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A New Proposal for Adjusting the Load-Settlement and Ultimate Load Using the Logistic Adjustment

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Abstract

The subsoil of the city of Recife is heterogeneous with deposits of soft soil scattered over the plain of the city at least 50% of its extension. In addition to layers of soft materials, stratigraphic profiles containing shells, coral fragments, sands and silts are found. Due to this heterogeneity of the subsoil profile and the real state increase, there was a considerable increase in constructions associated with land with low resistance. This fact favors the use of different types of foundation for each type of construction/terrain. The present work aims to propose a logistic adjustment developed by Verhulst, to be used as an adjustment of the load-settlement curve and to obtain the rupture load from static load tests. In order to validate the proposal, data from an infrastructure construction executed in Recife-PE, Brazil, with 822 laminated metallic piles in soft soil with low bearing capacity, considering the subsoil characterization tests (Standard Penetration Test), six static load tests (SLT) and nine dynamic load tests (DLT). The adjustment of the load-settlement curve obtained by the proposal shows that the load capacity values are very close to those measured by the DLT, while the average of the rupture loads obtained by the Van Der Veen method is double that found by the DLT; and coefficient of variation seven times greater. It is the first time that the Logistic Adjustment is used for applications in foundations and the proposal is very promising.

Keywords: Soft Soil; Building Foundation; Piles; Logistic Growth.

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1. Introduction

The land on the coastal plain of the city of Recife, located in the northeast of Brazil, originated from sediments brought in, mainly by the action of the sea and rivers. The soil has shells, silts and other types of materials, but there is a predominance of soft organic clayey soils, generally saturated due to the low altitude in relation to sea level. Recife has the second smallest urban area among the capitals of Brazilian states and a population that grows significantly, mainly due to the economic development of the state of Pernambuco. These facts led to the execution of increasingly slender buildings in soils with lower load capacity and high compactness, as the city has reduced space, the solution found for the number of inhabitants is the verticalization of buildings [1].The author in [2] explains that the city was formed by a series of geological events, the most influential being the transgressions and regressions marines, illustrated in Figure 1.

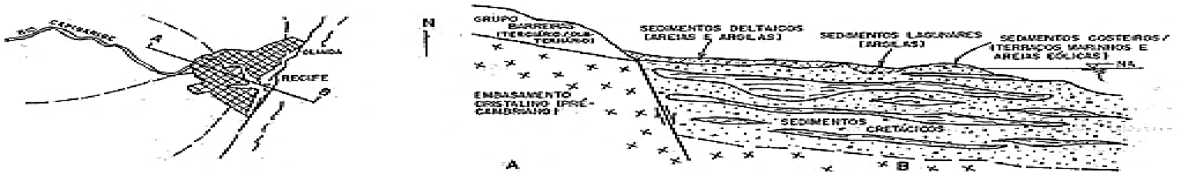

Figure 1: Geological events forming Recife [2]

The urban expansion of the city has caused a rapid shortage of locations with highly resistant soils. For this reason, constructions are performed on deposits of organic clays, using metallic piles and/or concrete piles in the foundations. Table 1 presents the stratigraphic column of the city of Recife, elaborated by the author in [3].

Table 1: Stratigraphic column of the sedimentary plain of Recife [3]

Width (m)	Convention	Material
0 - 20	::::::::::: - - - - - - - - - :::::::::::	Sand and recent consolidated clays, of fluvial origin – Deltaica, from mangroves, landfills or Dunes.
10 - 30	= = = = = = = ::::::::::;;;;;;; ::::::::::	Clays and Silts with sandy lenses of variegated colors predominating yellow and red – Barreiras Group – Plio – Plestocene.
4 - 80	= = = = = = = :::::::::: ####### :::::::::: :::::::::: ####### ::=:=:=:	Sand or sandstone with shell fragments, calciferous cement or not, with clayey lenses, grayish or yellow color with layers of limestone or calcarenite or even marl. Contains generally salty or brackish water – Gramane Formation, Litoranea Facies – Maestrichitiano
10 - 30	::::::::::;;;;;;; :::::::::: = = = = = = =	Grayish and greenish colored silts and clays with sandy lenses – Beberide Formation, Fáceis Lagunar.
50 - 200	::::::::: ::::::::: :::::::::	Sandstone of greyish color, well selected, presenting itself as friable or well consolidated, contains fresh water, being the best aquifer of the sandy sequence - Beberide Formation, Fáceis Fluvial - Santoniano.
	)})})})}	Crystalline basement – Cataclasites

In the last 15 years there has been an increase in the use of metallic piles as a deep foundation solution in the city, as can be seen in Figure 2 [4]. This type of foundation has 2 resistance parcels as geotechnical load capacity (Qu), namely: lateral friction resistance (Rl) and tip resistance (Rp). For the experimental determination of these 2 resistances, can be used 2 tests: Static Load Test (SLT) or Dynamic Load Test (DLT).

