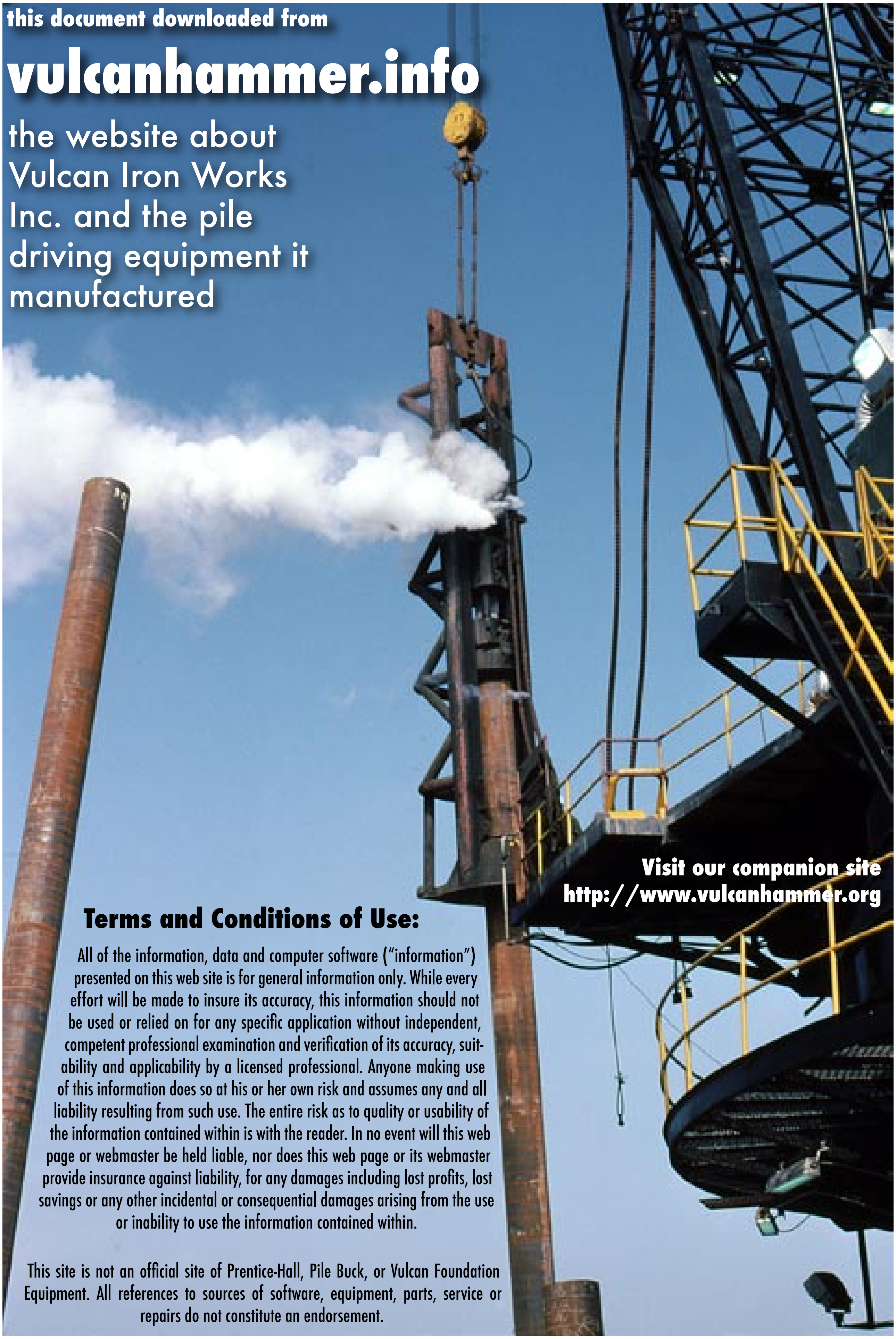

INVESTIGATION OF THE EFFECTIVENESS OF A HAMMER BLOW IN PILE DRIVING

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V. G. Esipenko

The structure of the impulse formed in the head of a pile following a hammer blow can often have a considerable influence of the effectiveness of using the energy. In this connection, attempts are made below to establish the relation between the parameters of the impulse in the pile head and the magnitude of its refusal and to develop a method of determining the characteristics of the elements participating in the collision that are optimal with respect to the driving capacity of the impulse.

