Estimation of Long Term Pile Capacity from Results of Short Term Pile Load Tests.

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Abstract

This paper presents results of a study on a method to estimate long term capacity of piles from results of short term pile load tests. In the study, dynamic pile load tests at initial driving, 1 min, 10 min, 120 min, 1 day, and 14 days were carried out at 27 sites distributed in the Bangkok and Metropolitan area. All tested piles were pre-stressed concrete I-shaped piles. The results of this study revealed that 1) increment of pile capacities with time is not a linear function of the logarithmic of time, as proposed by Skov and Denver (1988), 2) Lower bound pile capacity at 14 days is 1.3 times that at 2 hours, and 3) Pile capacity at 14 days (P14 days) can be estimated from pile capacities at 1 minute (P1 min) and 120 minutes (P120 min) by using the equation proposed in this report.

Keywords: *Pile set-up, Driven Pile, Bangkok Sub soil, Clay*

1. Introduction

Pile set-up is a phenomenon in which the pile capacity increases with elapsed time since the end of the installation. When a pile is driven into the ground, the soil around it gets disturbed. After it recovers from the disturbance, there is often an increase in pile capacity with time. In standard practice, there must be a waiting period of 2 weeks to one month before any pile capacity testing can be carried out, which causes a construction delay. Moreover, if the pile test result indicates that the capacity of the tested pile is less than that required, a rectification process must be applied, which leads to further construction delay and a waste of money. To avoid these problems, this study aims at developing a method to aid in estimating the long term pile capacity from the short term test results.

2. Objectives

The objective of this research is to study how to accurately obtain long term pile capacity from the results of the pile load test at initial driving.

3. Materials and Methods

This research was conducted according to the flow chart shown in Figure 1. The research started by conducting dynamic pile load tests at initial driving, 1 min, 10 min, 120 min, 1 day, and 14 days. The tests were carried out at 27 sites distributed in the Bangkok and Metropolitan area. The Bangkok and Metropolitan area is subdivided into three zones, namely; East, West, and Central Zones, as shown in Figure 3. The typical soil profile in Bangkok and Metropolitan consists of a soft clay layer that is 15 to 20 meters thick underlain by a stiff clay layer which is 5 to 10 meters thick and at the bottom of the stiff clay layer, there is a medium dense sand layer (see Figure 2). The soil conditions in each zone are slightly different. In the East Zone, the soft clay layer is thickest and softest, while in the Central Zone, the soft clay layer is thinner and relatively stronger than the other zones. Table 1 shows the number of sites tested in each zone.

Furthermore, all tested piles in this study were 0.22x0.22 m I-shaped pre-stressed concrete piles, which were designed to carry a safe load of 150 kN. The lengths of the piles varied from about 16-25 meters, and most of the pile tips were embedded in the stiff clay layer, while some were sitting on the medium dense sand layer.

