uenishi and Saitoh (2006).

References

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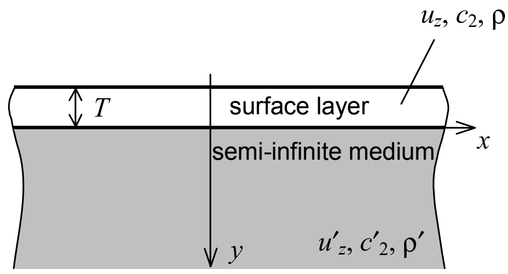

Figure 1. Geometry of the problem.

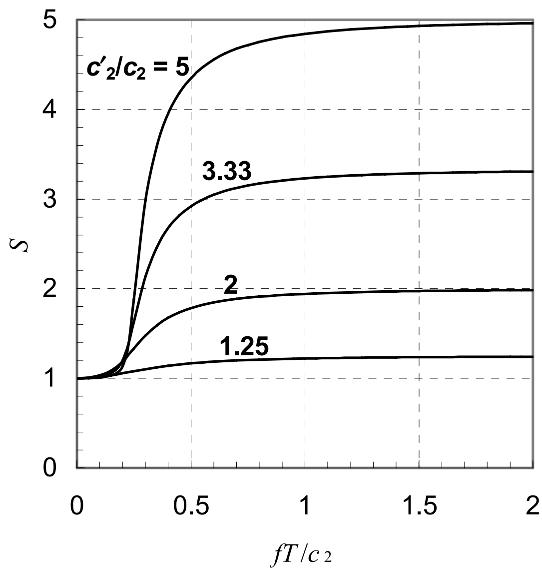

Figure 3. The coefficient S in the stress-particle velocity relation for a Love wave in the semi-infinite medium (fundamental mode, $\rho'/\rho = 1$).

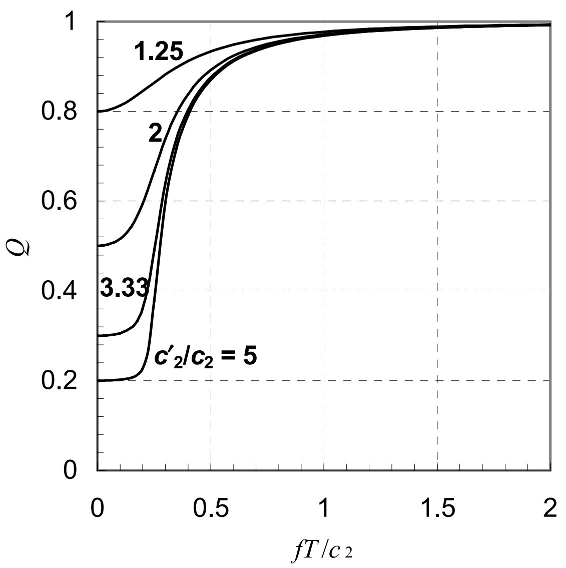

Figure 2. The coefficient Q in the stress-particle velocity relation for a Love wave in the layer (fundamental mode, $\rho'/\rho = 1$).

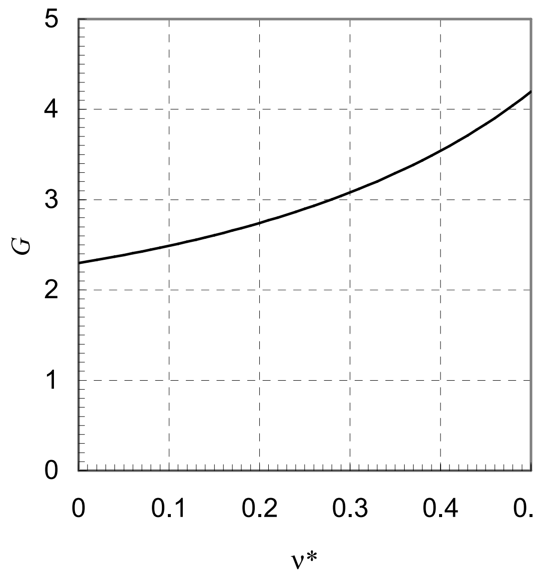

Figure 4. The coefficient G in the stress-particle velocity relation for a Rayleigh wave on the free surface.