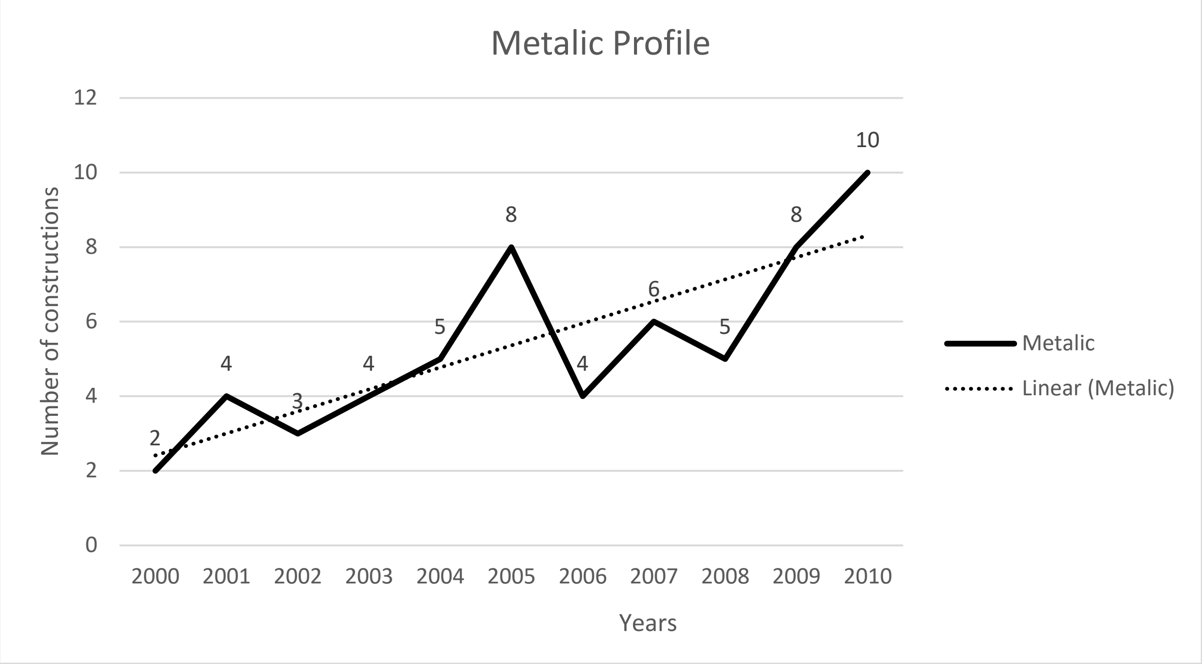

Figure 2: Increase in the number of constructions performed with metallic piles in Recife [4], adapted from [5] and [6]

2. Review and Discussion About Static Load Test (SLT)

The deep foundation system is composed of the piles (vertical element) and the foundation blocks and straps. In practice, the project designed by neglecting the portion of load that is transferred to the ground by the blocks and straps, assuming that all the load is dissipated by the piles in the form of resistance along the pile body, called the shaft, and at the tip of the pile. The resistance at the pile body is of a frictional and shear nature, and the tip resistance is of a compressive nature.

Static load tests (SLT) are used to evaluate the performance of an isolated pile, and it works applying load at the top of the pile where the settlements are also measured at the top. As the loads are applied, the system deforms, with very low speed but not zero, until the applied load is resisted by the ground (by friction of the shaft, or by compression at the tip, or a combination of the two parts), see Figure 3 and 4. An alternative test is the Dynamic Load Test (DLT). In this test, the friction and tip portions are obtained, as well as the total load and other parameters.