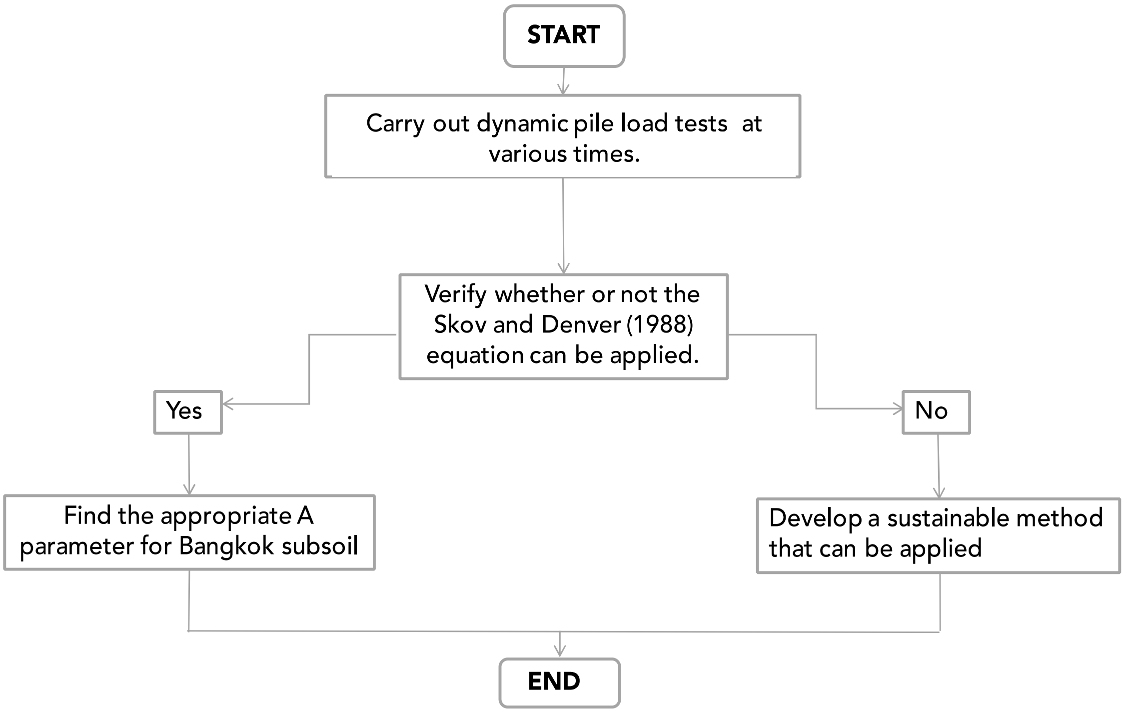

Figure 2 Zoning of Bangkok and Metropolitan

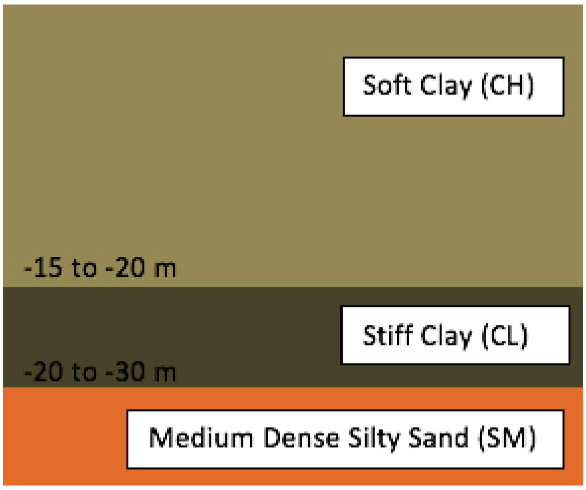

Figure 3 Typical soil profile in Bangkok and Metropolitan area

Table 1 Number of tested sites in each zone

Zone	Number of Sites
East	12
West	8
Central	7

4. Results and Discussion

The results of the dynamic pile load tests are presented in Figures 1, 2, and 3 for East, West, and Central Zones, respectively. In the figures, ratios of pile capacity at various times (Pt) to capacity at 1 minute (P 1 min.) were plotted against logarithmic of times. The results revealed that 1) Pile capacity does not linearly increase with the logarithmic of time. As a result, the equation of Skov and Denver (1988) cannot be applied. 2) In all the zones, the increments of pile capacity with time are quite scattered. It was found that after driving the piles for 14 days, pile capacities increase about 1.5 to 4 times. However, test pile No. E8 in the East zone showed an extreme result where the increment was about 6 times.

