Two Pile Driving Techniques: Top and Bottom Hammering

Mahmoud Ghazavi
Associate Professor, Civil Engineering Department, K. N. Toosi University of Technology, Tehran, IRAN
ghazavi_ma@kntu.ac.ir

Gholamhossein Tavakkoli.Mehrjardi
Graduate Student, K. N. Toosi University of Technology, Tehran, Iran
E-mail address: g_tavakoli2000@ yahoo.com

]Abstract

Piled foundations with large diameters are usually used for platform foundations and other offshore structures. In these situations, piles are normally driven into the ground. This paper contributes to investigate the feasibility of bottom hammering instead of traditional top hammering. To this aim, Plaxis 7.2 software is used to simulate the pile driving phenomenon. The large diameter pile is assumed to be made of steel. The pile material is assume to be linear, elastic, and of circular cross sectional area. The soil behavior is assumed to be elasto-plastic and its failure is controlled by the Mohr-Coulomb failure criterion. The pile is driven to the ground under the same released energy either by top or bottom hammering. The results on driving stresses and sets will be presented.

Keywords : Pile driving, wave equation, top and bottom hammering, driving stress, set

1.INTRODUTION

Piles are used for platform foundations and other offshore structures where normally soft deposits are present. In these situations, piles are normally driven into the ground. Smith (1962) developed a mathematical solution to the wave equation to solve complex pile driving problems. This method has been modified and refined since then. In pile driving analysis, the driving resistance is calculated from the analysis of stress waves measured near the pile head. In the traditional top hammering, the incident wave is quickly influenced by the shaft friction wave making the evaluation of driving resistance difficult. A new technique to drive tubular piles by an impact hammer inside the pile has been developed and tested in France by some contractors. According to Arentsen et al. (1996), this new technique has confirmed by performing field tests, resulting in the reduction of noise $(20-30dBA)$ and the opportunity to save steel. Also, a reduction in driving time and a higher bearing capacity has been observed during a test program upon using this technique.

In this paper, a numerical solution has been used to drive a steel tubular pile by the two techniques: top hammering and bottom hammering. The results of the two driving techniques are compared and some advantages are described.

2.DESCRIPTION OF FINITE ELEMENT MODEL

Soil and Pile Properties, Loading

The pile driving analysis is modeled by means of an axisymmetric finite element model in which the pile is located around the axis of symmetry and the analysis is done using Plaxis 7.2 software. A closed-ended tubular steel pile has been used with two centimeters thickness and 10 meters length and outer diameter of the pile is 1.02 meter. A saturated sand layer which is modeled according to the simple Mohr-Coulomb failure criterion. An air like material for inside of pile has been used as a blank area. The parameters of sand layer, pile, and air are listed in Table 1.

Table 1. Material Properties of Subsoil and Pile

Parameter	Young's Modulus (E, kPa)	Poisson's Ratio (υ)	Cohesion (C, kPa)	Friction Angle (ϕ, degree)	Weight ($\gamma, kN/m^3$)
Sand	10000	0.3	1	31	17
Pile	2.1E8	0.2	-----	-----	64
Air	0.01	0.499	-----	-----	0.012

The analysis is performed in three phases: placement of pile into the subsoil, applying dynamic load, and unloading

The typical time-force signals (half sinusoidal wave) recorded during pile driving at top and toe of pile is used for this analysis. Unlike the top hammering where the initial stress wave is of compression and propagates from the pile head to the tip, in the down-the-hole driving the initial wave at the pile tip is of tension and propagates upwards to the top. The initial tension wave interacts first with the soil near the pile tip. The main difference between the two driving techniques is that top piling pushes the pile into the soil (compression stress wave and positive Poisson effect) while down-the-hole driving pulls the pile down (tension stress wave and negative Poisson effect). The negative Poisson effect must be more remarkable for thin piles.

