TYPES OF DYNAMIC STRENGTH OF SOILS AND METHODS OF THEIR DETERMINATION

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ABSTRACT: The practice has shown that dynamic loadings are numerous, but there are only two types of reaction on the foundation soils: 1) active reaction due to direct cycling impact from the foundation machine, pile driving etc., 2) passive reaction due to the seismic effect from earthquakes, from transportation vehicles etc. Based on the analysis of the elastic, elastic-plastic and linear vibration theories, results of the study on the change of soil physico-mechanical parameters under the impact of the dynamic loadings [4,7,9,12] and based on the point of view of discrete medium dispersion system [15,21], this work had clarified the dynamic strength through dynamic cycling strength-characteristic seismic extreme dynamic strength for the passive and active reactions of the foundation soils. Simultaneously, mathematical expressions of the characteristic coefficients of various types of dynamic shearing strengths are presented and method of their determination is proposed.

OUTLINES

In the foundation soil dynamics most of the studies deal with dynamic cycling deformation and its characteristic parameters. In dealing with dynamic strength, the soil strength reduction and liquidation are mainly concerned, only few results are in the field of dynamic shearing strength such as of G.I Pocropxki; V.A. Ersop and Xediny (1962); H. Xid; D.D. Barcan R. Oxown E.D Sukina (1985);C. Choi and P. Arduino; M.D. Liu and J.P. Carter and others [14;15;23]. Recently there were some recommendations proposed and methods of determination of dynamic strength parameters were applied based on the Mohr such as Chinese standards.

General notation about the results of dynamic strength study in the foundation soil dynamic strength is that commonly widely foundation soil dynamic strength is dynamic cycling strength. Therefore, there is no difference between the different dynamic reactions.

In a word, dynamic loading foundation design and seismic foundation design are special foundation designs. This is the reason why were few new study results have been published.

PHYSICAL MECHANISM OF THE FOUNDATION DYNAMIC REACTIONS

From the geological standpoint of view, foundation soils are the products of geological processes which consist of material components existing in the form of solid, liquid and air and which were formed under difference conditions. This can be illustrated by a conceptual image (Figure 1), in which the solid phase consists of particles of different sizes and shapes, in between of which it may be liquid or air. In the natural balanced status of the foundation soils, the particles are in the stress balance with the neighboring particles in the soil medium by some potential status. When there is a change in that potential status due to the above or below loading, some relative movement of the particles dependently upon the magnitude and time of the loading and the particle inter-force. The difference between those two reactions is as follows:

For the above loading (downward stress), the particle movement is downwards and to horizontal directions until a new balance is established. This particle movement and rearrangement in this process is the reaction of the foundation soil in order to adapt with the loading. Therefore, this reaction is called passive reaction to the loading.

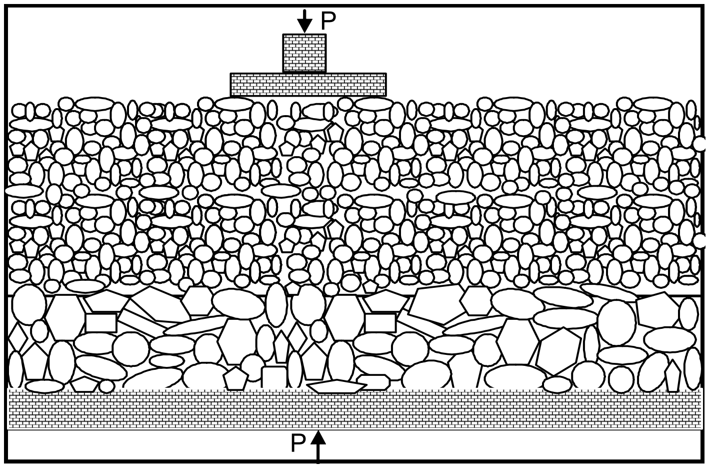

Figure 1 Conceptual Image of foundation soil and its reaction with dynamic loading

For the below loading (upward stress), the particle movement is chaos in the tendency that the lighter particles move farther than the heavier particles, and therefore, the lighter particles move upwards, the heavier particles move downwards. This particle movement has changed the position of the above loading. Therefore, the particle movement in this case is characteristic to active reaction of the foundation soil.