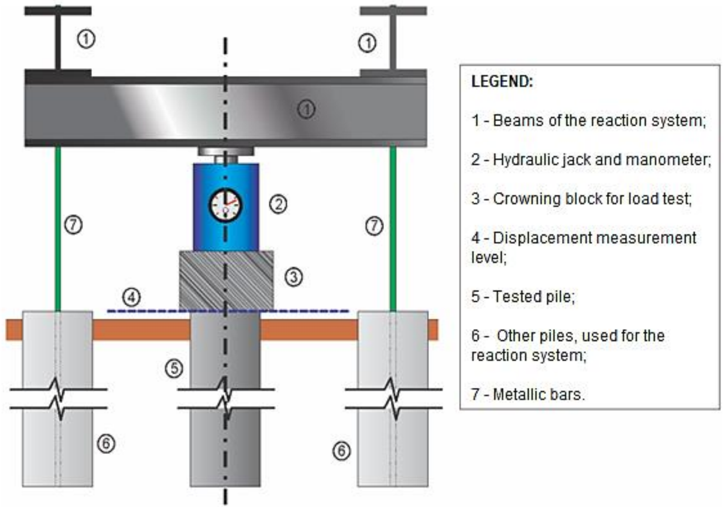

Figure 3: Scheme of a static load test, using reaction piles [6]

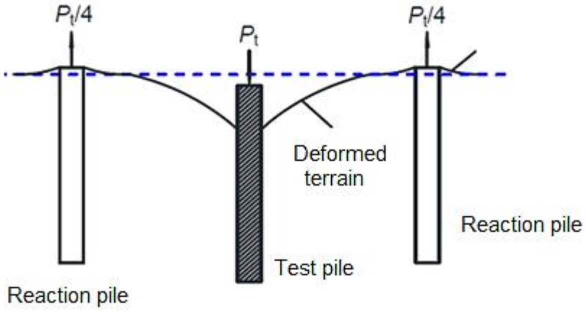

Figure 4: Typical compression test scheme using reaction piles from the same block [7]

According to the Brazilian Standard, NBR 6122 [8], the system rupture moment occurs when continuous settlements are verified without adding loads. Mathematically, the rupture occurs at a critical point, where the derivative at that point is zero. Then, Equation 1 can be written. The author in [6] calls the derivative of loads (Q) in relation to settlements (S) of Variational Rigidity (kv):

$$\frac{dQ}{dS}=0 \tag{1}$$

Normally, SLTs do not reach the ultimate load because the pile is still used as the foundation of the building. In a test, the load is expected to reach at least twice the value to which the pile will be subjected during its state of service (known as working load). According to the authors in [9] the typical load-settlement curve found for several tests in the world confirm a non-linear behavior, even for low load stages. The authors in [10] affirms the nonlinearity found is the typical response of the soil-pile interface.

In mathematical language, it can be assumed that the loads applied to the system will be contained in the interval between 0 and the rupture load (Qu). Therefore, Inequations 2 to 6 can be written:

$$0 \leq Q(S) \leq Q_u \tag{2}$$

From $Q(S) \leq Q_u$:

$$\frac{Q(S)}{Qu} \leq 1 \qquad (3)$$

$$1 - \frac{Q(S)}{Qu} \geq 0 \qquad (4)$$

Defining the first term as "ρ(S)" (the author in [6] called this index ΔQ_u).

$$\rho(S) = 1 - \frac{Q(S)}{Qu} \geq 0 \qquad (5)$$

as $Q(S) \geq 0$, if $Q = 0$, $\rho = 1$; if $Q=Qu$, $\rho=0$ (Note that as Q increases, there is a decrease in ρ):

$$0 \leq \rho(S) \leq 1 \qquad (6)$$

From Inequation 5, a general equation for correlation of loads with settlements can be written using the function ρ(S), Equation 7.

$$Q(S) = Q_u \,.\, [1 - \rho(S)] \qquad (7)$$

The author in [6] got the function ρ(S) for the methods of Van der Veen [11], Van der Veen generalized by Aoki [12], Chin [13] and Décourt [14], probably the most used in Brazil, Table 2.

Table 2: ρ(S) for the adjusting methods of load-settlements curve [6]

Method	ρ(S)	Equation obtained**
Van der Veen [11]	e^{-as}	$Q = Qu.(1 - e^{-as})$ *
Van der Veen Gener. [12]	e^{-as-b}	$Q = Qu.(1 - e^{-as-b})$ *
Chin [13]	$\frac{Qu.C2}{S + Qu.C2}$	$Q = Qu.(1 - \frac{Qu.C2}{S+Qu.C2})$*
Décourt [14]	$\frac{1}{1 - A.S}$	$Q = Qu.(1 - \frac{1}{1-AS})$*

* Constants a, b, C2, and A are adjustment constants of each method;

** Qu is particular to each methodology. For the methods of Chin [13] and Décourt [14] there are other formats for presenting your equations that can be consulted at [6].

