

ENGINEERING CHARACTERISTICS AND EARTHQUAKE RESPONSE ANALYSIS OF GROUND

HARUYUKI YAMAMOTO¹ and MUNKHUNUR TOGTOKHBUYAN²

¹Development Technology, Hiroshima University / IDEC, Higashi-Hiroshima, Japan ²Civil Engineering and Architecture, Mongolian University of Science and Technology, Ulaanbaatar, Mongolia

One-dimensional layered soil lumped mass ground response analysis was conducted for the representative site in Ulaanbaatar, Mongolia. The surficial geology of the site is predominantly composed of the gravely and sandy soil typical of this region in the central part of Ulaanbaatar. The natural period of soil profiles needs to be investigated under several circumstances. For example, these parameters-based study has indicated that damage due to earthquakes occurs when the natural periods, T_1 and T_2 , of the ground are closer to that of a superstructure. Various computational procedures or methods have been proposed for this kind of the ground response analysis. In this paper, the numerical analysis method such as the lumped mass method within eigenvalue analysis is used to determine the natural periods of the ground. The ground surface, soil deposits, and bedrock are assumed to be horizontal. The soil deposits are subjected to shear deformation such as shear modulus, G, on the other hand, excitation of vibration could be a shear modulus on each layer. As well as to determine an engineering bedrock depth in the site, the methodology that is utilized in this paper is focused on the use of the correlation between SPT-N value and soil elastic Young's modulus, E, in the soil profiles, and used over 100 boreholes data with SPT-N values in the vicinity of Ulaanbaatar.

Keywords: Natural periods, Lumped mass, Layered soil deposit, Elastic analysis.

1 INTRODUCTION

A large number of constructions have been built across the capital city Ulaanbaatar of Mongolia. Unfortunately, many believe buildings that are under construction in there suffer from a lack of thinking in a dynamic response analysis of the ground, that is based on either the engineering geology or seismology investigations and relates to the soil conditions. In the last several years, the fast growth in the number of available strong-motion records has allowed statistical studies of the characteristics of horizontal ground shaking, including the effect of local geology in many countries.

These studies have been purposed to obtain average values of peak ground acceleration, using different methods and data such as a basis for the comparison the Modified Mercalli Intensity Scale and several accelerograms for the various type of soil conditions on the site (Seed and Idriss 1967). These investigations and observations have also indicated that any buildings construct on deep or soft alluvium may be subjected to seismic forces several times larger than similar buildings on hard soil if the peak ground acceleration is the same in both cases. Therefore, the

statistical analysis suggests that stiffness and depth of soil should be assumed in the seismic design of structures.

In Ulaanbaatar, it lacks data for seismic response analysis of the ground due to the data in the national code of Mongolia has been adopted from the Code of Russian Federation. To eliminate or solve this problem, we need to find various approaches for the dynamic ground response analysis which are based on not only accelerograms but also detailed geotechnical data, geology information and so on.

One of the primary representations of this assumption is determining the natural period, T, of a soil deposit. On the other hand, this characteristic site period depends on the stiffness and depth to the rock-like material of the soil profile at the site. Simple procedures for estimating natural periods of horizontal soil layers are given (Idriss and Seed 1968).

In this paper, a simple method such as the one-dimensional lumped mass solution for estimating T of multilayer the gravelly and the sandy soil profile with a linearly elastic is used in the representative site of Ulaanbaatar.

2 CORRELATION BETWEEN SPT-N VALUE AND DEFORMATION MODULUS E FOR THE GRAVELLY AND THE SANDY SOILS AROUND ULAANBAATAR

The first, to evaluate the ground response of soil deposit, an empirical equation of correlation between the blow count N value of Standard Penetration Test (SPT-N value) and elastic Young's modulus E of the gravelly and the sandy soils around Ulaanbaatar which was obtained. It helps to determine the bedrock depth in the study area. If SPT-N blow numbers count more than 50 in a borehole depth of strata, it can be considered to be bedrock depth.

Figure 1 shows the weak positive relationship between two parameters for various types of gravelly and sandy soils together, and comparison with the case of normal consolidated and over consolidated sandy soils in Japan. It is modified in the next attempt.



Figure 1. The correlation between SPT-N value and Modulus of Deformation E for Sandy and Gravelly soil. The blue and the brown lines are the cases of normal-consolidated and over-consolidated sandy soil respectively, in Japan.

Figure 2 presents the modified scatter plot of the positive relationship between two parameters such as SPT-N value and E, the value of the gravelly and sandy soils around Ulaanbaatar city. In this case, as shown in the Figure 1, all different N values of a type of soil corresponding to the same amount of E, values, that is integrated as follows:



Figure 2. Modified scatter plot of the correlation between SPT-N value and Modulus of Deformation E for Sandy and Gravelly soil.

