[0019] For the load test conducted with the weight drop method using the soft cushion, the loading performed a plurality of times in the manner of heightening the hammer drop height in steps shall be adopted. Therefore, on the occasion of applying each blow, two or more unloading point loads are obtained together with two or more unloading point displacements corresponding thereto. Accordingly, the unloading points are simply connected, thereby allowing the R_w-w relation as shown in FIG. 2 to be simply obtained only by connecting the unloading points without any need to determine the damping constant C required for the Unloading Point (ULP) method.

[0020] However, for the Unloading Point (ULP) and Unloading Point Connection (ULPC) methods, the pile is assumed to be the point mass of the rigid body, and as a result, the effect of elastic deformation of the pile is made greater as the pile is larger in length. For instance, it happens that the result of the estimation on the load-displacement relation is affected by a pile acceleration measurement position.

[0021]

[Case method based on one-dimensional wave propagation theory]

The Case method, as described in non-patent document 2 below, is a method that has been used for an impulsive load test, more specifically, a method that is used to determine static penetration resistance based on one-dimensional wave propagation theory by use of both an empirical coefficient called the J_c coefficient and penetration resistance of the pile (soil resistance to the pile) upon receiving a blow. However, this method does not take the load-displacement relation determined with the rapid load test into consideration.

[0022] First of all, a downward traveling wave F_d and an upward traveling wave F_u are calculated from measured signals (axial force F and pile velocity v) (See the following equations (5) and (6)). After that, temporal changes of the penetration resistance R_{soil} of the pile are obtained using the following equation (7) (See FIG. 3).

[0023]

[Equation 5]

$$F_{\mathrm{d}}(x_{\mathrm{m}},t)=\frac{F(x_{\mathrm{m}},t)+Z\bullet v(x_{\mathrm{m}},t)}{2} \qquad (5)$$

[0024]

[Equation 6]

$$F_{\mathrm{u}}(x_{\mathrm{m}},t)=\frac{F(x_{\mathrm{m}},t)-Z\bullet v(x_{\mathrm{m}},t)}{2} \qquad (6)$$

[0025]

[Equation 7]

$$R_{\mathrm{soil}}(x_{\mathrm{m}},t)=F_{\mathrm{d}}\left(x_{\mathrm{m}},t-\frac{L_{\mathrm{m}}}{c}\right)+F_{\mathrm{u}}\left(x_{\mathrm{m}},t+\frac{L_{\mathrm{m}}}{c}\right) \qquad (7)$$

[0026] Here, x is coordinate along a pile axis (with the pile head set to be 0), x_m is measurement position, v is pile velocity, L_m is length from the measurement position to a pile tip, F is axial force, F_d is downward traveling wave, F_u is upward traveling wave, Z is impedance (EA/c) of the pile body, c is longitudinal wave velocity, E is Young's modulus of a pile material, A is cross-sectional area of the pile, and R_{soil} is penetration resistance.

[0027] The Case method is aimed at evaluating the penetration resistance of the pile during driving, and therefore, any load-displacement relation of the pile cannot be obtained with the Case method alone. However, because of the fact that the Case method is a method based on one-dimensional wave propagation theory, the Case method can evaluate the penetration resistance of the pile almost correctly, even when the pile is larger in length.

[0028] Non-patent document 3 below describes the numerical analysis of a rapid load test on a pile for weighing soil resistance obtained from analysis with the Case method against that obtained from analysis with the Unloading Point (ULP) method. The result of weighing shows that when a relative loading time $T_r=t_L/(2L_m/c)$ (where t_L is the loading duration) is below 5, the soil resistance obtained from the latter analysis overestimates the value obtained from the former analysis. However, this non-patent document 3 makes no mention of any effect on the load-displacement relation.

[0029] Non-patent document 4 describes a rapid load test on a tip bearing pile for determining a static load-displacement relation of the pile with the invocation of a Case method. For this test, a blow with a relatively large striking force has been applied once. For that reason, the determination of the damping constant C has been necessitated.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0030]

Patent document 1: Japanese Unexamined Patent Application Publication No. 2002-303570

Patent document 2: Japanese Unexamined Patent Application Publication No. 2005-068802

Patent document 3: Japanese Patent Publication No. 6613430

NON-PATENT DOCUMENTS

[0031]

Non-patent document 1: Kusakabe O., Matsumoto T. (1995): Statnamic tests of Shonan test program with review of signal interpretation, Proc. 1st Int. Statnamic Seminar, Vancouver, Canada, pp. 113-122.

Non-patent document 2: Raushe F. Goble G., Likins G.E. Jr. (1985): Dynamic determination of pile capacity, ASCE Jour. Geotech. Div., 111(3), pp. 367 to 383.

Non-patent document 3: Kojima, Nishimura (2021): Soil resistance analysis method in rapid load test, the 56th Japan National Conference on Geotechnical Engineering.

Non-patent document 4: Matsuzawa, Nakashima, Nakayama, Matsumoto (2008): A piling method accompanying rapid load testing, Proc. the 8th Int. Conf. on the Application of Stress-Wave Theory to Piles, Lisbon, Portugal, pp. 487 to 495.