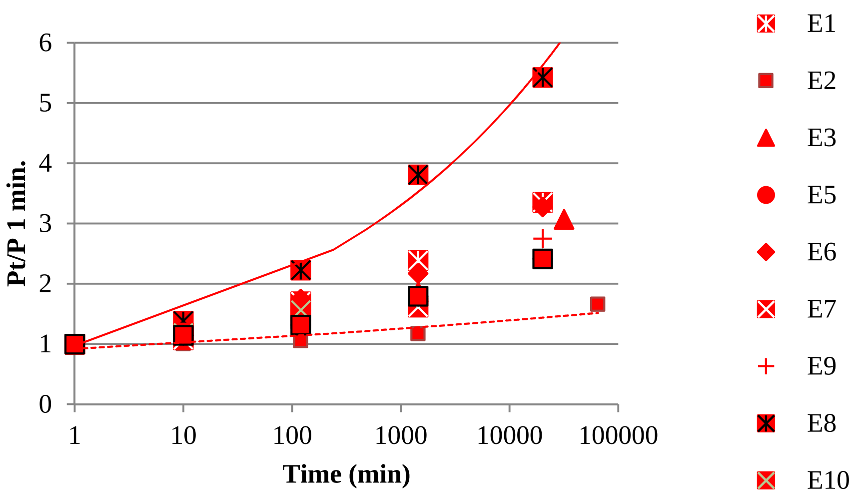

Figure 1 Pt/P1min Vs Log. Time (East)

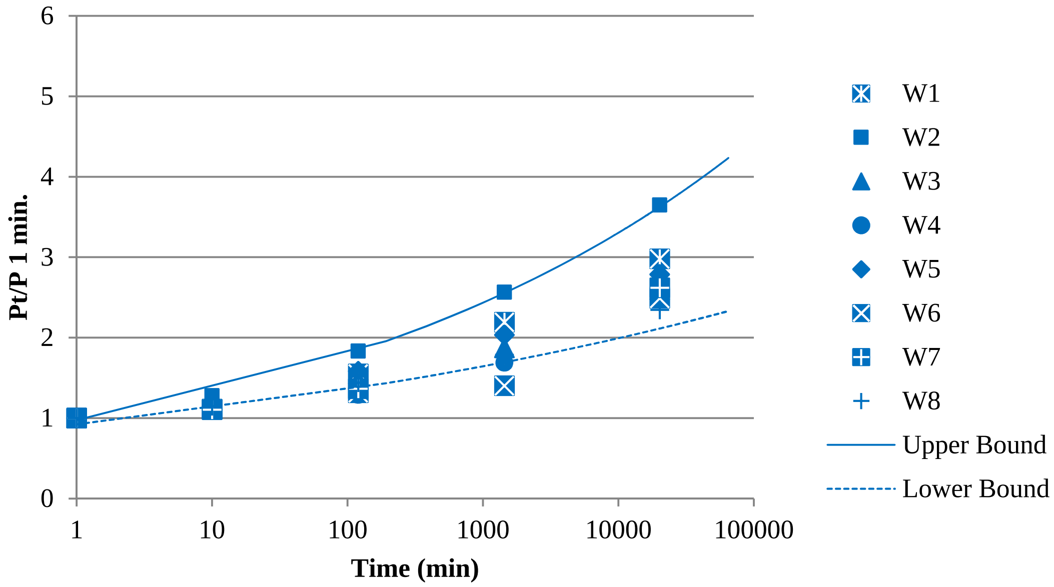

Figure 2 Pt/P1min Vs Log. Time (West)

