Stresses on Piles and Walls During Pile Driving

Contraintes sollicitant les pieux pendant leur fonçage, ainsi que les murs avoisinants

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Summary

This paper deals with problems of stresses in piles and with the deformation of a wall resulting from pile driving.

An electric strain recorder was used to record simultaneously and without friction the stresses in the piles and the vibrations of the wall during pile driving.

Sommaire

Cet article traite certains aspects du problème de la sollicitation des pieux pendant le battage et de la déformation des murs avoisinants.

Un dispositif électrique permet d'enregistrer simultanément et sans frottement les sollicitations et les ébranlements transmis aux murs au cours du battage des pieux.

Stating of the Problem

Alongside a party-wall several piles were driven into a soil composed of silty sand and peat lenses. Resisting marly rock was met at a depth of approximately 7 m (Fig. 1). The piles were driven into the soil at a distance of 1.00–1.25 m from the party wall.

During pile driving two phenomena occurred:

The pile points were destroyed, cracks appeared in the concrete, the concrete crumbled over a length of approximately 80 cm.

During pile driving the party-wall suffered considerably.

After these phenomena had been ascertained, the two following questions had to be answered:

What caused the damage to the concrete?

What is the stress in the wall during pile driving?

In order to answer these questions deformation measurements were carried out on the pile and the party wall. Assuming that *Hooke*'s law is valid for dynamic vibrations of approximately 21 c.p.s. the stresses in the wall and the piles can be calculated from the measured deformation. Since the elasticity modulus E of the type of concrete used and of the wall were known, it was possible to ascertain the stress σ in the piles and on the wall during pile driving, using *Hooke*'s law of deformation. This stress is

$$\sigma = \left(\frac{\Delta l}{l}\right) \cdot E \text{ in kg/cm}^2$$

$\frac{\Delta l}{l}$ = specific deformation, measured with stress recorders, expressed in percentage

E = elasticity modulus in kg/cm².

Measuring Apparatus

For measuring the deformation of piles and walls during pile driving there were at our disposal mechanical as well as electronic strain recorders. Electric strain-gauges were chosen and preferred to the mechanical method, because the former permit the measurement and graphic recording of the deformation at four measuring points simultaneously.

The measuring equipment used was a 4-channel dynamic strain recorder, system *Kelvin* and *Hughes*. With this recorder vibrations up to 80 c.p.s. can be recorded. The recording range of deformation varies between 0.005 and 1 per cent.

The deformations are indicated by an electric recording amplifier, i.e. electric current passes through the pen and through the specially prepared recording paper. The spark discharge between pen and paper records, through burning, the graph on the paper. Since the pen is not in direct contact with the paper, no friction can occur while the movements of the pen are being recorded.

Two rows of timing dots at intervals of $^1/_{40}$ sec were recorded on the paper near the edges. The chart revolved at a speed of 5 or 15 cm/sec.

Measuring Results

Piles. The measured deformation ε is shown in Fig. 2. The measurements of the deformation (ε) and of the time (t) are also given. The measuring point was at 70 cm below the pile point.

The greatest stress was:

(1) The pile point was at a depth of 1.70 m below the ground surface. Thus

$\sigma = 100^{-1} \cdot \varepsilon \cdot E.$

The maximum deformation measured at the head of the pile was $\varepsilon = 0.067$ per cent. Concrete similar to that used for moulding piles was set for 28 days and used to ascertain the elasticity modulus of the concrete (with the aid of prismatic tensile strength) at approximately 220,000 kg/cm².

Thus the stress on the concrete was:

$\sigma = 100^{-1} \times 0.067 \times 220{,}000$

$\sigma = 147$ kg/cm².