The authors in [9] define the parameter $\alpha_{i,j}$ of interaction between piles in a group, and claim that the interaction between piles i and j is approximately linear, but the response of an isolated pile is typically nonlinear, as for the main diagonal of the matrix α, where i=j, $\alpha_{i,i}$ can be, according to the authors, given by Equation 8, from which equation 9 is deduced. The same can be done in equation 7 by Equation 10.

$$\alpha_{i,i} = \frac{1}{(1 - \frac{Q}{Qu})} \qquad (8)$$

$$\alpha_{i,i} = \frac{1}{\rho(S)} \qquad (9)$$

$$Q = Qu \, . \, [1 - \frac{1}{a(S)}] \qquad (10)$$

3. Logistics Curve Model

The logistic curve is an adjustment equation that was initially thought to adjust population growth, and today it is used for other diverse applications, such as:

- Population growth, [15,16];
- Growth of tumor cells in the body [17,18,19];
- HIV growth studies [20,21].

The first discussions and concerns about population growth took place in the 18th century. It is from this time that Malthus' well-known statement that the population would grow in geometric proportion [15].

3.1. First growth model – exponential growth

Mathematically, the population growth rate would be proportional to the population (N) at a given instant of time (t), Equation 11, which results in an exponential growth modeled according to the author in [22], by Equation 12. The factor “r” is called the intrinsic growth rate.

$$\frac{dN}{dt} = r \, . \, N \qquad (11)$$

$$N(t) = N_0 \, . \, e^{-r.t} \qquad (12)$$

Where $N_0 = N(t=0)$.

This model predicts that the growth rate of the population of size N depends on the size of the population, this type of differential equation is called an autonomous equation, where the independent variable is not made explicit in the equation [23]. It is also important to note that Equation 11 leads to exponential growth, where the population would grow unlimitedly over time.

3.2. Logistics Growth Model [15,25]

According to the author in [15], population growth tends to present two distinct moments. The first, when the population is in its early stages, a growth close to exponential can be observed. But as population increases, so does competition for resources. So that with the passage of time and the full development of the population, the scarcity of resources makes the growth of the population tend to decrease, converging towards an upper limit.

This upper limit was defined by [15] as the upper limit of the population (K). According to [22,23], the upper limit can also be called the load capacity of the system and the Differential Equation obtained is (similar to Equation 11, of exponential growth):

$$\frac{dN}{dt} = r\,.\; N\,.(1 - \frac{N}{K}) \qquad (13)$$

It is important to note that, for population values (N) much smaller than the load capacity (K), Equation 13 converges to the exponential model. For values of (N) close to (K), the rate of change begins to approach 0. When N=K, the rate of change is equal to 0. Thus, the term (1-N/K) is intended to limit the growth of the exponential model, creating an asymptotic behavior around K, see Figure 5. According to [22], the integration of Equation 13, results in Equation 14. This equation leads to a non-linear S-shaped behavior (called a sigmoidal curve), starting from the value of N0 and converging to K. Therefore, Verhulst modeled the population growth problem in order to adapt the exponential model to fit a limited load capacity. The great contribution of the logistic adjustment consisted in establishing a population growth limit, which is more adherent to the observed reality. From a practical point of view, it would be impossible for populations to grow indefinitely.This contribution serves as a subsidy for other applications, as long as there is a shortage of resources, or a limited supply of inputs or input data. Thus, today there are several applications of the model, usually associated with growth rates, as seen in item 3, and in references 15, 16, 17, 18, 19, 20 and 21.

$$\boldsymbol{N}(t) = \frac{K}{1 + D.\; e^{-r.t}} \quad \therefore \; D = \frac{K - N_0}{N_0} \qquad (14)$$

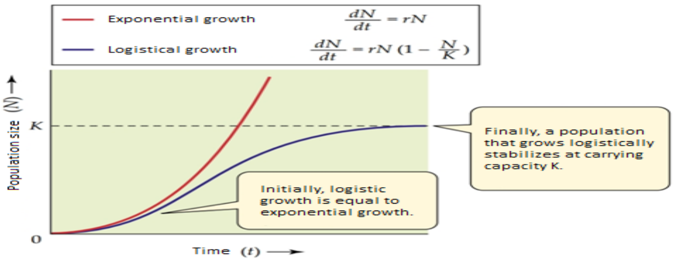

Figure 5(a): Didactic example of the logistic curve compared to the exponential curve [24]