In case if the loading is static, the diphase between stress and deformation has no meaning then the difference between active and passive reactions has no meaning. However, in case of dynamic loading, the diphase is the main characteristic, then the difference between active and passive reactions must be clarified.

TYPES OF FOUNDATION SOIL DYNAMIC STRENGTH

Based on the relationship between stress and deformation, [1] had considered foundation soil as a special continuous solid which has many pores of sizes greater than particle sizes. Under the vertical downward loading the foundation soil is vertically one-dimensionally deformed. This deformation is in two deformation components: 1) volume deformation which has compacting impact; and 2) sliding deformation. Dependently upon the loading magnitude and the foundation soil characteristics, the deformation may be mainly only compacting deformation which decreases with time, or sliding deformation which does not decrease with time. With this thinking, the foundation soil strength is the maximal stress under the foundation which does not cause sliding deformation. Therefore, if the loading is cycling dynamic then the soil strength is the maximal loading at some time which does not cause sliding deformation. However the dynamic loading is not only characterized by the initial value but also dependent upon the amplitude and frequency. Therefore, there will be a difference between the strengths in different reaction as follows.

Passive reaction: This is a condition which describes the foundation soil strength reduction under the above dynamic cycling loading with a known frequency under known initial stress (machine foundation etc.). The foundation soil strength in this reaction is the maximal stress amplitude such that the relationship between the stress and strain in all times between the cycles is linear. Therefore, this value is dependent upon the frequency and stress condition. The soil strength in this reaction is dynamic cycling strength.

Active reaction: This reaction describes the soil strength reduction under the foundation under unchanged static loading, but under seismic condition with known amplitude and frequency (earthquake). In this case, if the initial stress is known and dynamic cycling loading amplitude and frequency are known then maximal stress amplitude is the soil strength. The soil strength determined in this case is the extreme seismic strength.

Therefore, dynamic cycling strength and seismic extreme strength can be determined by three-axial dynamic cycling loading test (photo 1) by the following 2 different schemes:

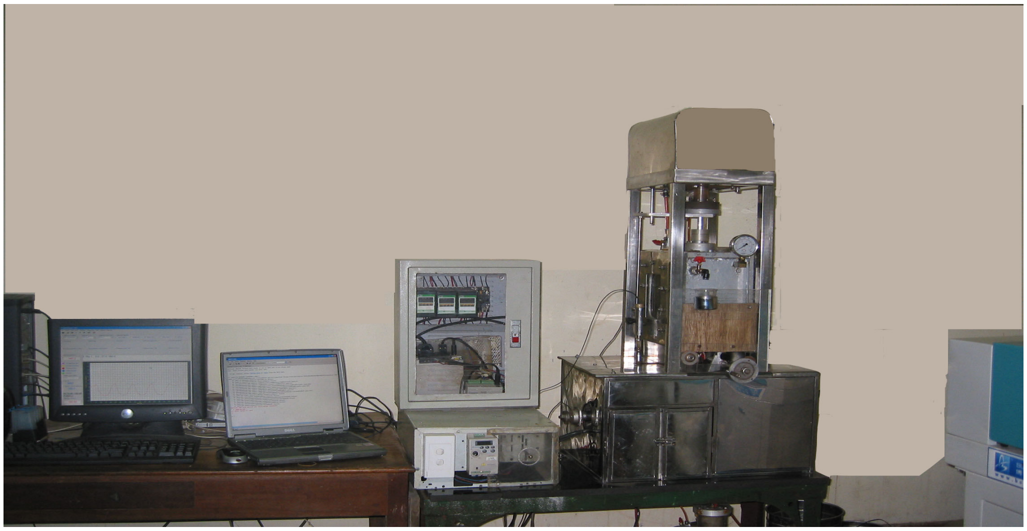

Photo 1 Three-axial dynamic cycling loading test equipment

For the dynamic cycling strength, the scheme of temporal linear incensement of loading amplitude has the following equation:

$$F_{(t)} = F_0 + at\sin\omega t \quad (1)$$

where $F_{(t)}$ _ loading changing with time

F_0 _ constant initial static loading

a _ coefficient of incensement of loading

ω _ loading frequency

t _ loading time

Together with $F_{(t)}$ the sample strain, the values in the three-axial dynamic cycling loading tests are recorded by the strain gage sensors. The dynamic cycling loading in this test usually has the form as shown in figure 2.