In classical pile driving, the shaft friction is first mobilized at the pile-soil interface, leading to a subsequent disturbance of the surrounding soil. The initial compression wave travels downwards to the pile tip (Fig.1). The soil layer is then compressed creating a high stress field around the pile and an increase in shaft resistance is observed. In bottom driving method, the tip resistance is first mobilized and the initial tension wave travels upwards toward the pile top (Fig.2). The energy transfer from the pile to the soil is made through the tension wave transmitted and reflected at the pile tip.

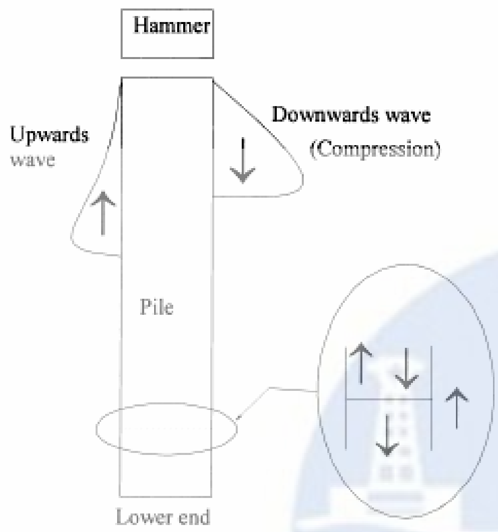

Fig.1. Wave propagation in top driving

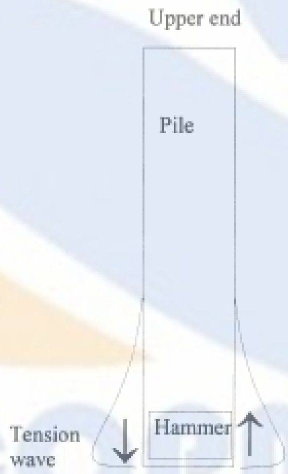

Fig.2. Wave propagation in bottom driving

3. RESULTS AND DISCUSSION

3.1. Penetration

Fig.3 shows pile tip penetration under bottom hammering and top hammering versus dynamic time for a single blow. It can be seen that the pile penetration under the bottom hammering is more than that of top hammering. In the top pile driving, the hammer pushes the pile into the soil, allowing a compression stress wave and the Poisson ratio is positive at this state due to the shaft expansion. Therefore, the interaction at the pile-soil interface increases. In bottom driving, the hammer pulls the pile down creating a tension stress wave and the Poisson ratio becomes negative due to the pile extensibility.

Consequently the interaction at the pile-soil interface decreases and the pile moves down more easily.

