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A NEW METHOD FOR CALCULATING THE DOMINANT PERIODS OF MULTILAYER OF SOIL

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After the large earthquake, damage surveys of buildings reveal the quality of construction, ground and soil conditions. Although, the ground and soil conditions are considered in the seismic design codes in numerous countries but still detailed study of the ground and soil conditions are required. The dynamic properties of soils are important in the design and theoretical studies. In view of the importance, we have performed the development of simplified methods of testing dynamic properties of heterogeneous soil foundation, for the division of soils into categories by the magnitude of predominant periods of vibrations and some concepts on the role of soil conditions during seismic effects. Here, a new method is proposed for the measurement of natural periods of soil. We have also discussed a comparison among the various used methods. We have supported our new approach with the solution of transitional equation and have found a good match.

Introduction

The natural periods of vibration of a soil profile are the most significant dynamic parameters involved in response analysis. Not only the numerical values needed for computations, but a comparison between experimentally determined and computed values are important to check the validity of simplified mathematical models which must be necessity be used in analysis.

The importance of the dominant period as an indication of the dynamic behavior of soils is emphasized by the introduction of this parameter into seismic resistant construction codes. These natural periods are related to the structural damage during a strong earthquake and may significantly alter the soil period. The natural period measurements prior to the construction might make our buildings more stable during earthquake. Analysis of earthquake recordings show, that during the earthquakes at the areas practically with the same epicentral distances, the values of horizontal, vertical and rotatory displacements, velocities and ground accelerations depend on geological sections of the registration site, physical and mechanical strength, deformation and acoustic properties of the subsurface soil. The damage surveys after earthquakes have shown relation of soil conditions and structural construction that the damages are caused either by deposits, slopes, overtiring or by the formation of relative deformations and cracking along the whole body of the building. The soil conditions change the kinematics parameters of seismic effect and the type of damages of buildings and constructions. These conditions should be taken in the seismic codes for better design of buildings.

The main criteria for codes compilation should be the quantitative parameters of soil divisions into categories according to its seismic properties, maximum accelerations of upper layers of soils of different categories and relations of dynamic properties of soils and overgrown buildings.

Periods of vibrations of heterogeneous soil

The top surface soil plays an important role in controlling the performance of buildings during the earthquake. The top surface of the soil transfers the seismic wave energy to the building. On the other hand, kinematic parameters of the soil depend on physical and mechanical and acoustic properties of subsurface layers. The period of the soil vibration is very much dependent on the damage of the building which is related to the velocity of secondary (transverse) wave.

$$T_0 = \frac{4H}{V_s}, \quad (1)$$

where $V_s = \sqrt{G/\rho}$ is the velocity of propagation of transverse waves.

From equation (1), one can get higher depth of the rocky soil which is directly proportional to the value of the dominant period of top soils, e.g. when H=200m (V_s=1000 m/sec. for the rock), T_0=0,8 *sec*. The velocity of propagation of transverse waves V_s is also increased by increasing the depth and, secondly, the total volume of the earth is not affected due to earthquake since the soil is present up to certain depth only. Therefore for bedrock grounds the value H is recommended to take no more than 30-50 m, and for alluvial grounds up to the level of original rock – from 10 to 300 and more meters.

Transitional wave equation

Let us suppose that the foundation of the building consists of several layers. Every layer can be represented by its elastic-plastic properties. Let *n* be the number of layers, ρ_k, G_k and H_k – density (mass), shear modulus and thickness of *k* layers respectively (Fig.1).

The origin of reading will be assumed at the point of the upper side of the very top layer and it will be marked by $h_0 = 0$, $h_k = \sum_{i=1}^{k} H_i$, $h_n = H$ (Khachian, 2000).

The exact solution of the task for the estimation of free vibrations frequency spectrum is in the solution of wave equation of the type

$$\rho_k \frac{\partial^2 U_k}{\partial t^2} - G_k \frac{\partial^2 U_k}{\partial x^2} = 0, \quad k=1, 2 \ldots n, \quad h_{k-1} \le x \le h_k. \quad (2)$$

Particular solution of the equation (2) we define as:

$$U_k(x,t) = U_k(x)f(t). \tag{3}$$

Substituting (3) in (2) and dividing the variables, we get:

$$\begin{aligned} &U_k''(x) + \lambda_k^2 U_k(x) = 0 \\ &f''(t) + P^2 f(t) = 0 \\ &k = 1,2,3......n \end{aligned} \tag{4}$$

where n – is the number of layers, P – cyclic frequency of the vibration for the whole system and through λ_k the following is defined:

$$\lambda_k^2 = \frac{P^2 \rho_k}{G_k}. \tag{5}$$

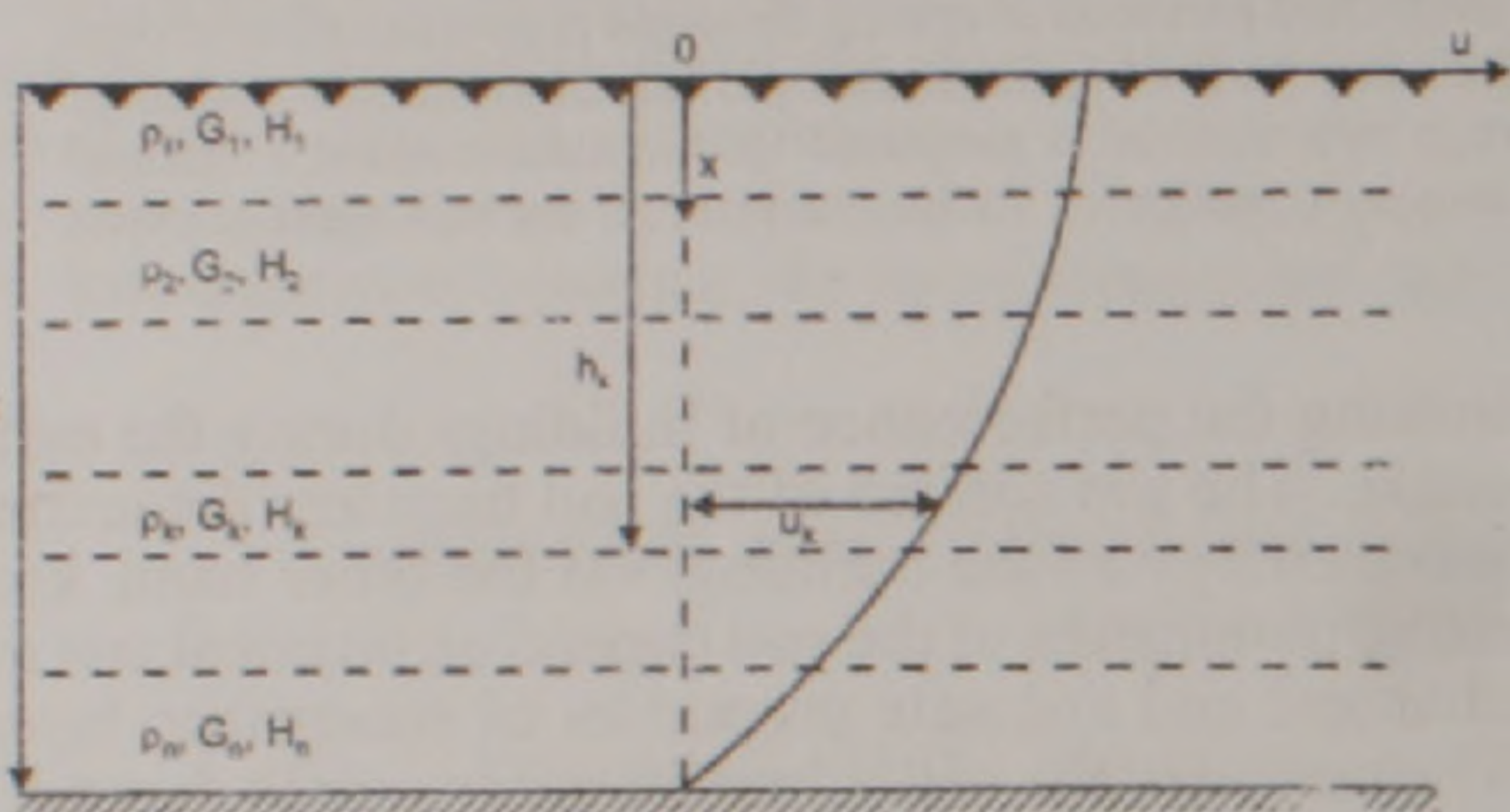

Figure 1: Layered model for estimation of soil's period equation.