To the colliding elements we refer the striking part of the hammer (ram), elastic packing of the helmet, and pile proper. Each of these elements is characterized by length L, period T=2L: c, and dynamic stiffness $A = \rho c f$, where ρ is the density of the material; c is the speed of sound in the material; f is the cross-sectional area. In this case $A_{mR} = A_m : A_R$; $T_{mR} = T_m : T_R$, where m and R are the designations of elements used henceforth for the ram 1, for the packing 2, and for the pile 3. The period of the ram T_1 is considered as the time modulus.

Problems of impact driving of piles are solved in the article by the graphic method of characteristics [1]. The data of experiments under natural conditions [2] are used for comparison of results and as the boundary and initial conditions.

It is postulated during the solution that the movement of the pile relative to the ground begins when the force P in it reaches the value of the force of maximum dynamic resistance of the soil R.

We see from Fig. 1 that state b, characterized by force P_b and velocity V_b, formed in the pile head on arriving in the end section H cannot preserve the force P > R. Here state c is formed in which the velocity V_c compensating the decrease of force to P_c=R represents the velocity of displacement of the end of the pile relative to the soil. The velocity of the elementary displacement impulse is

$$V_c = \frac{2}{A_3}\left(P_b - \frac{1}{2} R\right). \tag{1}$$

Thus, during time $t = T_1$ the elementary settlement of the pile is

$$S_c = \frac{2}{A_3}\left(P_b - \frac{1}{2} R\right) T_1. \tag{2}$$

States 5 and 8 are formed in exactly the same way except that the increases of forces are achieved due to a decrease of velocities. The total settlment of the pile per blow is determined by the sum of the elementary settlements. Representing (2) in a general form, we obtain the total settlement

$$S = \frac{2}{A_3}\sum_{1}^{n}\left(P - \frac{1}{2} R\right)T_1, \tag{3}$$

where n is the number of stages of the impulse with duration T_1 for which

$$P \geqslant \frac{1}{2} R.$$

Melitopol' Institute of Mechanization of Agriculture. Translated from Osnovaniya, Fundamenty i Mekhanika Gruntov, No. 1, pp. 14-16, January-February, 1974.

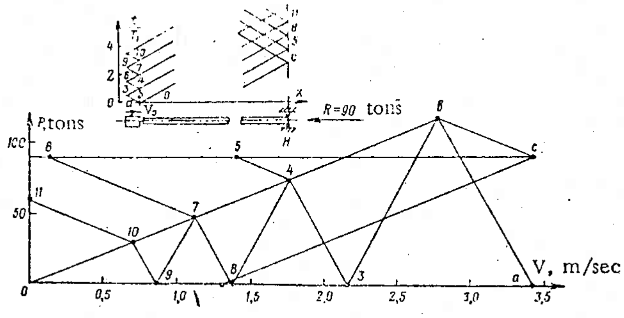


Fig. 1

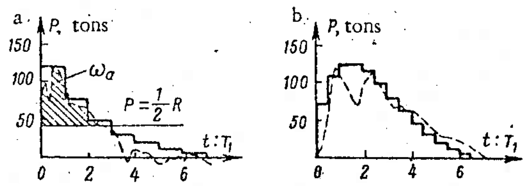


Fig. 2

Fig. 1. Solution of the problem of impact driving of a pile by the method of characteristics.

Fig. 2. Impulses of forces in pile head upon impact. a) Without packing; b) through packing obtained from the calculated (solid line) and experimental (dashed line) data.

TABLE 1

Length of pile in soil, mm	Pile refusal, mm, determined by Eq. (4)	by meas.
15	41	70
37	20	25
50	8,6	7,2
52	22,6	18
57	9,2	7

The right side of Eq. (3) corresponds to the doubled area ω_a (Fig. 2a) of the part of the impulse lying above the line $P={}^1/_2R$ (the impulse of force in Fig. 2a corresponds to the solution given in Fig. 1). Since this part of the impulse in the pile head determines its driving, we will call it the active part of the impulse. Consequently, calculation of pile refusal regardless of the type of hammer can reduce to a determination of the area of the active part of the impulse

$$S = 2\,\omega_a : A_3. \tag{4}$$

Equation (4) on the basis of the pile refusal and graph of the area of the active part of the corresponding impulse as a function of the resistance permits solving the opposite problem – determination of the dynamic resistance of the soil upon impact. Table 1 shows the sufficient convergence of results of determining refusal from the active part of the impulse with the natural measurements for a long pile. The deviations increase with decrease of pile length, which confirms the need to take into account the interference effect of its movement and the reaction of the medium on the formation of the impulse in the head of a short pile and on the magnitude of its refusal [1]. Here the division of piles into long and short is done on the basis of the interference character of the effect of the boundary conditions on the formation of the impact impulse in the pile head. For a short pile the soil reaction has a noticeable effect on the formation of the impulse in the pile head; there is no such effect for a long pile.

