Comparative Study of Static and Dynamic Piles Load Tests Carried Out in Different Testing Sites in Vilnius City

Kęstutis Tumosa¹, Vaidas Martinkus²

¹*Vilniaus Rentinys, JSC, Vilnius, Lithuania*

²*Department of Geotechnical engineering, Faculty of Civil engineering,
Vilnius Gediminas Technical University, Vilnius, Lithuania*

E-mails: ¹konstruktoriai@rentinys.lt; ²vaidas.martinkus@vgtu.lt (corresponding author)

Abstract. The current paper presents experimental results and analysis of static and dynamic load tests carried out in different undergoing construction sites in Vilnius city. The piles testing procedures, used equipment, as well as geological condition are presented and discussed. Furthermore, the conclusions of feasibility of used pile testing technique in particular testing sites are given.

Keywords: static, dynamic, load test, pile, CFA, displacement pile, sand.

Conference topic: Case studies.

Introduction

A notable increase in demand of premium class multi-storey commercial and residential building has been noticed recently in Vilnius city. As a consequence, this tendency increases piles testing demand, which results in a considerable amount of expenses necessary for buildings' geotechnical part. Another trend is related with growing demand in shortening of buildings' construction time. Under these circumstances, the Static load test (SLT) as a pile bearing capacity determination technique lacks of economy and time consumption efficiency, therefore, the Dynamic load test (DLT) starts to be more often applied in order to reduce the mentioned shortcomings of SLT.

Fig. 1. Location of the testing sites in the centre of Vilnius city

Due to lack of local experience in DLT application, the comparative study was performed on the basis of SLT and DLT data of two undergoing construction sites in Vilnius city.

34.5 m height A class commercial purpose building which has 32500 m² usable floor area (named as 1st testing site) is located in Konstitucijos avenue no. 29 (location in the city see Fig. 1). Building consists of in situ reinforced concrete (RC) columns, pre-stressed in situ RC slabs and in situ RC bracing cores. A continuous flight auger (CFA) point bearing piles were chosen as the most rational foundation type due to high underground water level and vibration free requirement determined by neighbouring urbanised territory. Another 5 storey residential buildings complex which has 45000 m² usable floor area (named as 2nd testing site) is located in Linkmenų street no. 29 (see Fig. 1). Buildings consist of in situ RC columns, pre-cast RC slabs and brick bracing walls. A displacement point bearing piles were chosen to transmit the loads of buildings to the bearing stratum due to high underground water level and higher reliability as well as economic efficiency in comparison with CFA piles.

Piles testing procedures

In the 1st testing site three SLT for 0.6 m width and variable length 7.0–9.0 m (see Fig. 2a–2c) piles were carried out, afterwards the same piles were tested using DLT. In the 2nd testing site one SLT for 0.33 m width and 11.05 m length (see Fig. 2d) pile was performed, afterwards the same pile was tested using DLT.

Geological condition

From geomorphology point of view both testing sites are on the terrace above the floodplain of right shore of the

Neris river. A good location of discussed area is the reason why it is covered by various thickness technogenic soil layers. It should be mentioned, that in testing site 2 the thick organic deposit and peat layer was met at shallow depth. The deeper layers consist of medium dense and dense silica sands which were chosen as a bearing stratum for deep foundation. A detail description of 1st testing site geological condition see Figure 2a–2c, and of 2nd testing site see Figure 2d.

Fig. 2. Cone penetration tests and boreholes data of a) 1st testing site pile No.K29-1, b) 1st testing site pile No.K29-2, c) 1st testing site pile No.K29-3, d) 2nd testing site pile No.L29-1

The water table, which varies from 0.7 to 6.2 m below ground level, was ascertained using borehole observation method.

Static load test program

Principal scheme of SLT is given in Figure 3. The hydraulic jack with hinged top was used for the experiments in order to eliminate an eccentric loading impact. For the measurement of vertical displacements two perpendicular linear pot indicators were used, which were attached to an independent reference beam. The supporting beam with connected anchoring piles were used as the rest of the hydraulic jack. For the adjustment of loading, supporting and measuring systems the primary loading up to 5% of a total testing load was used, afterward it was reduced up to 10 kN, then the displacement indicators were set to zero readings. The loading was performed in 6 loading and 3 unloading steps.

Load maintenance duration was adopted from one of these criterion depending on which one of them is reached the last:

- 60 min;
- 0.2 mm per 20 min;
- settlement equal to 10% of pile diameter.