The solution of the first equation (4) will be:

$$U_k(x) = A_k \sin\lambda_k x + B_k \cos\lambda_k x . \tag{6}$$

For the definition of 2n coefficients A_k, B_k and cyclic frequency P we have two boundary conditions: when

$$x = H,\ U_n(H) = 0, \quad \text{and} \quad x = 0\ U_1'(0) = 0 \tag{7}$$

and 2n-2 are the conditions of deflection continuity and lateral force on the line dividing two next layers:

$$\begin{aligned} &U_k(h_k) = U_{k+1}(h_k) \\ &G_k U_k'(h_k) = G_{k+1} U_{k+1}'(h_k) \\ &k = 1,2,3.......n-1 \end{aligned} \tag{8}$$

Substituting equation (6) into the boundary conditions given by equation (7) and into the conditions of continuity (8) we get the system of homogeneous equations for the definition of 2n coefficient A_k, B_k and cyclic frequency P:

$$\begin{aligned} &A_n \sin\lambda_n H + B_n \cos\lambda_n H = 0 \\ &A_1 = 0 \\ &A_k \sin h_k\lambda_k + B_k \cos h_k\lambda_k = A_{k+1} \sin h_k\lambda_{k+1} + B_{k+1} \cos h_k\lambda_{k+1} \\ &A_k G_k \lambda_k \cos\lambda_k h_k - B_k G_k \lambda_k \sin\lambda_k h_k = \\ &= A_{k+1} G_{k+1} \lambda_{k+1} \cos\lambda_{k+1} h_k - B_{k+1} G_{k+1} \lambda_{k+1} \cos\lambda_{k+1} h_k \\ &k = 1, 2, 3.....n-1 \end{aligned} \tag{9}$$

Equating the determinant of the system (9) to zero, we obtain the complicated transitional equation in relation to cyclic frequency P. The solution of this equation is significantly complicated by increasing the number of layers. Even for the simple two-layer foundations the exact estimation of dominant periods is connected with the root calculation of the transitional equation (Khachian, 1963; Madera, 1970).

$$tg\frac{2\pi}{T_0}H_1\sqrt{\frac{\rho_1}{G_1}}\, tg\frac{2\pi}{T_0}H_2\sqrt{\frac{\rho_2}{G_2}} = \sqrt{\frac{\rho_1\rho_2}{G_1G_2}}, \tag{10}$$

Similarly we find the solution of transitional equation for 3 and 4 layers as given in (11) and (12) respectively (Khachian, 2000; 2001)

n = 3

$$\sqrt{\frac{\rho_1G_1}{\rho_2G_2}}tg\frac{2\pi}{T_0}\alpha_1 tg\frac{2\pi}{T_0}\alpha_2 + \sqrt{\frac{\rho_2G_2}{\rho_3G_3}}tg\frac{2\pi}{T_0}\alpha_2 tg\frac{2\pi}{T_0}\alpha_3 + \sqrt{\frac{\rho_1G_1}{\rho_3G_3}}tg\frac{2\pi}{T_0}\alpha_1 tg\frac{2\pi}{T_0}\alpha_3 - 1 = 0 \tag{11}$$

n = 4

$$\begin{aligned} &\sqrt{\frac{\rho_1G_1}{\rho_2G_2}}tg\frac{2\pi}{T_0}\alpha_1 tg\frac{2\pi}{T_0}\alpha_2 + \sqrt{\frac{\rho_1G_1}{\rho_3G_3}}tg\frac{2\pi}{T_0}\alpha_2 tg\frac{2\pi}{T_0}\alpha_3 + \sqrt{\frac{\rho_1G_1}{\rho_4G_4}}tg\frac{2\pi}{T_0}\alpha_1 tg\frac{2\pi}{T_0}\alpha_4 + \sqrt{\frac{\rho_2G_2}{\rho_3G_3}}tg\frac{2\pi}{T_0}\alpha_2 tg\frac{2\pi}{T_0}\alpha_3 + \\ &+\sqrt{\frac{\rho_2G_2}{\rho_4G_4}}tg\frac{2\pi}{T_0}\alpha_2 tg\frac{2\pi}{T_0}\alpha_4 + \sqrt{\frac{\rho_3G_3}{\rho_4G_4}}tg\frac{2\pi}{T_0}\alpha_3 tg\frac{2\pi}{T_0}\alpha_4 - \sqrt{\frac{\rho_1G_1\rho_3G_3}{\rho_2G_2\rho_4G_4}}tg\frac{2\pi}{T_0}\alpha_1 tg\frac{2\pi}{T_0}\alpha_2 tg\frac{2\pi}{T_0}\alpha_3 tg\frac{2\pi}{T_0}\alpha_4 - 1 = 0 \end{aligned} \tag{12}$$

here

$$\alpha_1 = H_1\sqrt{\frac{\rho_1}{G_1}},\ \alpha_2 = H_2\sqrt{\frac{\rho_2}{G_2}},\ \alpha_3 = H_3\sqrt{\frac{\rho_3}{G_3}},\ \alpha_4 = H_4\sqrt{\frac{\rho_4}{G_4}}.$$

$T_0 = \frac{2\pi}{P}$ – free vibrations period of whol system.

A new method

Since, there are no suitable relation which deals with the dynamic properties of multilayer heterogeneous soil foundation. We have made efforts to develop a suitable equation based on the solution of transitional equation for 2 layers. Let us consider a model consists of 2 layers as shown in figure 2. The soil period for the first layer is

$$T_1 = \frac{4H_1}{V_1} = 4H_1\sqrt{\frac{\rho_1}{G_1}}. \qquad (13.1)$$

The soil period for the second layer is:

$$T_2 = \frac{4H_2}{V_2} = 4H_2\sqrt{\frac{\rho_2}{G_2}}. \qquad (13.2)$$

Substituting equations (13.1) and (13.2) in equation (10), the following equation will be estimated:

$$tg\frac{\pi}{2}\frac{T_1}{T_0}\ tg\frac{\pi}{2}\frac{T_2}{T_0} = \frac{\rho_2}{\rho_1}\frac{H_2}{T_2}\frac{T_1}{H_1} = \frac{\rho_2}{\rho_1}\frac{H_2}{H_1}\frac{T_1}{T_2}.$$

Now considering:

$$\frac{\pi}{2}\frac{T_1}{T_0} = x,\ \frac{H_1}{H_2} = \alpha,\ \frac{T_1}{T_2} = \beta,\ T_2 = \frac{T_1}{\beta},\ \frac{\rho_2}{\rho_1} = \gamma.$$

Considering $\rho_2/\rho_1 \approx 1$, so the final equation will be given as follows:

$$tgx\,tg\frac{x}{\beta} = \frac{\beta}{\alpha}. \qquad (14)$$

Following simplified equation can be used to estimate period of soil as a function of first layer soil period as follows:

$$T_{0i} = \frac{\pi}{2x_i}T_1. \qquad (15)$$

While x_i is the root of transitional equation. Now by knowing the dynamic properties of each layer of any soil profiles, we can very simply calculate the most closest answer to transitional solution. We have computed the ratio of T_{0i}/T_i versus ratios of first layer period T_1 and second layer period T_2 in the following range $0.025 \le \beta = T_1/T_2 \le 25$, with varying 2 layers thicknesess ratios in range $0.025 \le \alpha = H_1/H_2 \le 100$, where H_1 and H_2 are the thickness for the first and second layer respectively. The results are shown in figure 2.