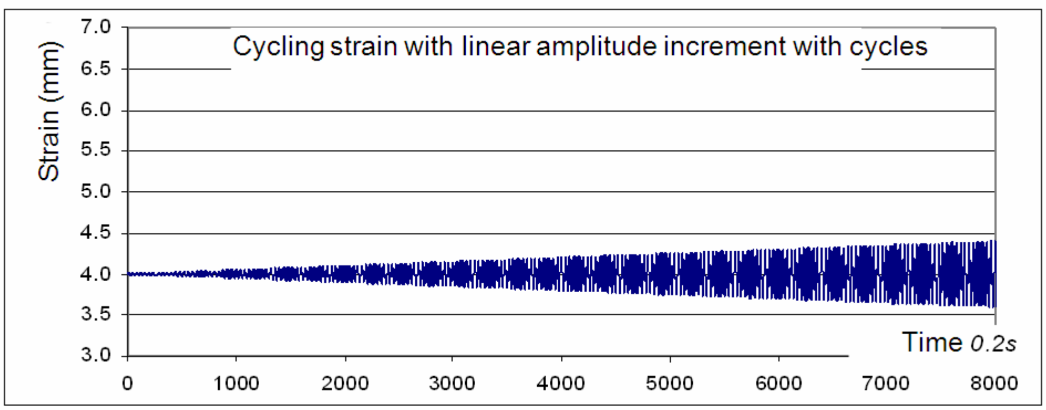

Figure 2 Strain graph for determination of dynamic cycling strength

For the seismic extreme strength, the scheme of temporal linear incensement of de-phasing loading in case of unchanged frequency and amplitude has the following equation:

$$F_{(t)} = at + A\sin\omega t \quad (2)$$

where A _ linear axial loading increment with time t

$F_{(t)}$ _ loading changing with time

F_0 _ constant initial static loading

a _ coefficient of increment of loading

ω _ loading frequency

A _ loading amplitude

t _ loading time

Together with $F_{(t)}$ the sample strain values in the three-axial dynamic cycling loading test are recorded by the strain gage sensors. The dynamic cycling loading in this test usually has the form as shown in figure 3

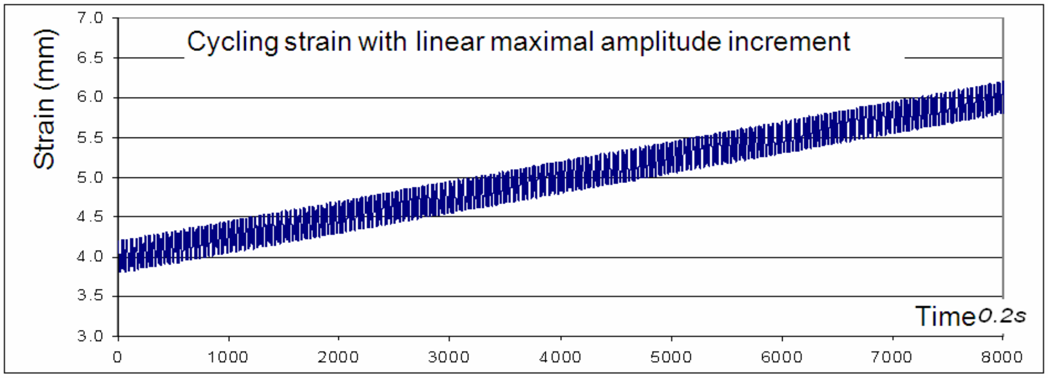

Figure 3 Strain graph used for determination of seismic extreme strength

Therefore, if it is required to correlate seismic extreme strength with static strength, then it can be said that, seismic extreme strength is a general concept about soil strength under different conditions of dynamic loadings. Static loading strength is only one special case with zero amplitude or frequency. Study of seismic extreme strength of a given soil under different frequencies and amplitudes will give loading capacity of foundation soil under the foundation basement with known loading in the time of dynamic loading with a given frequency or amplitude. Meanwhile, dynamic cycling strength and static strength have completely different natures. The comparison of their magnitudes depends upon many factors.