Fig. 3. Principal scheme of static load test

Two times larger than the maximum serviceability limit state load was adopted as the total testing load. For the case of 1st testing site's piles No.K29-1–K29-3 it was equal to 2250 kN, and for the case of 2nd testing site's pile No.L29-1 testing load adopted 780 kN. The duration between installation and piles testing was at least 28 days.

Dynamic load test program

Principal scheme of DLT is given in Figure 4. Portable dynamic loading frame with 21 kN weight was used for the tests. The frame has adjustable height system which enables to generate a necessary amount of energy for most common cases. For the measurement of the residual vertical displacements a theodolite was used, which was placed in more than 10 m distance from the vicinity axis of tested piles. The 0.025 m thickness pad made of oak was used in order to increase the efficiency of dynamic loading. For the case of 1st testing site's piles No.K29-1–K29-3 the falling height was set to 1.55 m, and for the case of 2nd testing site's pile No.L29-1 it was set to 1.38 m.

Driving formula

The approach proposed by Hiley (1925) was adopted for the interpretation of DLT data (as one of the most acknowledged and often applied for end bearing piles (Likins *et al.* 2012)):

$$R = \frac{(\alpha Wh)\eta}{(S + (C_1 + C_2 + C_3)/2)}, \quad (1)$$

Fig. 4. Principal scheme of dynamic load test

where: R – ultimate driving resistance; α – hammer fall efficiency; W – weight of hammer ram; h – height of fall; η – efficiency of blow; S – residual displacement per blow; C_1 – temporary compression of dolly or pad; C_2 – temporary compression of pile; C_3 – temporary compression of bearing stratum.

Hammer fall efficiency factor α equal to 1 was adopted for the free falling weight. The efficiency of blow η when $W > P$ was estimated using following relation (Hiley 1925):

$$\eta = \frac{(W + Pe^2)}{(W + P)}, \quad (2)$$

where: P – pile weight; e – coefficient of restitution of the materials under impact (adopted 0.4 according to Civil engineering code of practice No. 4 U.D.C. 624.15) (The Institution of Civil Engineers 1954).

When $W < P$ the efficiency of blow was equal to (Hiley 1925):

$$\eta = \frac{(W + Pe^2)}{(W + P)} - \frac{(W - Pe)^2}{(W + P)}. \quad (3)$$

Temporary compressions of pad C_1 , pile C_2 and bearing stratum C_3 were adopted according to Civil engineering code of practice No. 4 U.D.C. 624.15 depending on hardness of driving.

Results and discussion

According to British standard BS 8004:1986 the resistance to driving of a pile can be determined from the kinetic energy of the driving hammer and the movement of the pile under a blow, furthermore the resistance to driving is equal to the ultimate bearing capacity for static loads. According to these assumptions the comparative graphs of SLT and DLT can be presented.

The SLT of pile No.K29-1 (see Fig. 5) showed that the ultimate load (assumed static vertical force measured when pile's head displacement reached 10% of pile di-

ameter D) was equal to 2060 kN. The ultimate load determined using DLT was 9.6% lower and was equal to 1880 kN. Determined correlation is in good agreement with BS 8004:1986 standard which defines that driving formulae should give a calculated result within the range of 40% to 130% of the ultimate bearing capacity that would be determined by SLT.

During the SLT of pile No.K29-2 (see Fig. 6) the relative displacement equal to 0.1D was not reached. The maximum load determined during SLT at 10.4 mm head's vertical displacement was equal to 1830 kN. The ultimate load determined using DLT was equal to 1880 kN.

According to the SLT of pile No.K29-3 (see Fig. 7) the ultimate load determined was equal to 1160 kN. The ultimate load obtained from DLT was 1.6% higher and was equal to 1179 kN.

Fig. 5. Graphs of SLT and DLT of pile No.K29-1

Fig. 6. Graphs of SLT and DLT of pile No.K29-2

Fig. 7. Graphs of SLT and DLT of pile No.K29-3

Fig. 8. Graphs of SLT and DLT of pile No.L29-1

During the SLT of pile No.L29-1 (see Fig. 8) the relative ultimate phase was not reached. The maximum load determined during SLT at 12.7 mm head's displacement was equal to 787 kN. The ultimate load determined using DLT was equal to 918 kN.

Conclusions

Despite the existing controversy in using the pile driving formula (Likins *et al.* 2012), the obtained SLT and DLT results of piles No.K29-1 and K29-3 were in good agreement for this particular case and varied from 1.6 to 9.6%.

Even though the development of Lithuanian comparative database of SLT and DLT should be carried on, moreover, the stress wave theory based pile testing methods should be considered for future investigations.

References

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