To simplify the new adopted method for users a total of 91×64=5824 variants (α – 91 and β – 64) have been used and the roots of transitional equation have been estimated. These data $\pi/2x_i$ or T_{0i}/T_i have been analyzed to obtain the final simplified equation. The final estimated function takes the following form as given in the following equation (16).

$$\frac{T_{01}}{T_1} = a\left(\frac{T_1}{T_2}\right)^{-b} \quad \text{or} \quad T_{01} = aT_1\left(\frac{T_1}{T_2}\right)^{-b}. \qquad (16)$$

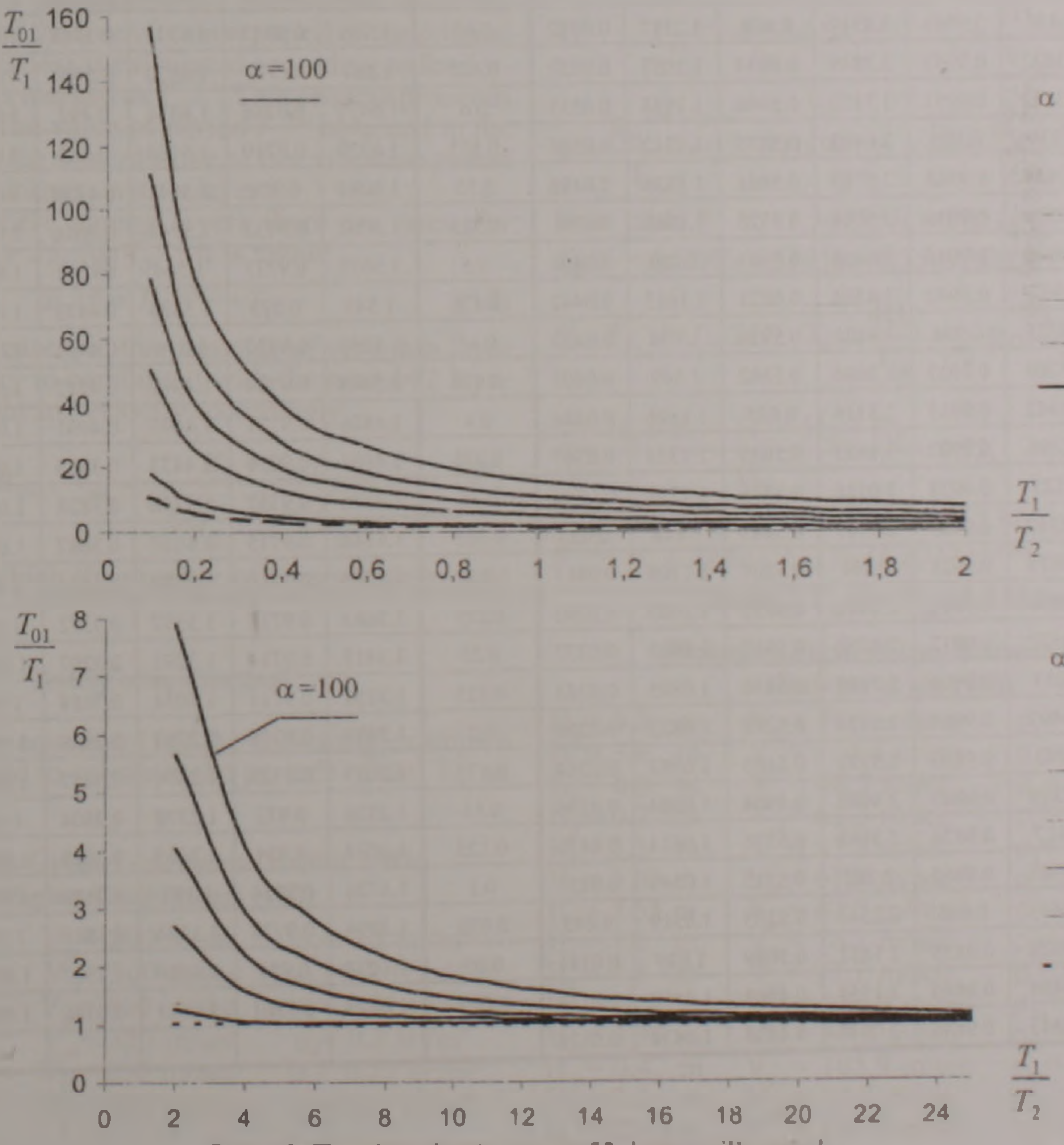

Figure 2. The adopted main curves of 2- layers soil's periods

Table 1: The values of "*a*" and "*b*" for calculation of T_{01}/T_1 using equation (16)

