Effect of foundation embedment on the dynamic behaviour of the foundation–soil system

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The effect of embedment on dynamic response of footings is very important, particularly for bodies embedded in a stratum or for cases of horizontal excitation. Despite this, the literature concerning embedment is limited. Therefore, the Author's effort to establish more information by means of laboratory tests can be appreciated.

Some knowledge of the subject has already been acquired in recent years and it may be useful to mention some of the findings for some reason not reflected in the Paper.

Field experiments are of great importance because the wave propagation is not obstructed as in laboratory tests. (See Novak, 1960; Novak, 1970; Fry, 1963 and Novak and Beredugo, 1971.) Laboratory experiments similar to those of the Author were reported by Chae (1971).

Experiments alone are difficult to generalize and, therefore, any guidelines derived from theoretical solutions are helpful.

Increase in static stiffness because of embedment was studied by Kaldjian (1969) using the finite element method. The same technique was used by Lysmer and Kuhlemeyer (1969, 1971) to solve the vertical dynamic response. An approximate analytical approach was used by Novak and Beredugo (1971) to solve vertical, horizontal, rocking and coupled vibrations of embedded footings. This approach can be simplified for design purposes. Stiffness and damping constants can be derived which can be introduced into the dynamic analysis of any structure supported by embedded footings (Beredugo and Novak, 1972).

The difficulties with generalizing the Author's experimental results can be illustrated by equation (3) or item (g) of his conclusions. The Author found that the damping factor is *directly proportional* to (depth of embedment D_e/foundation width B)^2

$$\xi \propto (D_e/B)^2$$

First, this cannot be true because with $D_e=0$ damping would be zero. Second, it can be seen from Fig. 9 in the Paper, referred to by the Author, that the observed damping factor is actually

$$\xi = C_1+C_2(D_e/B)^2$$

where C_1 and C_2 are constants different for each of the Author's blocks.

Third, the Author's findings would also imply that doubling the footing width would reduce the damping to $\frac{1}{4}$ of the original value which is a dubious suggestion. Clearly, footing dimensions, mass and soil properties, must appear in any meaningful formula.

Another factor which affects the Author's findings is the way in which the coefficient of elastic uniform compression was determined. The measured response curves were not used to establish this coefficient; instead, repeated load tests were conducted. In view of the recognized differences between static and dynamic tests, it seems preferable to establish all information from the response curves. This can be easily done, e.g. see Novak (1971).

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Undrained creep behaviour of a coastal organic silty clay

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The discussion is limited to saturated consolidated clays (in the laboratory or field) tested in triaxial shear apparatus by a controlled stress rate method, i.e. either by the test procedure given by the Authors or that suggested by Tan (1961), to determine its creep strength. In order to determine the creep strength of a soil sample some conditions have to be fulfilled by the test procedure followed and by the soil sample tested by that procedure.

The creep strength of a soil is the shear resistance as measured by the principal stress difference, at which the rate of strain at steady state creep condition (Mitchell *et al.*, 1965) is neither accelerating nor decelerating but is constant independent of the time for which the sustained constant shear stress is acting.

The prerequisite for satisfying the above definition of creep shear strength of soil is that it should have a structure (Lambe, 1953) which would not change with deformation of the soil when subjected to a sustained constant shear stress. If the structure of soil would change with deformation so that stronger contacts between clay particles would develop then the rate of strain would decelerate. On the other hand, with deformation, if weaker contacts develop so that the strength of the soil decreases with deformation and time, then the rate of strain would be accelerating. It seems that the only type of structure that would not change with deformation, and time, is the ideal dispersed structure. The clay soil with an ideal dispersed structure has flat surfaces of clay particles oriented parallel to each other and to the potential plane of failure. The distance between clay particles is a function of the normal stress acting on the potential plane of failure. (The possibility of change in a structure because of change in an electrolyte content of pore water is excluded.)

The shear strength of the soil of an ideal dispersed structure is its creep shear strength. The creep shear strength of soil is quantitatively the same as that of its residual shear strength (Skempton, 1964). Qualitatively the residual shear strength of soil is its after-failure strength (Hvorslev, 1960) whereas the creep shear strength is such that any shear stress of magnitude less than it would be unable to bring shear failure of soil irrespective of the time for which it is acting.

In order to find the creep shear strength of a clay soil in the laboratory, an ideal dispersed structure should be developed in the zone of failure before the failure of the soil occurs, i.e. the