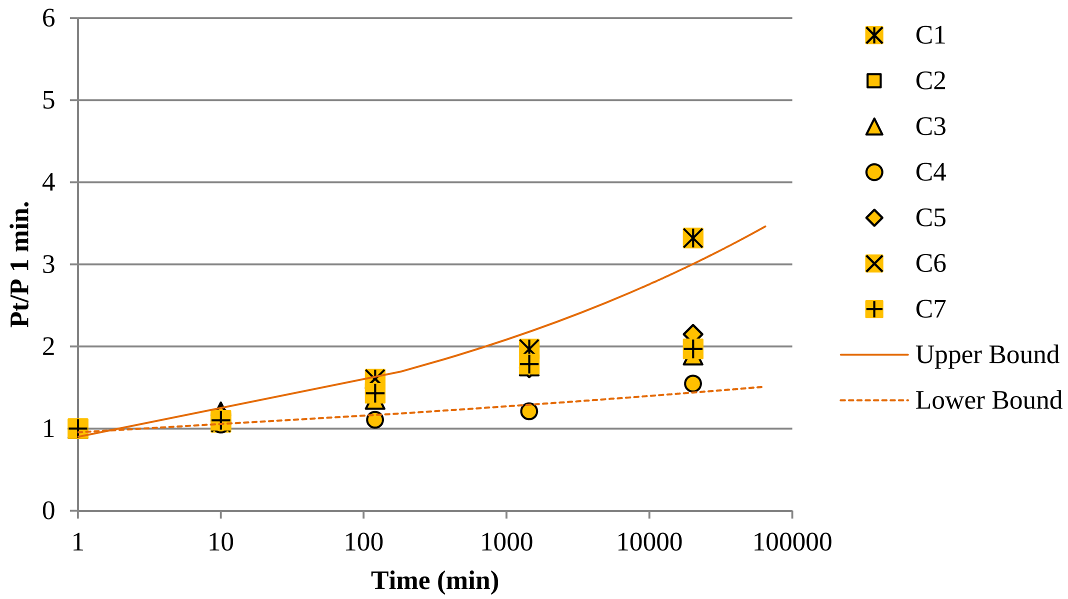

Figure 3 Pt/P1min Vs. Log. Time (Central)

The above results demonstrate that it is not good to use results of pile load tests at 1-minute reference time for estimating capacities at 14 days since the scattering of the outcome is very large. Therefore, the use of reference times other than 1 minute was explored in this study. Ratios of pile capacities at 14 days ($P_{14\ days}$) to capacities at reference times of 1 minute ($P_{1\ min}$), 10 minutes ($P_{10\ min}$), 120 minutes ($P_{120\ min}$), and at 1 day ($P_{1\ day}$) were plotted against reference times as shown in Fig. 5.4. The results are also summarized in Table 2 in terms of the average (Av. Ratio), the standard deviation (SD.), the coefficient of variation (COV), and the magnitude of average ratios minus two standard deviations (Av-2SD) which cover 97% confident level. The results reveal that the COVs of the ratios significantly decrease with increasing reference time up to 120 minutes. In other words, scattering of the ratios decreases as reference time increases up to 120 minutes. This finding suggests that a reference time of 120 minutes should be the optimum one since the scattering of the results is small, and the waiting period does not cause significant delay.

