THE FUNDAMENTAL PERIOD OF FOUR-LAYER SOIL DEPOSITS

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Significant role of local geological condition in associated damage of destructive earthquakes to engineered structures has been well confirmed. Furthermore, carried out investigation by Seed et al. (1974) showed that tall buildings located on deep or soft deposits may be exposed to higher amount of seismic forces than similar buildings on rock (if the peak ground acceleration is the same in both cases). Therefore, employing a parameter which is capable of providing an appropriate description of local soil geology is a vital issue in geotechnical earthquake engineering. Average shear wave velocity in the upper 30 m of the soil deposit $\left(v_{s30}\right)$ is utilized by Iranian Seismic Code (BHRC, 2007) for site classification. On the other hand, Zhao (2011) indicated that fundamental period of surface layer above bedrock is more dependable criteria than v_{s30} for prediction of amplification ratios particularly in long period deposits. Consequently, different methods for estimation of fundamental period of soil deposits has become the subject of considerable interest and research. In this regard, Dobry et al. (1976) presented closed form solutions and approximate approaches for estimation of fundamental period. Moreover, a comprehensive review of various solutions was conducted by Medhat Sefvati and Kamalian (2018). Among gathered solutions lack of accurate one which is straightforward and does not require iteration procedure for layered soil profiles is evident. In this context, Medhat Sefvati (2016) acquired an equation by means of analytical solution for exact calculation of natural periods of three-layer deposits. In the same spirit, a system including four undamped homogeneous soil layers on a bedrock is considered (Figure 1).

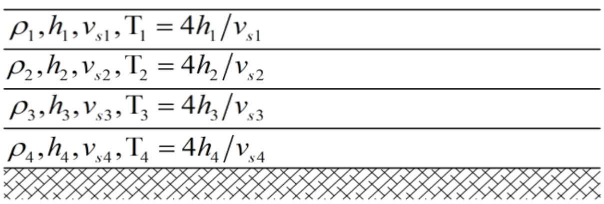

Figure 1. four-layer soil profile.

ρ_n, h_n, v_{sn} are representative of mass density, thickness and shear wave velocity of soil layers in which n is the number of layers. In case of vertically SH waves propagation general solution for a steady state harmonic motion with frequency ω is obtained and boundary conditions are satisfied. Amplification function $AF_1(\omega)$ is achieved as the ratio of the amplitude of motion at free surface (point A) to the amplitude of motion at interface between soil and rock (point B) (Figure 2).

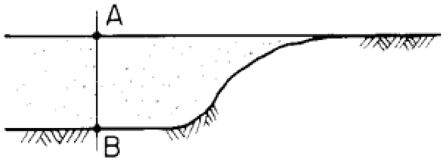

Figure 2. Soil amplification geometry (Roesset, 1977).

Amplification function becomes infinite (resonance condition) at natural periods. Therefore, the denominator of amplification function is made equal to zero and desired equation for estimation of natural periods is acquired.

$$
\begin{aligned}
& q_1 \tan(\Xi_1)\tan(\Xi_2) + q_2 \tan(\Xi_2)\tan(\Xi_3) + q_3 \tan(\Xi_3)\tan(\Xi_4) \\
& + q_1 q_2 \tan(\Xi_1)\tan(\Xi_3) - q_1 q_3 \tan(\Xi_1)\tan(\Xi_2)\tan(\Xi_3)\tan(\Xi_4) \\
& + q_2 q_3 \tan(\Xi_2)\tan(\Xi_4) + q_1 q_2 q_3 \tan(\Xi_1)\tan(\Xi_4) = 1
\end{aligned} \tag{1}
$$

where $\Xi_1 = \frac{\pi}{2}\frac{T_1}{T}, \Xi_2 = \frac{\pi}{2}\frac{T_2}{T}, \Xi_3 = \frac{\pi}{2}\frac{T_3}{T}, \Xi_4 = \frac{\pi}{2}\frac{T_4}{T}$ and $q_1 = \frac{\rho_1 v_{s1}}{\rho_2 v_{s2}}, q_2 = \frac{\rho_2 v_{s2}}{\rho_3 v_{s3}}, q_3 = \frac{\rho_3 v_{s3}}{\rho_4 v_{s4}}$

Among different values for T in Equation 1, the highest one is representative of fundamental period corresponding to the first mode. Results of the examined four-layer profiles by the proposed equation are in good agreement with Schnabel (1972). Accurate performance of the presented formula stems from its ability to consider the position of layers in soil deposits and is significant with respect to the approximate methods, which apply average properties of layers. Furthermore, iterative procedure is not needed in solving process.

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