As a result of the correlation procedure, the empirical equation between SPT-N value and E value for gravelly and sandy soil was given by

$$E(MPa) = 0.976 \cdot N$$
 (1)

A beneficial relationship that can provide the elastic properties from an in-situ test result it is given in Table 1, and the computed equation in this study is also compared with several countries in here.

	Japan (MPa)	USA and Russia Es (KPa)	Mongolia (MPa)
Sand (normally consolidated)	Es = 1.4N	Es = 0.5(N+0.015)	
Sand (over consolidated)	Es = 2.8N	Es = 40 + 1.05N	F – 0.976N
Gravelly sand		$\begin{split} & \text{IF, N} > 15 \text{Es} = 0.6(\text{N} + 0.06) + 2 \\ & \text{IF, N} < 15 \text{Es} = 0.6(\text{N} + 0.06) \end{split}$	It is found in case of all sandy and gravelly soils in Ulaanbaatar area
Clayey sand		Es = 0.32(N+0.015)	
Silts, sandy silt, or clayey silt		Es = 0.3(N+0.006)	

 Table 1. Correlations between SPT-N values and Elastic Young`s Modulus of soils, the case of several countries.

Totally over 429 boreholes without SPT investigation were carried out for the engineering geological investigation, and information has been accumulated in this study area. From the total boreholes, 132 boreholes, which were used in this research due to the majority of them drilled by shallow (around 6 meters' depth). Their engineering bedrock depth is specified by Eq. (1). For instance, in the case of 132 boreholes, if the SPT-N value is estimated by Eq. (1) is closer to the 50 in a stratum, which were assumed by the bedrock level for the site.

3 MODELING OF THE SOIL DEPOSIT

In many cases, the one-dimensional analysis gives larger displacement than the multidimensional analysis, when the ground layers are close to the horizontally layered. In this study, the one-dimensional coordinate system is chosen, where soil column can move freely under the one-dimensional analysis. Furthermore, the lumped mass idealization of the horizontal soil layers' model is created, as shown in Figure 3. In such a case, each layer including surface and bedrock boundary layers is assumed to be parallel with each other. Where m_i is a mass of layer i, h_i is a thickness of each corresponding layer i, k_i is spring constant, c_i and c_E are viscous and dashpot damping, during undamped free vibration both of them are null.



Figure 3. The lumped mass idealization of horizontal soil layers' model.

3.1 Numerical Analysis Method

For determining the natural period of the ground, the theory of the eigenvalue analysis is used. The undamped free vibration basic equation is given by;

$$[M]{\vec{y}} + [k]{y} = 0$$
(2)

Where, [M] is mass, or the diagonal matrix and [k] is the stiffness matrix, respectively.

Furthermore, the natural periods can be obtained by the general method. In this study, damping is neglected completely in ground response analysis, values of natural period T_1 and T_2 calculated by the Fortran programs for the based on the above general theory. As mentioned before one hundred thirty-two soil profiles were selected and their fundamental periods were estimated. For all spatial analysis, to create the counter map which corresponds with the results, ArcGIS has been used.

4 DISCUSSION OF RESULTS

According to the result of the counter map in Figure 4 and 5, the natural periods represents $T_1=0.05-1.6$ sec and $T_2=0.01-0.57$ sec respectively.



Figure 4. Natural period: T_1 distribution map.

Figure 5. Natural period: T₂ distribution map.

These maps illustrate which area is risky or safe for the ground response due to the induced vibration, and so on. For example, as shown in Figure 4, two points are delineated by the red circle. One of them is related to the maximum natural period area and another presents the minimum natural period area. In such a case, the high-rise building in the maximum natural period area may be susceptible to the shock, but the small-rise building may show no damage.

As shown in Figure 6, the relationships between depth and natural period in a site are obtained. It could be useful for the study of geotechnical earthquake engineering and for the structural engineers in the future. If the special area of any object is interested in the apparent depth in the study area, the natural periods can be obtained using this chart.



Figure 6. The relationship between ground depth and natural periods T_1 and T_2 .

5 CONCLUSIONS

A simple method for estimating the natural periods of soil profiles with the determining engineering bedrock depth in the site has been presented. On the other hand, the linear elastic one-dimensional lumped mass ground response analysis was performed for the multilayered the gravelly and the sandy soil profiles. Input motion related to accelerograms-time history and damping was neglected, and horizontal excitation of motion was assumed by the shear stress of the ground. This study should be taken into account for the clay deposits around Ulaanbaatar city.

References

Idriss, I. M., and Seed, H. B., Seismic Response of Horizontal Soil Layers, *Journal of Soil Mechanics and Foundations Division*, 94, SM4,1003-1031, 1968.

Seed, H., and Idriss, I., Analysis of Soil Liquefaction: Niigata Earthquake, *Journal of Soil Mechanics and Foundations Division*, 93, SM3,83-108, 1967.