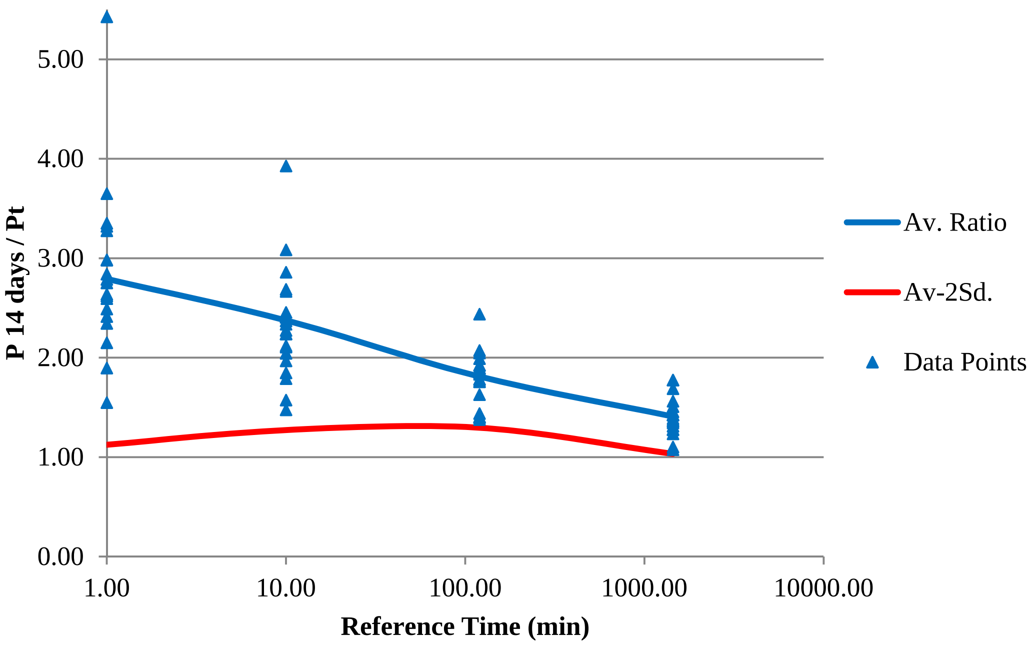

Figure 4 Relationship $P_{14\ days}$/ Pt ratios and reference time

Table 2 Ratios of pile capacity at 14 days to those at various times

	Av. Ratio	SD	COV	Av-2SD
$P_{14\ days}/ P_i$	3.15	0.99	0.31	1.18
$P_{14\ days} / P_{1\ min}$.	2.79	0.83	0.30	1.12
$P_{14\ days} / P_{10\ min.}$	2.38	0.55	0.23	1.27
$P_{14\ days} / P_{120\ min.}$	1.81	0.26	0.14	1.30
$P_{14\ days} / P_{1\ day}$	1.41	0.19	0.13	1.03

An alternative method to estimate capacities at 14 days was also explored in this study. The concept of this method was based on the assumption that there should be a strong relationship among ratios of pile capacities carried out at different elapsed times after driving (Augustesen, 2005; Clausen, 2000). Therefore, two load tests carried out at two different reference times, P_{T1} and $P_{T2,}$ can be used to predict pile capacity at 14 days provided that the relationship between $P_{14\ day}/P_{T1}$ andP_{T2}/P_{T1} is known. To demonstrate how this concept works, graphs of $P_{14\ days} / P_{1\ min}$ versus $P_{10\ min} / P_{1\ min,}$ $P_{14\ days} / P_{1\ min}$ versus $P_{120\ min} / P_{1\ min}$ and$P_{14\ days} / P_{1\ min}$ versus $P_{1\ day} / P_{1\ min}$ are presented in Figure 5.5, 5.6 and 5.7 respectively. In each graph, the trend line and the lower bound line are also included. Moreover, in each graph, the line predicted using Skov and Denver (1988) equation is also presented. The equation of $P_{14\ days}$ / $P_{1\ min}$ as a function of $P_{14\ days}$ / P_t derived based upon Skov and Denver's (1988) equation is shown in Equation 1. The equations for times t equal to 10 minutes, 120 minutes, and 1 day are Equation. 2, 3, and 4, respectively.

$$\frac{P_{14\,days}}{P_{1\,min}} = \frac{log(14x24x60)}{log(t)}\left(\frac{P_t}{P_{1\,min}} - 1\right) + 1 \quad (1)$$

$$\frac{P_{14\,days}}{P_{1\,min}} = 4.304\left(\frac{P_{10\,min}}{P_{1\,min}} - 1\right) + 1 \quad (2)$$

$$\frac{P_{14\,days}}{P_{1\,min}} = 2.070\left(\frac{P_{120\,min}}{P_{1\,min}} - 1\right) + 1 \quad (3)$$

$$\frac{P_{14\,days}}{P_{1\,min}} = 1.363\left(\frac{P_{1day}}{P_{1\,min}} - 1\right) + 1 \quad (4)$$