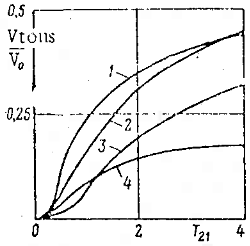
Although Eq. (4) determined the dependence of pile refusal on the impact impulse in the most exteme case, it clearly establishes that refusal depends not only on the magnitude of energy transmitted to the pile but also on the form of the impulse to a considerable extent.

For a quantitative evaluation of the structure of the impulse we introduce the concept of degree of its effectiveness $\bar{\omega}_a = \omega_a : \omega$, where ω is the area of the impulse. Accordingly the forces exceeding half the magnitude of the soil reaction are called active.

Thus, an increase of the active part of the impulse is the condition of increase of settlement of the pile per blow and consequently of the output of the pile-driving equipment. In practice such an increase can be achieved by increasing the duration of the active forces. For this purpose, in pile driving one uses, in particular, helmets including a packing made of material with a dynamic stiffness less than that of the pile and ram. A comparison of the impulses in the head of a reinforced-concrete pile formed by the same hammer following impact without a packing (Fig.2a) and through a wooden packing (Fig. 2b) shows hows under the effect of the packing the duration of the forces, close in magnitude to the maximum, which remained practically constant, increased.

Comparing the forms of the impulses, we can conclude that the duration of the active forces increases with lengthening of the packing. In this case it is of interest to investigate the rebound velocities of the ram. since energy losses are related with them.

With an increase of the length of the packing (Fig. 3) the rebound velocities at first increase sharply, then the rate of increase of the rebound velocities decreases.



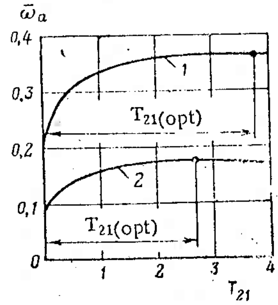


Fig. 3 Fig. 4

Fig. 3. Effect of packing length on rebound velocity of the ram for values of A_{mk} equal to 1) $A_{13} = 6$, $A_{23} = 0.06$; 2) $A_{13} = 6$, $A_{23} = 0.14$; 3) $A_{13} = 12$, $A_{23} = 0.14$; 4) $A_{13} = 6$, $A_{23} = 0.22$.

Fig. 4. Determination of the optimal length of the packing as a function of the degree of effectiveness of the impulse ω_a for 1) $R = 1\ P_b$; 2) $R = 1.4\ P_b$.

The character of change of the rebound velocities can be explained by the fact that in the case of a considerable length of the packing with a small dynamic stiffness in comparison with the adjacent elements, the packing participates in the collision as a semi-infinite bar. In this case the rebound velocity approaches zero, and the greater part of the energy in the impulse being formed is accounted for by the tail part of the impulse and cannot be used for driving the pile.

Thus, despite the decrease of energy losses due to rebound of the hammer, the energy of the latter in the case of a long packing is transmitted to the pile unproductively. Consequently, there should exist a form of the impulse whose structure provides the optimal use of the impact energy for driving the pile. The degree of effectiveness of the impulse established above is the quantity reflecting the structure of the impulse.

Figure 4 gives examples of a graphic determination of the optimal lengths of packings $T_{21\,(opt)}$ as a function of the degrees of effectiveness of the impulses ω_a, from which we see, in particular, that their length should be reduced with increase of soil resistance.

As is known, in addition to the packing the form of the impulse is affected by the characteristics also of other elements participating in the collisions. It goes without saying that the selection of the optimal characteristics of these elements can be done also on the basis of the degree of effectiveness of the impulse.

Thus the parameters of the impulse in the head of a long pile have a considerable influence on the effectiveness of using the impact energy of the hammer. The pile refusal in this case can be calculated on the basis of the area of the active part of the impulse of force in the pile head. With consideration of soil resistance the optimal characteristics of pile-driving equipment should be determined on the basis of the degree of effectiveness of the impulse.

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