$\alpha = \frac{H_1}{H_2}$	a_1	b_1	a_2	b_2	a_3	b_3	$\alpha = \frac{H_1}{H_2}$	a_1	b_1	a_2	b_2	a_3	b_3
100	15.751	0.9995	15.341	0.9404	5.124	0.4654	1.5	2.2314	0.9836	2.0329	0.4697	1.0407	0.0118
90	14.947	0.9995	14.52	0.9344	4.6367	0.4385	1.4	2.1748	0.9829	1.9801	0.4551	1.0381	0.0111
80	14.097	0.9995	13.648	0.9266	4.1578	0.4088	1.3	2.1166	0.9821	1.9263	0.4395	1.0352	0.0102
70	13.192	0.9994	12.727	0.9179	3.6899	0.376	1.2	2.0567	0.9813	1.8711	0.4229	1.0325	0.0095
60	12.387	0.98	11.732	0.9062	3.2355	0.3394	1.1	1.9947	0.9804	1.8147	0.4052	1.0296	0.0086
50	11.166	0.9993	10.649	0.8904	2.7975	0.2986	1	1.9309	0.9794	1.9135	0.5988	1.027	0.0079
25	7.9378	0.9985	7.335	0.8116	1.7993	0.1722	0.975	1.9145	0.9791	1.8974	0.5935	1.0263	0.0077
20	7.1182	0.9982	6.4947	0.779	1.621	0.1419	0.95	1.898	0.9789	1.8808	0.5877	1.0256	0.0075
15	6.1913	0.9976	5.5645	0.7342	1.451	0.1096	0.925	1.8813	0.9786	1.8645	0.5826	1.025	0.0073
10	5.0982	0.9965	4.4781	0.6625	1.2901	0.0751	0.9	1.8645	0.9783	1.8478	0.5768	1.0243	0.0071
9.75	5.05373	0.9964	4.4187	0.6578	1.2824	0.0734	0.875	1.8475	0.9781	1.8312	0.5712	1.0236	0.0069
9.5	4.9758	0.9963	4.3585	0.6529	1.2747	0.0716	0.85	1.8304	0.9778	1.814	0.565	1.0227	0.0066
9.25	4.9134	0.9962	4.2976	0.6479	1.267	0.0698	0.825	1.8131	0.9775	1.7968	0.5586	1.0223	0.0065
9	4.8502	0.9961	4.2363	0.6428	1.2592	0.068	0.8	1.7955	0.9772	1.7794	0.5522	1.0216	0.0063
8.75	4.7861	0.996	4.1738	0.6375	1.2514	0.0662	0.775	1.7778	0.9769	1.7619	0.5456	1.0209	0.0061
8.5	4.7213	0.9959	4.1109	0.632	1.244	0.0644	0.75	1.7601	0.9771	1.744	0.5388	1.0202	0.0059
8.25	4.6554	0.9958	4.0473	0.6263	1.2364	0.0626	0.725	1.7418	0.9762	1.7261	0.5315	1.0194	0.0057
8	4.5886	0.9957	3.983	0.6205	1.2287	0.0608	0.7	1.723	0.976	1.7083	0.5248	1.0189	0.0055
7.75	4.5209	0.9956	3.918	0.6143	1.2213	0.059	0.675	1.7049	0.9756	1.6896	0.5166	1.0181	0.0053
7.5	4.452	0.9954	3.8517	0.608	1.2137	0.0572	0.65	1.686	0.9753	1.6712	0.5088	1.0175	0.0051
7.25	4.3822	0.9953	3.7849	0.6014	1.2057	0.0552	0.625	1.667	0.975	1.6522	0.5004	1.0169	0.005
7	4.3112	0.9951	3.7172	0.5946	1.1986	0.0535	0.6	1.6477	0.9746	1.6331	0.492	1.0162	0.0047
6.75	4.239	0.995	3.6485	0.5875	1.1912	0.0516	0.575	1.6379	0.9719	1.6136	0.483	1.0155	0.0045
6.5	4.1656	0.9948	3.5789	0.5801	1.1836	0.0498	0.55	1.6084	0.974	1.5941	0.4739	1.0148	0.0043
6.25	4.0908	0.9946	3.5084	0.5725	1.1764	0.048	0.525	1.5902	0.9732	1.5745	0.4646	1.0141	0.0042
6	4.0146	0.9944	3.4424	0.5941	1.169	0.0461	0.5	1.5677	0.9733	1.554	04543	1.0135	0.004
5.75	3.937	0.9942	3.4584	0.6025	1.1615	0.0442	0.475	1.547	0.973	1.5333	0.4437	1.0128	0.0038
5.5	3.8577	0.994	3.3822	0.5936	1.154	0.0423	0.45	1.5259	0.9727	1.516	0.4461	1.0121	0.0035
5.25	3.7769	0.9937	3.3046	0.5842	1.147	0.0405	0.425	1.5045	0.9724	1.4912	0.4212	1.0114	0.0034
5	3.6942	0.9935	3.3316	0.635	1.1396	0.0386	0.4	1.4826	0.9721	1.4695	0.4091	1.0107	0.0032
4.75	3.6096	0.9932	3.1453	0.5639	1.1324	0.0367	0.375	1.4603	0.9719	1.4473	0.3963	1.0101	0.003
4.5	3.523	0.9928	3.0516	0.5516	1.1252	0.0349	0.35	1.4376	0.9717	1.4248	0.3828	1.0094	0.0028
4.25	3.4342	0.9925	2.9797	0.5413	1.118	0.033	0.325	1.4144	0.9715	1.4017	0.3687	1.0087	0.0026
4	3.3429	0.9921	2.894	0.5289	1.1108	0.0311	0.3	1.3906	0.9714	1.3782	0.3536	1.008	0.0024
3.75	3.2493	0.9916	2.8982	0.5757	1.1037	0.0292	0.275	1.3663	0.9713	1.3537	0.3372	1.007	0.0022
3.5	3.1527	0.9912	2.8052	0.5612	1.0963	0.0272	0.25	1.3413	0.9714	1.3292	0.3207	1.0067	0.002
3.25	3.053	0.9906	2.7103	0.5456	1.0895	0.0253	0.225	1.3157	0.9715	1.3034	0.3018	1.006	0.0018
3	2.9492	0.9901	2.6126	0.5288	1.0823	0.0234	0.2	1.2893	0.9718	1.2769	0.2819	1.0054	0.0016
2.75	2.843	0.9893	2.5121	0.5104	1.0752	0.0214	0.175	1.2619	0.9723	1.2674	0.3057	1.0047	0.0014
2.5	2.7319	0.9885	2.4085	0.4904	1.0684	0.0196	0.15	1.2336	0.973	1.2378	0.2804	1.004	0.0012
2.25	2.617	0.9874	2.3988	0.5571	1.0614	0.0176	0.125	1.2038	0.974	1.2065	0.2518	1.0034	0.001
2	2.4945	0.9865	2.282	0.5315	1.0544	0.0157	0.1	1.1724	0.9756	1.173	0.2188	1.0027	0.0008
1.9	2.4443	0.986	2.2341	0.5205	1.0519	0.015	0.075	1.1394	0.9778	1.1376	0.1816	1.002	0.0006
1.8	2.3929	0.9855	2.1851	0.5089	1.049	0.0141	0.05	1.1032	0.981	1.0986	0.1367	1.0014	0.0004
1.7	2.3405	0.9849	2.1354	0.4965	1.0462	0.0134	0.025	1.0623	0.9861	1.0541	0.0796	1.0006	0.0002
1.6	2.2843	0.9846	2.0846	0.4835	1.0434	0.0126							

The values of a and b for various α are given in table 2, for $T_1/T_2<1$ one must use the values of a_1 and b_1 from the table, and for $T_1/T_2>1$ – the values of a_2 and b_2, and for $T_1/T_2>1\le25$ – the values of a_3 and b_3; finally, for $T_1/T_2>25$, $a=1$, $b=0$.

A procedure to define the value of free vibrations period for any thickness with n layers is performed in the following sequence. First of all, according to data from boring or other geotechnical methods on the basis of layers capacities H_k, shear wave velocities V_{sk} or shear modules G_k and density ρ_k, the free vibration periods of each layer (as homogeneous environment) are determined according to the formula

$$T_k = \frac{4H_k}{V_{sk}}, \quad k = 1,2,3,...,n \tag{17}$$

Then, at first it is considered that the thickness consists of the top two layers with their H_1 and H_2, T_1 and T_2. Next, by T_1/T_2 relationships for given relationship H_1/H_2, the values of a and b parameters are determined according to the table 1, and the free vibration period of conditional two-layer thickness (from the first two layers) is calculated according to the formula (16). This period is marked as T_{01}^{1-2}. Further, the top two layers are considered as one equivalent layer with capacity H_1+H_2 and period T_{01}^{1-2}, and it is now considered with the third layer with capacity H_3 and period T_3. Similarly, by relationships T_{01}^{1-2}/T_3 and $(H_1+H_2)/H_3$ the new values of a and b parameters are determined from the same table 1, and the free vibration period of conditional three-layer thickness is calculated according to the formula (16) and is marked as T_{01}^{1-3}. This process proceeds for all layers. The value of period T_{01}^{1-n} obtained in the last step will be the desired value of free vibration period of the whole thickness with n layers.

In case where among layers there are ones, for which $T_{01}^{k-1}/T_k > 25$, for T_{01}^{1-k} it is taken:

$$T_{01}^{1-k} = T_{01}^{1-(k-1)} + T_k \tag{18}$$

In exceptional cases, in the presence of very thin layer k, it is necessary to combine it with the next $k+1$ layer with given height and velocity accordingly:

$$\bar{H}_k = H_k + H_{k+1}, \quad \bar{V}_{sk} = \frac{H_k + H_{k+1}}{H_k/V_{sk} + H_{k+1}/V_{sk+1}}, \tag{19}$$

as a result of which the number of layers is decreased by one unit.