Figure. 5 to 7 show that the R^2values of the trend lines increase from 0.418 to 0.875 as the second test time increases from 10 minutes to one day. In other words, the closer the second test time is to 14 days, the better the prediction power. If the second test is carried out at 1 day, the lower bound line is very close to the line predicted using the Skov and Denver (1988) equation. However, in practice point of view, T2 of 120 minutes seems to be more appropriate since the test process can be completed, and engineers can decide whether the capacity of the test pile is acceptable or not in just two hours. Moreover, the R^2 of the trend line is 0.855, which is not much different from that of 1 day. The lower bound capacity of the pile at 14 days (P_{14}) can be computed from pile capacities tested at 1 minute ($P_{1\ min}$) and 120 minutes ($P_{120\ min}$) by using the following equation.

$$\frac{P_{14\,days}}{P_{1\,min}} = -17.02\left(\frac{P_{120\,min}}{P_{1\,min}}\right)^2 + 45.97\left(\frac{P_{120\,min}}{P_{1\,min}}\right) - 28.13 \quad (5\text{-}5)$$

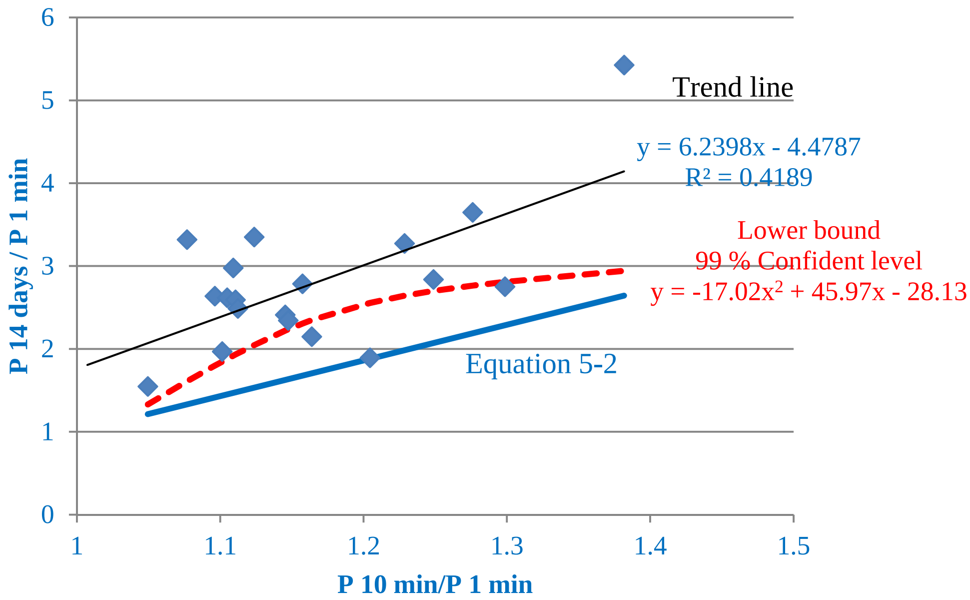

Figure 5 Relationship between $P_{14\ days}$/ P_{1min} and $P_{10\ min}$/P_{1min}