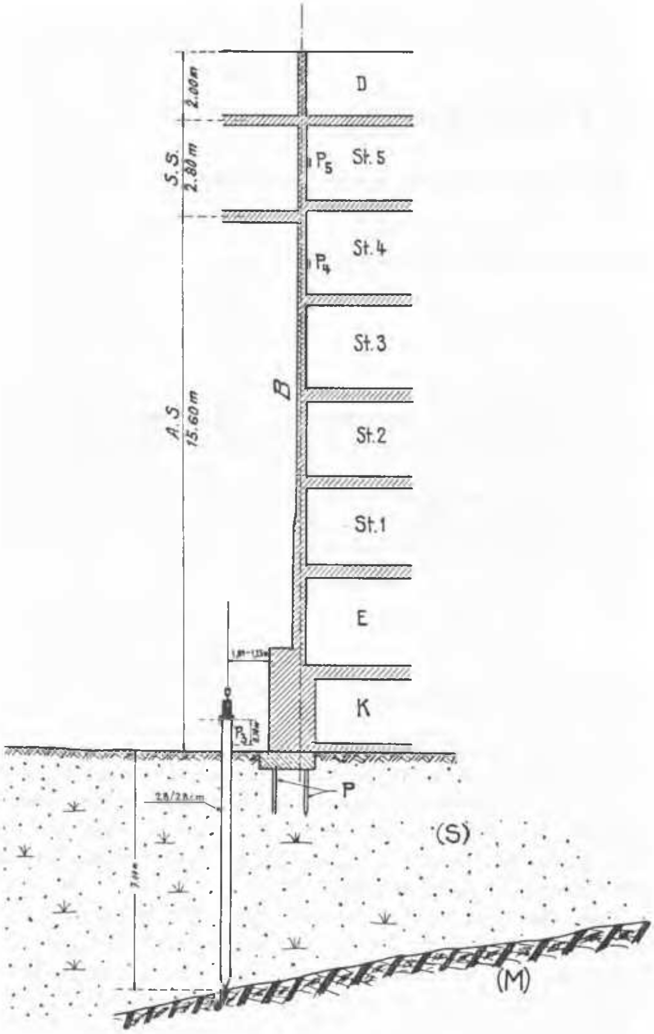

Fig. 1 M = Tertiary Sandstone and Marls (Molasse)
Grès et marne tertiaire (Molasse)
S = Silty Sand Containing Peat
Sable glaiseux avec tourbe
P = Wooden Piles; ⌀ 10–12 cm; length 1.0–1.2 m
Pilotis; ⌀ 10 à 12 cm; longueur 1,0 à 1,2 m
AS = Demolished Floors
Etages démolis
SS = Remaining Floors
Etages subsistants
K = Cellar
Cave
P_3, P_4, P_5 = Measuring Points
Points de mesurement
E = Ground Floor
Rez-de-chaussée
$St_1 – St_6$ = Floors
Etages
D = Attic
Grenier
B = Party-wall
Mur mitoyen

(2) When the pile point reached the rock level, the deformation ε of the pile head increased to 0.184 per cent. In this case the stress on the concrete was calculated as follows:

$\sigma = 100^{-1} \times 0.184 \times 220{,}000 = 405$ kg/cm².

This stress exceeds the maximum bearing capacity of the concrete.

The conclusions indicated that a minimal compressive resistance of 450 kg/cm² in the concrete was necessary for piles to be driven in without exceeding the bearing capacity.

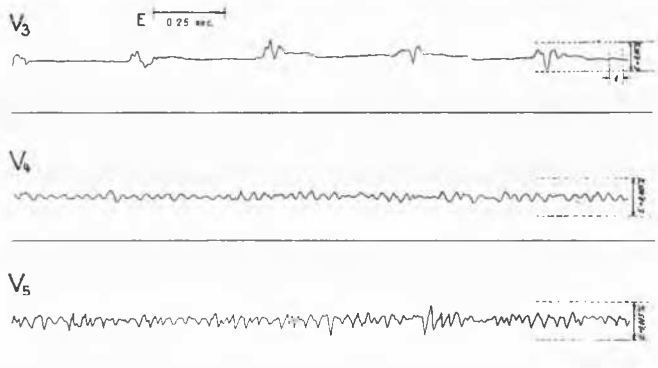

Fig. 2 Deformation of Piles and Walls During Pile Driving
Déformation de pieux et murs pendant le battage
V_5 = Deformation of the Wall on the 5th Floor; Point 5 in Fig. 1
Déformation du mur au 5^{e} étage; point 5 dans la Fig. 1
V_4 = Deformation of the Wall on the 4th Floor; Point 4 in Fig. 1
Déformation du mur au 4^{e} étage; point 4 dans la Fig. 1
V_3 = Deformation of Pile Point; Point 3 in Fig. 1
Déformation de la pointe du pieu; point 3 dans la Fig. 1
E = Time unit
Unité de temps

Wall. Next to the driving site there was a party wall (Fig. 1). The deformations of the party wall resulting from pile driving were measured on the 4th and 5th floors (measuring points P_4 and P_5 in Fig. 1).

The deformations measured on the 4th and 5th floors and those of the concrete pile are shown in Fig. 2. As a 4-channel dynamic strain recorder was available, the deformations of the wall could be measured in 4 places simultaneously.

Surprisingly, the deformation of the pile diminished immediately after driving whereas the wall remains deformed for more than half a second. The greatest deformation recorded was to $\frac{\Delta l}{l} = 0.0285$ per cent. The frequency was 21 c.p.s.

The elasticity modulus of a similar wall had been calculated in previous cases at 90,000–104,000 kg/cm². Thus, the elasticity modulus of the wall, $E_{\text{wall}} = 97{,}000$ kg/cm² was assumed. From this the stress on the wall was calculated as being:

$$\pm \sigma_{\text{wall}} = \frac{\Delta l}{l} \cdot E_{\text{wall}}$$

or

$$\pm \sigma = \pm (0.000285) \times 97{,}000 = \pm 27.6 \text{ kg/cm}^2,$$

i.e. it was deduced that the tensile strength of the wall was almost exceeded.

The extent of tensile stresses which appear after blasting was also determined. The permissible blasting load was decided upon, so that the tensile stresses in the wall did not exceed +25 kg/cm². No cracks appeared in the wall as long as only the prescribed blasting load was used; but they did appear when a larger load had been used.

Further Examples

The ventilation channel of a large cinema cracked apparently because of vibrations resulting from pile driving.

The deformation measurements of the ventilation channel clearly showed that the greatest deformation had not occurred as a result of driving, but of excavations. A bulldozer had been excavating extremely damp marly soil in the vicinity of the driving hammer.

The stress on the ventilation channel was:

resulting from driving	$\pm$ 33 kg/cm^2
resulting from rail-road traffic	$\pm$ 45 kg/cm^2
resulting from excavations	$\pm$ 22 to 67 kg/cm^2
resulting from rail-road traffic and excavations	90 kg/cm^2

Reference

Bendel, L. (1948): Ingenieurgeologie, Vol. II, Chapter: Dynamische Baugrundaufgaben, p. 563–633.