Testing of new method

To test the equation (16) the following examples have been solved to calculate the periods of soil T_{01} as follows.

Example 1. Gyumri – Armenia (Hajian, 1993; Yegian, Ghahraman, 1992)

$H_1 = 5.5$ m	$V_{s1} = 200$ m/sec	$\rho_1 = 0.2\ ts^2/m^4$
$H_2 = 7$ m	$V_{s2} = 300$ m/sec	$\rho_2 = 0.2\ ts^2/m^4$
$H_3 = 12.5$ m	$V_{s3} = 450$ m/sec	$\rho_3 = 0.21\ ts^2/m^4$
$H_4 = 25$ m	$V_{s4} = 350$ m/sec	$\rho_4 = 0.2\ ts^2/m^4$
$H_5 = 100$ m	$V_{s5} = 550$ m/sec	$\rho_5 = 0.21\ ts^2/m^4$
$H_6 = 200$ m	$V_{s6} = 800$ m/sec	$\rho_6 = 0.21\ ts^2/m^4$

1) $T_1 = \frac{4H_1}{V_{s1}} = 0.11$, $\quad T_2 = \frac{4H_2}{V_{s2}} = 0.09333$,

$\alpha = \frac{H_1}{H_2} = 0.7857$, $\quad \beta = \frac{T_1}{T_2} = 1.17857>1$,

from table 1 $a_2=1.76939$, $b_2=0.5484248$

$T_{01}^{1-2}=1.76939\times0.11\times(1.17857)^{0.5484248}=0.177862$ **sec.**

2) $T_{01}^{1-2}=0.177862$, $\quad T_3 = \frac{4H_3}{V_{s3}} = 0.1111$,

$\alpha = \frac{H_1+H_2}{H_3} = 1$, $\quad \beta = \frac{T_{01}^{1-2}}{T_3} = 1.6>1$,

from table 1 $a_2=1.9135$, $b_2=0.5988$

$T_{01}^{1-3}=1.9135\times0.177862\times(1.6)^{0.5988}=0.2567781$ **sec.**

3) $T_{01}^{1-3}=0.2567786$, $\quad T_4 = \frac{4H_4}{V_{s4}} = 0.2857143$,

$\alpha = \frac{H_1+H_2+H_3}{H_4} = 1$, $\quad \beta = \frac{T_{01}^{1-3}}{T_4} = 0.898725<1$,

from table 1 $a_1=1.9309$, $b_1=0.9804$

$T_{01}^{1-4}=1.9309\times0.2567786\times(0.898725)^{0.9804}= 0.55053$ **sec.**

4) $T_{01}^{1-4}=0.55053$, $\quad T_5 = \frac{4H_5}{V_{s5}} = 0.7272727$,

$\beta = \frac{T_{01}^{1-4}}{T_5} = 0.7569788<1$, $\alpha = \frac{H_1+H_2+H_3+H_4}{H_5} = 0.5$,

from table 1 $a_1=1.5677$, $b_1=0.9733$

$T_{01}^{1-5}=1.5677\times0.55053\times(0.7569788)^{0.9733}= 1.1317$ **sec.**

5) $T_{01}^{1-5}=1.1317$, $\quad T_6 = \frac{4H_6}{V_{s6}} = 1$, $\quad \beta = \frac{T_{01}^{1-5}}{T_6} = 1.1317$,

$\alpha = \frac{H_1+H_2+H_3+H_4+H_5}{H_6} = 0.75$,

from table 1 $a_2=1.744$, $b_2=0.5388$

$T_{01}^{1-6} = 1.744\times1.1317\times(1.1317)^{0.5388} = 1.8464$ **sec.**

Finally $T_{01}^{1-6} = T_{01} = 1.8464$ ***sec***

Example 2 Mexico City – Alameda Park (Butcher et all, 1988)

$H_1 = 5.5$ m	$V_{s1} = 76.9$ m/sec	$\rho_1 = 0.169\ ts^2/m^4$
$H_2 = 3.6$ m	$V_{s2} = 114.4$ m/sec	$\rho_2 = 0.153\ ts^2/m^4$
$H_3 = 6.6$ m	$V_{s3} = 48.5$ m/sec	$\rho_3 = 0.119\ ts^2/m^4$
$H_4 = 0.7$ m	$V_{s4} = 62.3$ m/sec	$\rho_4 = 0.18\ ts^2/m^4$
$H_5 = 3.3$ m	$V_{s5} = 55.2$ m/sec	$\rho_5 = 0.118\ ts^2/m^4$
$H_6 = 3.85$ m	$V_{s6} = 61.0$ m/sec	$\rho_6 = 0.126\ ts^2/m^4$
$H_7 = 3.55$ m	$V_{s7} = 62.5$ m/sec	$\rho_7 = 0.12\ ts^2/m^4$
$H_8 = 1.9$ m	$V_{s8} = 76.7$ m/sec	$\rho_8 = 0.122\ ts^2/m^4$
$H_9 = 4.4$ m	$V_{s9} = 77.7$ m/sec	$\rho_9 = 0.119\ ts^2/m^4$
$H_{10} = 4.7$ m	$V_{s10} = 148.9$ m/sec	$\rho_{10} = 0.18\ ts^2/m^4$
$H_{11} = 3.35$ m	$V_{s11} = 87.0$ m/sec	$\rho_{11} = 0.129\ ts^2/m^4$
$H_{12} = 0.4$ m	$V_{s12} = 105.9$ m/sec	$\rho_{12} = 0.178\ ts^2/m^4$
$H_{13} = 3.3$ m	$V_{s13} = 93.8$ m/sec	$\rho_{13} = 0.127\ ts^2/m^4$
$H_{14} = 2.45$ m	$V_{s14} = 138.4$ m/sec	$\rho_{14} = 0.13\ ts^2/m^4$

1) $T_1 = \frac{4H_1}{V_{s1}} = 0.286086$, $T_2 = \frac{4H_2}{V_{s2}} = 0.125874$, $\alpha = \frac{H_1}{H_2} = 1.52778$, $\beta = \frac{T_1}{T_2} = 2.2728$,

from table 1 $a_2 = 2.05$, $b_2 = 0.47$

$$T_{01}^{1\text{-}2} = 2.05 \times 0.286086 \times (2.2728)^{-0.47} = 0.39872 \text{ sec.}$$

2) $T_{01}^{1\text{-}2} = 0.39872$, $T_3 = \frac{4H_3}{V_{s3}} = 0.54433$, $\alpha = \frac{H_1 + H_2}{H_3} = 1.37879$, $\beta = \frac{T_{01}^{1-2}}{T_3} = 0.7325$,

from table 1 $a_1 = 2.17$, $b_1 = 0.9828$

$$T_{01}^{1\text{-}3} = 2.17 \times 0.39872 \times (0.7325)^{-0.9828} = 1.155678 \text{sec.}$$

3) $T_{01}^{1\text{-}3} = 1.155678$, $T_4 = \frac{4H_4}{V_{s4}} = 0.0449438$, $\alpha = \frac{H_1 + H_2 + H_3}{H_4} = 22.42857$, $\beta = \frac{T_{01}^{1-3}}{T_4} = 25.966 > 25$,

accepting:

$$T_{01}^{1\text{-}4} = T_{01}^{1\text{-}3} + T_4 = 1.155678 + 0.0449438 = 1.200616 \text{ sec.}$$