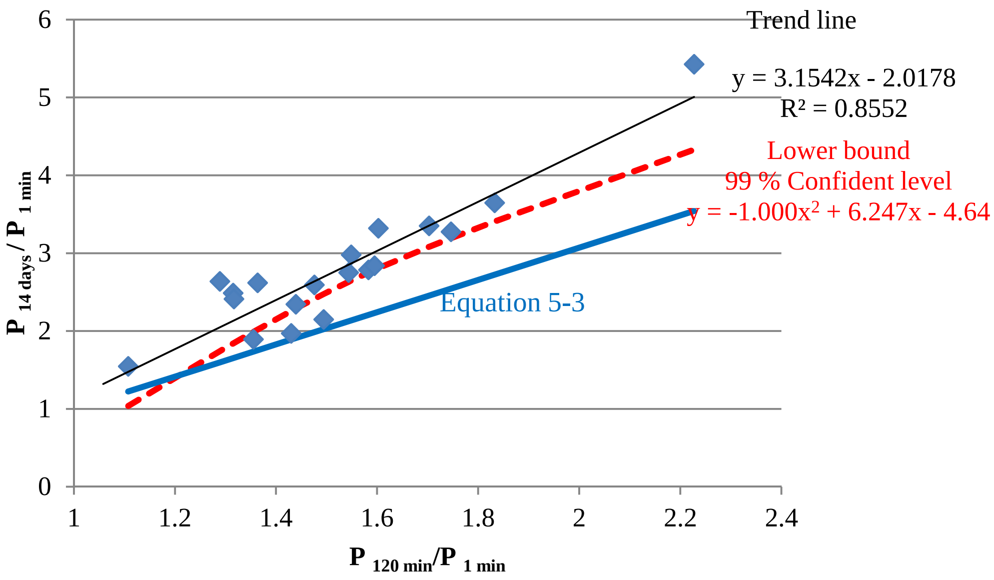

Figure 6 Relationship between $P_{14\ days}/P_{1min}$ and $P_{120\ min}/P_{1min}$

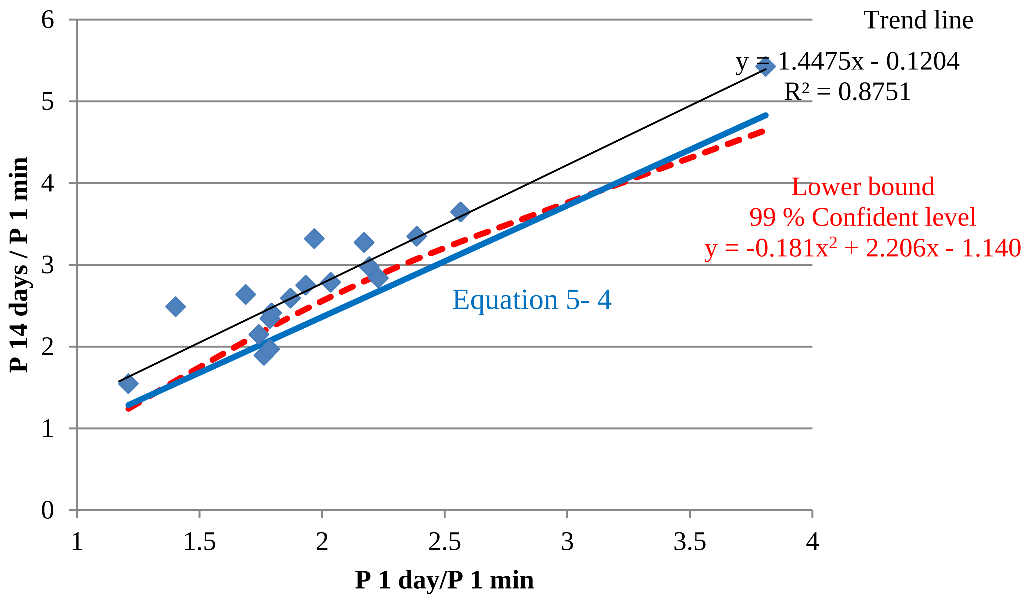

Figure 7 Relationship between $P_{14\ days}/P_{1min}$ and $P_{1\ day}/P_{1min}$

5. Conclusions

The conclusions drawn from this research are as follows:

1. Increment of pile capacities with time is not a linear function of the logarithmic of time.
2. Lower bound pile capacity at 14 days is 1.3 times that at 2 hours.
3. Alternatively, lower bound Pile capacity at 14 days ($P_{14\ days}$) can be estimated from pile capacities tasted at 1 minute ($P_{1\ min}$) and 120 minutes ($P_{120\ min}$) by using the following equation.

$$\frac{P_{14\ days}}{P_{1\ min}} = -17.02\left(\frac{P_{120\ min}}{P_{1\ min}}\right)^2 + 45.97\left(\frac{P_{120\ min}}{P_{1\ min}}\right) - 28.13$$

6. Acknowledgements

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7. References

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