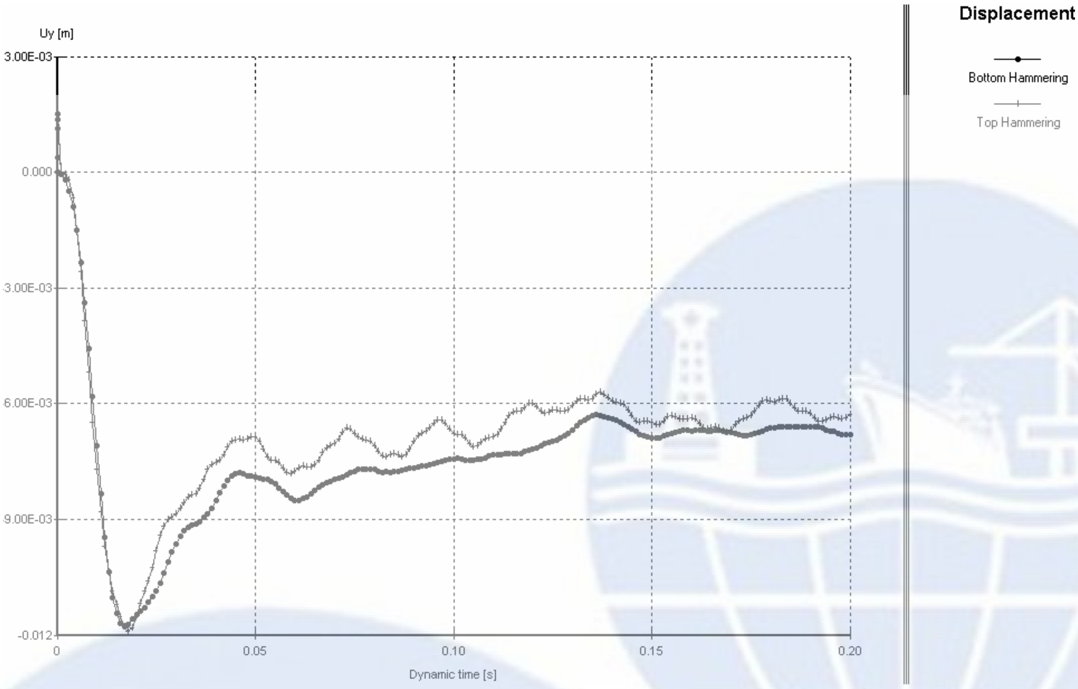

Fig.3. Comparison of pile tip penetration in two piling techniques

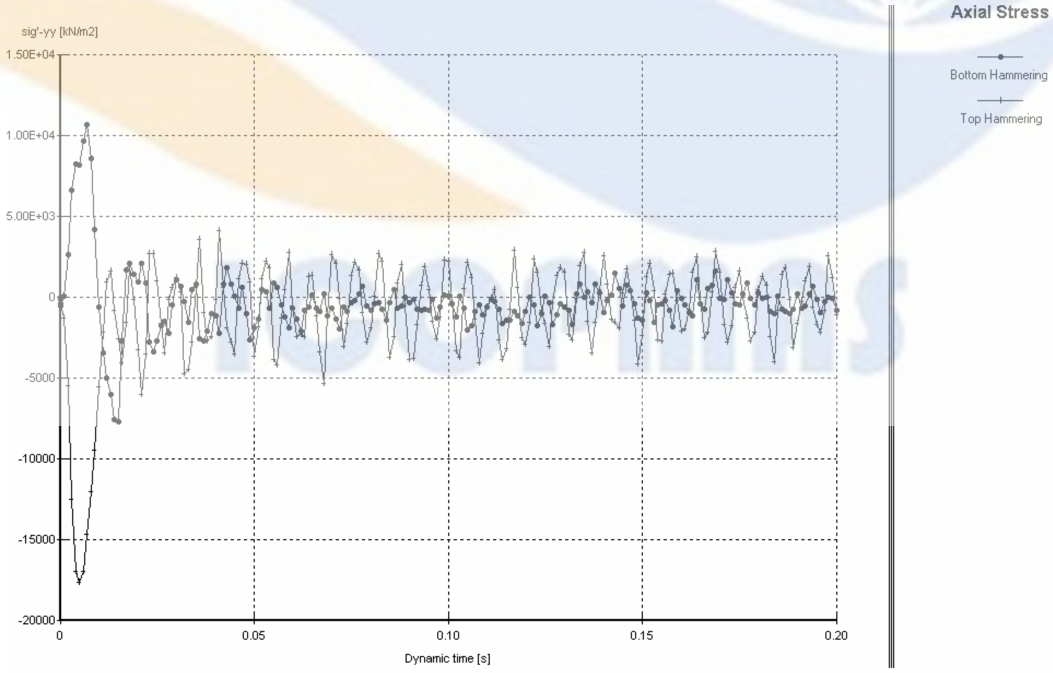

Fig.4. Axial stress at the middle of pile in two piling ways

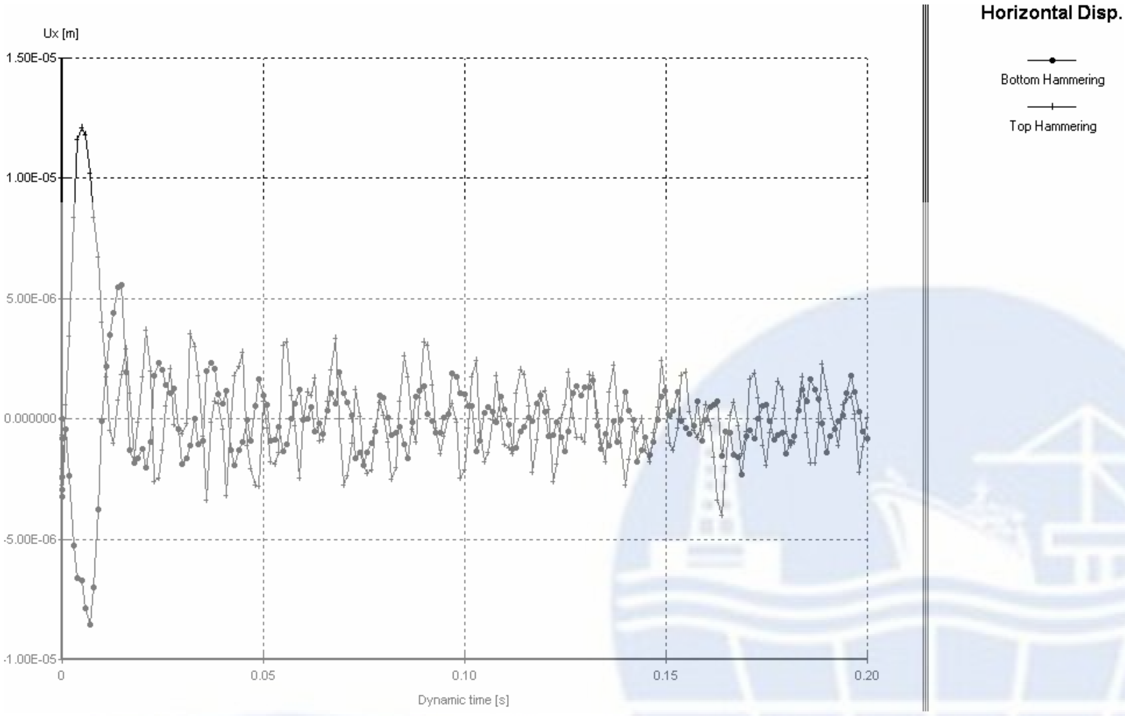

Fig.5. Horizontal deflection at the middle of pile

3.2. Stress Wave Propagation

Fig.4 illustrates driving stress in the mid-height of pile under both hammering locations versus dynamic time. It is observed that the compression stress is produced under top hammering whereas the tension stress is produced under the bottom hammering. Indeed, the main difference between the two driving techniques is that top hammering pushes the pile into the soil, whereas the bottom hammering pulls the pile down. Moreover, the axial stress under top hammering is more than the axial stress under bottom hammering. I addition, the gravity center of the pile and hammer system is much lower, and thus the pile stability during driving is enhanced. As a result, the likelihood of pile buckling during driving decreases. Furthermore, the pile thickness is reduced.

3.3. Horizontal Deflection

Fig.5 shows the horizontal deflection at the middle of pile in both driving types. It is seen that the pile is expanded under the compression wave in top hammering and gets slender under the tension wave in bottom hammering.

3.4 OTHER ADVANTAGES

It is obvious that in bottom hammering, the noise associated with pile driving decreases. Moreover, the safety increases for work forces. In addition, with the same driving energy, in top hammering, the stress amplitudes and the unit friction increase compared with the case of are more important because of the densification of the sand around the pile upon driving. This is more pronounced in dense sand where hard pile driving is encountered. In top hammering, the penetration of the pile decreases due to greater interaction between the pile and soil at their interface. In bottom hammering, besides a reduction in driving time, reduction in driving energy, reduction of the possibility of pile buckling, and obvious reduction in noise, which are all advantageous, designers may be allowed to choose thinner walls for steel piles, resulting in savings time and costs.

4. CONCLUSION

The performed numerical study aims to compare top and bottom hammering in driving large diameter steel piles. The numerical results show that the driving stresses change from compression to tension and tensile stress magnitudes are also less than compressive stresses. The permanent displacement of the pile (set) also increases. It is necessary to perform field tests and more analyses to generalize the findings in this paper.

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