4) $T_{01}^{1\text{-}4} = 1.200616$, $T_5 = \frac{4H_5}{V_{s5}} = 0.23913043$, $\beta = \frac{T_{01}^{1-4}}{T_5} = 5.02076$, $\alpha = \frac{H_1 + H_2 + H_3 + H_4}{H_5} = 4.97$,

from table 1 $a_2 = 3.33$, $b_2 = 0.635$

$$T_{01}^{1\text{-}5} = 3.33 \times 1.200616 \times (5.02076)^{-0.635} = 1.435 \text{ sec.}$$

5) $T_{01}^{1\text{-}5} = 1.435$, $T_6 = \frac{4H_6}{V_{s6}} = 0.25246$, $\beta = \frac{T_{01}^{1-5}}{T_6} = 5.68417$, $\alpha = \frac{H_1 + H_2 + H_3 + H_4 + H_5}{H_6} = 5.1169$,

from table 1 $a_2 = 3.338$, $b_2 = 0.587$

$$T_{01}^{1\text{-}6} = 3.338 \times 1.435 \times (5.68417)^{-0.587} = 1.72722 \text{ sec.}$$

6) $T_{01}^{1\text{-}6} = 1.72722$, $T_7 = \frac{4H_7}{V_{s7}} = 0.2272$, $\beta = \frac{T_{01}^{1-6}}{T_7} = 7.6022$, $\alpha = \frac{H_1 + H_2 + H_3 + H_4 + H_5 + H_6}{H_7} = 6.633$,

from table 1 $a_2 = 3.61615$, $b_2 = 0.5875$

$$T_{01}^{1\text{-}7} = 3.61615 \times 1.72722 \times (7.6022)^{-0.58216} = 1.91755 \text{ sec.}$$

7) $T_{01}^{1\text{-}7} = 1.91755$, $T_8 = \frac{4H_8}{V_{s8}} = 0.09909$, $\beta = \frac{T_{01}^{1-7}}{T_8} = 19.3516 > 10$, $\alpha = \frac{H_1 + H_2 + H_3 + H_4 + H_5 + H_6 + H_7}{H_8} = 14.263$,

from table 1 $a_3 = 1.4273$, $b_3 = 0.1045$

$$T_{01}^{1\text{-}8} = 1.4273 \times 1.91755 \times (19.3516)^{-0.1045} = 2.008168 \text{ sec.}$$

8) $T_{01}^{1\text{-}8} = 2.008168$, $T_9 = \frac{4H_9}{V_{s9}} = 0.2265$, $\beta = \frac{T_{01}^{1-8}}{T_9} = 8.86608$, $\alpha = \frac{H_1 + H_2 + H_3 + H_4 + H_5 + H_6 + H_7 + H_8}{H_9} = 6.591$,

from table 1 $a_2 = 3.60423$, $b_2 = 0.5828$

$$T_{01}^{1\text{-}9} = 3.60423 \times 2.008168 \times (8.86608)^{-0.5828} = 2.028965 \text{ sec.}$$

9) $T_{01}^{1\text{-}9} = 2.028965$, $T_{10} = \frac{4H_{10}}{V_{s10}} = 0.12626$, $\beta = \frac{T_{01}^{1-9}}{T_{10}} = 16.07 > 10$,

$$\alpha = \frac{H_1 + H_2 + H_3 + H_4 + H_5 + H_6 + H_7 + H_8 + H_9}{H_{10}} = 7.1064,$$

from table 1 $a_3 = 1.20162$, $b_3 = 0.05422$

$$T_{01}^{1\text{-}10} = 1.20162 \times 2.028965 \times (16.07)^{-0.05422} = 2.09726 \text{ sec.}$$

10) $T_{01}^{1-10} = 2.09726$, $T_{11} = \dfrac{4H_{11}}{V_{s11}} = 0.154023$, $\beta = \dfrac{T_{01}^{1-10}}{T_{11}} = 13.6165 > 10$,

$$\alpha = \frac{H_1 + H_2 + H_3 + H_4 + H_5 + H_6 + H_7 + H_8 + H_9 + H_{10}}{H_{11}} = 11.3731,$$

from table 1 $a_3 = 1.33429$, $b_3 = 0.08457$

$$T_{01}^{1-11} = 1.33429 \times 2.09726 \times (13.6165)^{-0.08457} = 2.24385 \text{ sec.}$$

11) $T_{01}^{1-11} = 2.24385$, $T_{12} = \dfrac{4H_{12}}{V_{s12}} = 0.0151$, $\beta = \dfrac{T_{01}^{1-11}}{T_{12}} = 148.6 > 25$,

$$\alpha = \frac{H_1 + H_2 + H_3 + H_4 + H_5 + H_6 + H_7 + H_8 + H_9 + H_{10} + H_{11}}{H_{12}} = 103.625,$$

accepting:

$$T_{01}^{1-12} = T_{01}^{1-11} + T_{12} = 2.24385 + 0.0151 = 2.25895 \text{ sec.}$$

12) $T_{01}^{1-12} = 2.25895$, $T_{13} = \dfrac{4H_{13}}{V_{s13}} = 0.140725$, $\beta = \dfrac{T_{01}^{1-12}}{T_{13}} = 16.0522 > 10$,

$$\alpha = \frac{H_1 + H_2 + H_3 + H_4 + H_5 + H_6 + H_7 + H_8 + H_9 + H_{10} + H_{11} + H_{12}}{H_{13}} = 12.682$$

from table 1 $a_3 = 1.3764$, $b_3 = 0.0936$

$$T_{01}^{1-13} = 1.3764 \times 2.25895 \times (16.0522)^{-0.0936} = 2.3978 \text{ sec.}$$

13) $T_{01}^{1-13} = 2.3978$, $T_{14} = \dfrac{4H_{14}}{V_{s14}} = 0.070809$, $\beta = \dfrac{T_{01}^{1-13}}{T_{14}} = 33.863 > 25$,

$$\alpha = \frac{H_1 + H_2 + H_3 + H_4 + H_5 + H_6 + H_7 + H_8 + H_9 + H_{10} + H_{11} + H_{12} + H_{13}}{H_{14}} = 8.42857$$

accepting:

$$T_{01}^{1-14} = T_{01}^{1-13} + T_{14} = 2.3978 + 0.070809 = 2.4686 \text{ sec.}$$

$$\textbf{Finally} \quad T_{01}^{1-14} = T_{01} = 2.4686 \text{ sec.}$$

Table 2

Relationship among T_{01}, T_{02} and T_{03} for 2 layers when $V_2 = 800$ & $V_1 \le 800$ ($V_1/V_2 \le 1$)

V_1 \ H_1/H		0.1	0.15	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
50	T_{01}/T_{02}	1.88	2.71	2.96	3.05	3	3.02	3.00	2.95	2.99	3.12	3
	T_{01}/T_{03}	3.15	3.25	5.15	5.07	4.94	4.99	5.00	4.92	5.10	5.20	5
100	T_{01}/T_{02}	1.54	1.69	3.27	2.87	2.98	2.99	3.00	3	3.00	2.99	3
	T_{01}/T_{03}	3.48	3.37	5.27	3.73	4.77	4.98	4.99	5.00	5.00	5	5
150	T_{01}/T_{02}	1.99	1.67	1.77	2.39	2.87	2.97	2.98	2.99	2.99	3	3
	T_{01}/T_{03}	3.43	3.67	3.53	3.43	3.92	4.73	4.95	4.99	5	5	5
200	T_{01}/T_{02}	2.42	1.92	1.79	2.09	2.62	2.91	2.98	2.99	3	3	3
	T_{01}/T_{03}	3.56	3.62	3.79	3.57	3.64	5.57	4.83	4.98	4.99	5	5
400	T_{01}/T_{02}	2.94	2.74	2.52	2.22	2.27	2.50	2.88	2.94	2.99	3	3
	T_{01}/T_{03}	4.6	4.14	4.00	4.18	4.13	4.01	4.2	4.65	4.98	5	5
600	T_{01}/T_{02}	2.98	2.95	2.87	2.68	2.58	2.61	2.71	2.87	2.96	3	3
	T_{01}/T_{03}	4.9	4.76	4.56	4.47	4.56	4.54	4.46	4.57	4.82	5	5
700	T_{01}/T_{02}	3	2.97	2.93	2.84	2.75	2.72	2.79	2.9	2.96	3	3
	T_{01}/T_{03}	5	4.89	4.77	4.67	4.74	4.70	4.67	4.70	4.88	5	5