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0032] For the Unloading Point and Unloading Point Connection methods, the shorter the relative loading time T_r is, the more inferior the analysis precision becomes. Accordingly, there have been such problems that the test equipment on a considerably large scale is needed to lengthen the relative loading time T_r, and that much increase in the cost for the test conducted once is incurred as well.

[0033] An object of the present invention is to provide a rapid load test method for a pile, with which a more highly precious load-displacement relation can be determined by use of a newly developed analysis method in which the concept of a Case method used for an impulsive load test is incorporated in a conventional Unloading Point Connection (ULPC) method, on the premise that a rapid load tests shall be conducted on a pile head a plurality of times.

MEANS FOR SOLVING THE PROBLEMS

[0034]

The present invention addresses the problem of providing a rapid load test method for a pile, in which a weight is dropped onto a pile head to determine a static load-displacement relation of the pile from a relation between a load caused by the drop of the weight and a displacement of the pile head, wherein the rapid load test method comprises the steps of:

conducting a plurality of rapid load tests on said pile head in the manner of changing the drop height h of said weight,

determining soil resistance R_{soil} to the pile under receiving a blow, in

order of the following procedures (a) and (b) according to a Case method based on one-dimensional wave propagation theory, for each of the plurality of rapid load tests,

determining a relation between a displacement w of said pile head and said soil resistance R_{soil} from temporal changes of the directly measured displacement w of said pile head,

determining an unloading point load P_h and an unloading point displacement w_h by assuming that the soil resistance $R_{soil(max)}$ as of the maximum displacement w_{max} is being static resistance R_w, and

determining a pile head load P_h-pile head displacement w_h relation resulting from connecting said unloading point load P_h and said unloading point displacement w_h, respectively obtained for each different drop height h.

[0035]

(a) Calculating a downward traveling wave F_d and an upward traveling wave F_u from axial force F and pile velocity v in the rapid load test by using the following equations (5) and (6).

[Equation 5]

$$F_d(x_m,t)=\frac{F(x_m,t)+Z\bullet v(x_m,t)}{2} \qquad (5)$$

[Equation 6]

$$F_u(x_m,t)=\frac{F(x_m,t)-Z\bullet v(x_m,t)}{2} \qquad (6)$$

(b) Subsequently, obtaining the temporal changes of the soil resistance R_{soil} to the pile by using the following equation (7).

[Equation 7]

$$R_{soil}(x_m,t)=F_d\left(x_m,t-\frac{L_m}{c}\right)+F_u\left(x_m,t+\frac{L_m}{c}\right) \qquad (7)$$

Where x is coordinate along a pile axis (with the pile head set to be 0), x_m is measurement position, v is pile velocity, L_m is length from the measurement position to a pile tip, F is axial force, F_d is downward traveling wave, F_u is upward traveling wave, Z is impedance (EA/c) of a pile body, c is longitudinal wave velocity, E is Young's modulus of a pile material, A is cross-sectional area of the pile, and R_{soil} is soil resistance.

[0036] Namely, for the present invention, a certain pile is subjected to application of a blow (the rapid load test) a plurality of times, and then, the w-R_{soil} relation is determined

from both of the soil resistance R_{soil} obtained from the Case method and the temporal changes of the directly measured displacement w of the pile to obtain the unloading point load R_{ULP} and the unloading point displacement from the determined w-R_{soil} relation. After that, two or more unloading points are connected, likewise the Unloading Point Connection (ULPC) method, with the result that the static load-displacement relation can be finally determined.

EFFECTS OF THE INVENTION

[0037] According to the rapid load test method for the pile in the present invention, it is possible to provide a rapid load test method for a pile, with which a more highly precise load-displacement relation can be determined by use of a newly developed analysis method in which the concept of the Case method used for the impulsive load test is incorporated in the conventional Unloading Point Connection (ULPC) method, on the premise that a rapid load test shall be conducted on the pile head more than once.

[0038] The rapid load test method for the pile in the present invention is considered to be based on one-dimensional wave propagation theory, and hence, can dispense with any inertial force correction for the pile. Accordingly, this rapid load test method provides the advantage that restrictions on application thereof due to the pile length or due to the relative loading time can be eased, for instance. Besides, in contrast to the conventional Unloading Point and Unloading Point Connection methods, which have had such problems that the test equipment on the considerably large scale is needed to lengthen the relative loading time T_r and that much increase in the cost for the test conducted once is incurred as well, it is made possible for this rapid load test method to solve these problems.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039]

[FIG. 1] FIG. 1 is a graphical representation of a load-displacement relation regarding an Unloading Point (ULP) method, given as one conventional rapid load test method.

[FIG. 2] FIG. 2 is a graphical representation of a load-displacement relation regarding an Unloading Point Connection (ULPC) method, given as another conventional rapid load test method.

[FIG. 3] FIG. 3 is a view for summarizing a Case method used for a conventional impulsive load test.

[FIG. 4] FIG. 4 is a view showing N-value distributions at a testing site and a state of pile penetration thereat.

[FIG. 5] FIG. 5 is a graphical representation of a pile head load P_h-pile head displacement