CHARACTERISTIC COEFFICIENTS OF DYNAMIC STRENGTH

Foundation soil stability in term of strength under loading is evaluated based on strength characteristic parameters: soil internal friction angle φ and cohesion C, in which the strength characteristics are determined under condition that strain rate is significantly small and unchanged. In the progress of continuous increment of static loading, the soil disturbance is corresponding to the maximal stress. Meanwhile, under dynamic loading, the soil reaction is the cycling deformation and the deformation rate changes with time. During the dynamic deformation the resulting stress changes with cycles.

In a word, the conditions which result in soil static strength are different from those resulting in dynamic cycling strength. Therefore its is required to have determine the characteristic coefficients of the dynamic strength and method of their determination.

Let consider Coulomb model which had leaded to concept of strengths through linear relationship between normal stress σ and shearing stress τ with internal friction angle φ and cohesion C[27].

$$\tau = \sigma tg\varphi + C \qquad (3)$$

This relationship is formed at the moment of extreme stress under gravitational condition.

For the extreme seismic dynamic strength, the formation of the seismic dynamic strength under three-axial dynamic cycling tests is occurred without change of normal and shearing stresses as in static cases, the difference only occurs under dynamic conditions with acceleration different from gravitational acceleration. Therefore, the difference in the values of the strength coefficients of the extreme seismic dynamic strength and static strength would express the change in mechanical properties of the soil under the external dynamic loading with acceleration different from gravitational acceleration. This allows to use the ratio between the gravitational acceleration and seismic acceleration to evaluate extreme seismic strength and its characteristic coefficients in accordance with Coulomb model.

For the dynamic cycling strength, its formation during the three-axial dynamic cycling tests is occurred with normal cycling stresses and cycling strains. The value of dynamic cycling strength during some stress condition (confining pressure) is the maximal stress amplitude under that condition. Therefore, the seismic cycling strengths and their corresponding confining pressures always form a tight relationship. However, in order to simplify it can be used linear relationship as follows:

$$\tau = k\sigma_b + \sigma_0 \qquad (4)$$

where τ _ extreme seismic shearing strength at some frequency

σ_b _ confining pressure

k and σ_0 _ coefficients of each soil dependent upon the applied frequency

Based on that relationship it can determine characteristic strength coefficients using testing data under different confining pressures and a given known frequency of the foundation. On the contrary, if the characteristic strength coefficients are known, it can determine extreme seismic shearing strength at all different normal stresses under foundation with known frequency. However, the analysis of balance conditions at different points in the foundation under dynamic cycling loadings are completely complicated, but it can accept one general analysis for the whole foundation through determination of characteristic strength coefficients for the soil layer just beneath the foundation foot.

In a word, in the analysis of stability of foundation soil under machine foundation foot the characteristic dynamic cycling strength coefficients are to be used. In the analysis of stability of foundation soil under seismic (earthquake) conditions the characteristic extreme seismic strength coefficients are to be used

DISCUSSION

The clarification of dynamic strength has shown that the dynamic variety makes the foundation soil reactions very various, what leads to complication of dynamic strength in the soil reactions. Therefore, it requires the three-axial testing model change not only in amplitude, frequency and confining pressure and recording high stresses and strains, but also the functions in changing the way of linear loading as well the amplitude and frequency with time. The structure and working mechanism of the testing equipment which were used and are presented in this work (Photo 1) do meet the above-mentioned requirements.

In accordance with elastic theory of dynamic problem [2], the vibration in the foundation soil is the unlimited vibration with infinite order of freedom, in which all points have the same frequency, but the amplitude is continuously decreased from the loading source, and increased from the low potential points to higher potential points. On the contrary, the existing studies on vibration have shown that the change of frequency in space depends upon the soil and rock media, which are characterized by the soil connection, density and the liquid phase content. Therefore, in order to better solve the foundation soil stability, it is required the to combine with dynamic deformation through analysis of characteristic dynamic cycling strength coefficients such as Young modulus, seismic reduced coefficient, and the amplitude of extreme strain amplitudes.

CONCLUSION

In Vietnam, the reaction of the foundation soils are not show in the foundation design for dynamic and seismic loading conditions. The explanation of dynamic strength through concept of dynamic cycling strength and extreme dynamic strength would serve as fundamentals for completion of method of foundation soil stability under dynamic loading conditions. and seismic conditions.

Some results of determination of the characteristic dynamic cycling strength coefficients by the method and testing procedure described in this work have been applied in the foundation design under seismic conditions to some high buildings in My Dinh and Ha Dong and to some machine foundations under dynamic loadings.

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