Table 2

Relationship among T_{01}, T_{02} and T_{03} for 2 layers when $\mathbf{V_1 = 800}$ & $\mathbf{V_2 \le 800}$ ($V_1/V_2 \ge 1$)

V_2 \ H_1/H		0.1	0.15	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95	1
50	T_{01}/T_{02}	3.02	3.06	3.13	3.34	3.66	4.09	4.68	5.55	6.97	10.06	11.98	3
	T_{01}/T_{03}	5.09	5.24	5.45	6.02	6.76	7.73	8.99	10.8	20.44	17.64	24.5	5
100	T_{01}/T_{02}	3.02	3.06	3.13	3.34	3.65	4.08	4.67	5.52	12.79	8.55	6.41	3
	T_{01}/T_{03}	5.09	5.24	5.45	6.01	6.75	7.70	8.96	10.71	26.57	20.8	12.3	5
150	T_{01}/T_{02}	3.02	3.06	3.13	3.34	3.65	4.07	4.64	5.46	6.65	6.13	4.64	3
	T_{01}/T_{03}	5.09	5.23	5.44	6	6.73	7.67	8.87	6.65	9.51	10.22	8.87	5
200	T_{01}/T_{02}	3.02	3.12	3.12	3.33	3.63	4.04	4.60	5.35	6.06	4.87	3.85	3
	T_{01}/T_{03}	5.08	5.23	5.44	5.98	6.70	11.1	8.68	8.99	8.06	9.06	7.19	5
400	T_{01}/T_{02}	3.01	3.05	3.11	3.29	3.54	6.73	4.19	4.26	6.73	3.30	3.07	3
	T_{01}/T_{03}	5.07	5.02	5.38	5.85	6.40	8.73	6.44	6.34	8.73	5.89	5.28	5
600	T_{01}/T_{02}	3.01	3.03	3.07	3.20	5.72	3.51	3.54	3.41	3.21	3.04	3.00	3
	T_{01}/T_{03}	5.05	5.14	5.27	5.57	7.72	5.61	5.56	5.71	5.59	5.18	5.03	5
700	T_{01}/T_{02}	3.00	3.02	3.05	3.14	3.24	3.30	3.29	3.2	3.09	3.01	3.00	3
	T_{01}/T_{03}	5.03	5.10	5.19	5.36	5.39	5.32	5.34	5.41	5.28	5.06	5.01	5

Table 3

Calculated predominant periods $T_{01} = \frac{4H}{V_2} k_1$ for the first 30^{th} m when ($\mathbf{V_2 = 800}$ & $\mathbf{V_1 \le 800}$)

and correction factors k_1

V_1 \ H_1/H		0.05	0.1	0.15	0.2	0.25	0.3	0.4	0.5	0.6	0.7	0.8	0.9
25	k_1	1.63	3.22	4.82	6.42	8.01	9.61	12.40	16.02	19.19	22.42	25.38	26.88
50	k_1	1.04	1.66	2.45	3.24	4.04	4.94	6.34	8.02	9.61	11.06	13.08	14.22
100	k_1	1.00	1.07	1.34	1.70	2.09	2.48	3.27	4.56	4.84	5.63	6.42	7.20
150	k_1	0.99	1.01	1.09	1.27	1.49	1.73	2.24	2.75	3.26	3.78	4.30	4.81
200	k_1	0.99	1.00	1.03	1.11	1.24	1.39	1.75	2.11	2.49	2.86	3.24	3.62
300	k_1	0.99	0.99	1.03	1.02	1.06	1.13	1.30	1.51	1.74	1.97	2.18	2.43
400	k_1	0.99	0.99	0.99	1.00	1.01	1.04	1.13	1.25	1.39	1.53	1.69	1.84
500	k_1	0.99	0.99	0.99	0.99	0.99	1.00	1.05	1.11	1.20	1.29	1.39	1.491
600	k_1	0.99	0.98	0.98	0.98	0.98	0.99	1.01	1.04	1.08	1.14	1.20	1.26
700	k_1	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	1.04	1.07	1.10

Table 3

Calculated predominant periods $T_{01} = \frac{4H}{V_1} k_2$ for the first 30^{th} m when ($\mathbf{V_1 = 800}$ & $\mathbf{V_2 \le 800}$)

and correction factors k_2

V_2 \ H_1/H		0.05	0.1	0.15	0.2	0.25	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
25	k_2	32.15	32.3	32.4	32.4	32.31	32.15	31.5	30.3	28.4	25.72	21.9	16.1	11.6
50	k_2	16.08	16.14	16.2	16.2	16.16	16.07	15.74	15.13	14.2	12.87	10.96	8.08	5.85
100	k_2	8.04	8.07	8.09	8.09	8.08	8.02	7.78	7.57	7.11	6.45	5.51	4.1	3.02
150	k_2	5.36	5.38	5.39	5.04	5.39	5.36	5.25	5.06	4.76	4.33	3.71	2.8	2.12
200	k_2	4.02	4.03	4.05	4.05	4.04	4.02	3.95	3.8	3.59	3.3	2.83	2.2	1.69
300	k_2	2.68	2.69	2.7	2.7	2.7	2.7	2.64	2.55	2.42	2.23	1.96	1.57	1.32
400	k_2	2	2.02	2.03	2.03	2.03	2.02	1.99	1.93	1.85	1.72	1.55	1.31	1.17
500	k_2	1.61	1.16	1.62	1.62	1.62	1.62	1.6	1.57	1.51	1.43	1.31	1.17	1.09
600	k_2	1.33	1.35	1.35	1.35	1.35	1.35	1.35	1.32	1.29	1.24	1.17	1.09	1.05
700	k_2	1.15	1.15	1.16	1.16	1.17	1.17	1.16	1.15	1.14	1.11	1.08	1.04	1.02

It is known that for homogeneous basis for vibration periods of second and third modes the ratios are:

$$T_2 = \frac{T_1}{3}, \quad T_3 = \frac{T_1}{5}. \qquad (20)$$

On the example of two-layer basis the relationships T_1/T_2 and T_1/T_3 for heterogeneous basis with common capacity $H=H_1+H_2=30$m have been determined at various H_1/H and V_{s1}/V_{s2} relationships. The obtained results are presented on table 2 and show that the relationships (20) vary sharply, when $H_1/H<0.4$ at $V_{s1}<V_{s2}$ and when $H_1/H>0.5$ at $V_{s1}>V_{s2}$.

The influence of a very thin layer on the periods of all system has been also investigated. It is shown that if the thickness of a thin layer is less than 0.05H and it is located in the upper part of a thickness (the first layer) its influence can be neglected. The influence of a thin layer is essential if it is located in the lower part of a thickness. For these two arrangements of a thin layer all correction factors k_1 and k_2 have been calculated by equation (10) depending on H_1/H and V_1/V_2, which results are shown on table 3.

The carried out calculations have shown that at identical values of V_{s1} and H_1/H, the vibration periods of two-layer basis with V_{s2} equal to 800m/sec or 1000m/sec almost do not differ from each other. It indirectly testifies that the lower limit of transverse waves velocity for soils of I category by seismic properties can be accepted equal to V_s=800 *m/sec*.

CONCLUSIONS

– The new method to define the predominant period of multilayered soil thickness is developed by its sequential reduction to two-layer thickness. The practical application of the method is shown on two examples with n=6 and n=14 number of layers.

– It is shown that the relationships T_1/T_2 and T_1/T_3 essentially differ from 3 and 5, when $H_1/H<0.4$, $V_{s1}<V_{s2}$ and when $H_1/H>0.5$, $V_{s1}>V_{s2}$.

– The analysis of dynamic characteristics of 30-meter standard basis with shear wave velocities of the lower layer equal to 800m/sec or 1000m/sec has shown that at $H_1/H>0.4$ the distinction between the predominant periods is negligible. Therefore, the value of V_s=800m/sec can be considered as the lower limit for soils of I category.

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ԲԱԶՄԱՇԵՐՏ ԳՐՈՒՆՏԱՅԻՆ ՀԻՄՆԱՏԱԿԻ ԳԵՐԱԿՇՌՈՂ ՊԱՐԲԵՐՈՒԹՅՈՒՆՆԵՐԻ ՀԱՇՎԱՐԿՄԱՆ ՆՈՐ ԵՂԱՆԱԿ

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Ա մ փ ո փ ու մ

Հոդվածը նվիրված է բազմաշերտ գրունտային հիմնատակի (նկ.1) ազատ տատանումների պարբերությունների հաշվարկման նոր եղանակի մշակմանը՝ նպատակ ունենալով խուսափել բարձր աստիճանի դետերմինանտների ձևով ներկայացվող հաճախությունների տրանսցենդենտ հավասարումների արմատների որոնումները համակարգիչի օգնությամբ։ Եղանակի էությունը կայանում է նրանում, որ բազմաշերտ հիմնատակը հաջորդաբար բերվում է երկշերտանի հիմնատակի, որի համար ստացված է հաճախությունների (պարբերությունների) (10) ճշգրիտ տրանսցենդենտ հավասարումը։ Այդ հավասարման համար ստացվել են արմատների մեծությունները H_1/H_2 և T_1/T_2 արժեքների բոլոր հնարավոր 5824 տարբերակների դեպքում։ Ստացված արդյունքների հիման վրա երկշերտ հիմնատակի տատանման առաջին ձևի T_{01} պարբերության համար ստացված է (16) բանաձևը, որի մեջ մտնող *a* և *b* գործակիցների արժեքները բերված են աղյուսակ 1-ում ($T_1/T_2<1$ դեպքում օգտագործվում են a_1 և b_1 արժեքները; $1<T_1/T_2<25$ - a_2 և b_2 արժեքները և $T_1/T_2>25$ դեպքում a_3 և b_3 արժեքները)։

Ցանկացած n թվով շերտերով հիմնատակի ազատ տատանումների պարբերության մեծության որոշման գործընթացը իրականացվում է հետևյալ հաջորդականությամբ։ Սկզբում հորատացման կամ այլ գեոտեխնիկական եղանակներով որոշվում են կտրվածքի բոլոր շերտերի H_k հզորությունները, G_k սահքի մոդուլի արժեքները, ρ_k խտությունները և V_{sk} սահքի ալիքի տարածման արագությունները և տվյալ շերտի պայմանական պարբերությունները $T_k=4H_k/V_{sk}$, k=1,2...n բանաձևով: Այնուհետև ընդունում ենք, որ հիմնատակը բաղկացած է միայն վերին երկու շերտերից՝ իրենց H_1, H_2 և T_1, T_2 արժեքներով: Աղյուսակ 1-ից T_1/T_2 և H_1/H_2 հարաբերություններով որոշվում են *a* և *b* գործակիցների արժեքները և (16) բանաձևի օգնությամբ որոշում պայմանական երկշերտանի հիմնատակի պարբերությունը՝ նշանակելով այն T_{01}^{1-2}: Հաջորդ քայլում վերին երկու շերտերը միասին դիտարկվում է որպես մեկ պայմանական շերտ T_{01}^{1-2} պարբերությամբ ու $H_1 + H_2$ հզորությամբ և այն դիտարկվում երրորդ T_3 պարբերությամբ և H_3 հզորությամբ շերտի հետ: Այժմ նման ձևով T_{01}^{1-2}/T_3 և $(H_1 + H_2)/H_3$ հարաբերությունների հիման վրա օգտվելով նույն աղյուսակից և (16) բանաձևից որոշվում է առաջին երեք շերտերից բաղկացած պայմանական հիմնատակի T_{01}^{1-3} պարբերությունը: Այս գործընթացը հաջորդաբար շարունակվում է հիմնատակի բոլոր շերտերի համար: Վերջին փուլում ստացված T_{01}^{1-n} արժեքը ընդունվում է որպես ամբողջ n-շերտանոց հիմնատակի ազատ տատանման պարբերության իրական մեծություն: Հոդվածի 45-47 էջերում որպես օրինակ բերված են 6 (Գյումրի) և 14 (Մեխիկո) շերտանի հիմնատակերի պարբերությունների որոշման հաշվարկումները:

НОВЫЙ МЕТОД ОПРЕДЕЛЕНИЯ ПРЕОБЛАДАЮЩИХ ПЕРИОДОВ МНОГОСЛОЙНОГО ГРУНТОВОГО ОСНОВАНИЯ

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Резюме

Статья посвящена разработке нового метода определения периода свободных колебаний многослойного грунтового основания (рис.1). Цель метода – избежать определения с помощью компьютера корней трансцендентных частотных уравнений в виде детерминантов высоких порядков. Сущность метода заключается в последовательном приведении многослойного основания к двухслойному, для которого в зависимости от всевозможных отношений H_1/H_2 и T_1/T_2 5824 вариантов вычислены все корни трансцендентного частотного уравнения (10). Результаты этих вычислений приведены на рис.2, в табл.1, а их аналитическая интерпретация – согласно формуле (16).

Процедура определения значения периода свободных колебаний для любой толщи с n слоями производится в следующей последовательности. Сначала по данным бурения или других геотехнических методов на основании мощностей слоев H_k, скоростей волн сдвига V_{sk}, модулей сдвига G_k и плотностей ρ_k определяются периоды свободных колебаний каждого слоя (как однородной среды) по формуле $T_k=4H_k/V_{sk}$.

Затем, сначала считается, что толща состоит из верхних двух слоев со своими H_1 и H_2 и T_1 и T_2. По отношениям T_1/T_2, для данного отношения H_1/H_2 согласно таблице 1, определяются значения параметров *a* и *b* и по формуле (16) вычисляется период свободного колебания условной двухслойной толщи (из первых двух слоев). Этот период обозначается через T_{01}^{1-2}. Далее, верхние два слоя рассматриваются как один эквивалентный слой с мощностью $H_1 + H_2$ и периодом T_{01}^{1-2} и рассматривается уже с третьим слоем с мощностью H_3 и периодом T_3. Аналогичным образом, по отношениям T_{01}^{1-2}/T_3 и $(H_1 + H_2)/H_3$ по той же таблице 1 определяются новые значения параметров *a* и *b* и по той же формуле (16) вычисляется период свободных колебаний условной трехслойной толщи, который обозначается T_{01}^{1-3}. Этот процесс продолжается для всех слоев. Полученное в последнем этапе значение периода T_{01}^{1-n} и будет искомое значение периода свободных колебаний всей толщи с n слоями. На страницах 45-47 статьи в качестве примеров приведена процедура определения периодов для 6-ти – (Гюмри) и 14-тислойных оснований (Мехико).