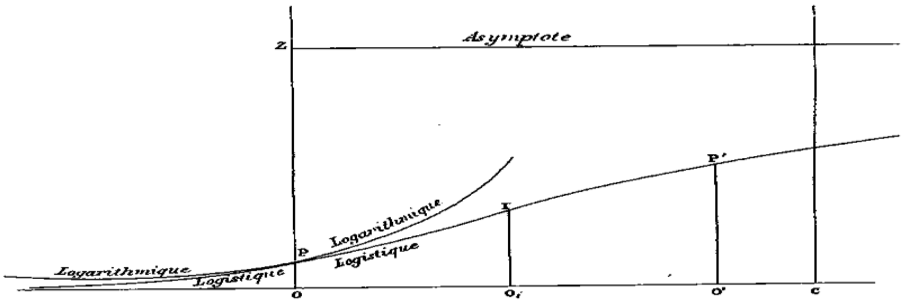

Figure 5(b): Engraving belonging to the original article [25]

Figure 5: Examples of comparison between the curves: exponential and logistic.

4. Proposed of Logistics Adjustment for Static Load Test

The applications mentioned above associate the growth of the dependent variable as a function of time. For this work, the proposal is to model the growth rate of the measured resistance of a building foundation according to the displacement level imposed during the static load test.

The proposal is based on using Equation 14 to adjust the load-settlement result of a Static Load Test. The independent variable (t) would be the settlements (S), the independent variable (N) would be the loads (Q), and the load capacity (K) would be the load capacity of the pile (Qu). In this way Equations 13 and 14 could be rewritten using Equations 15 and 16.

$$\frac{dQ}{dS} = r \cdot Q \cdot \left(1 - \frac{Q}{Qu}\right) \qquad (15)$$

It is possible to notice that the term (1-Q/Qu) is exactly the term ρ(S), which according to the authors in [9] is responsible for the nonlinearity of the load-settlement curve. And according to [15] it is the term responsible for limiting exponential growth. As previously mentioned, as in Equation 14, Equation 16 leads to a nonlinear S-shaped behavior (called a sigmoidal curve), starting from the value of Q_0 and converging to Q_u.

$$Q(S) = \frac{Q_u}{1 + D \cdot e^{-r.S}} \quad \therefore \; D = \frac{Q_u - Q_0}{Q_0} \qquad (16)$$

The adjustment of constants Q_u, D e r, can be done using software that performs the logistic adjustment, such as Mathcad, or the free and online tool Geogebra.

5. Field Tests Used

To apply the described proposal, the results of Static Load Test (SLT) were used in a construction in northeast of Brazil, of a sewage treatment station. The piles are laminated metallic profile of HP310x79 with lengths ranging from 21 to 23 m, set in subsoil with alternating layers of soft soil and sand, see Figure 6. A total of 822 piles were driven, distributed in an area of 4000 m².

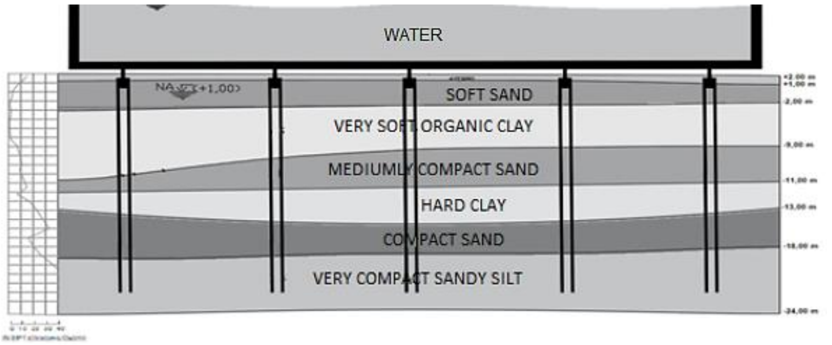

Figure 6: Soil profile and foundation solution

To evaluate the performance of the foundation, 6 static load test and 10 dynamic load tests were executed. Table

3 and Figure 7 shows the results of the static load tests.

Table 3: SLT results

Name	Type	Length (m)	Work Load (kN)	Test Load (kN)	Settlement		
					Max. (mm)	Residual (mm)	Elastic (mm)
ET1	Metalic Profile HP 310x79	21,40	800,00	2200,00	119,10	2,90	16,20
ET2	Metalic Profile HP 310x79	21,80	800,00	2200,00	18,80	3,50	15,30
ET3	Metalic Profile HP 310x79	27,50	800,00	2200,00	42,28	24,03	18,25
ET4	Metalic Profile HP 310x79	24,30	800,00	2200,00	19,11	0,56	18,55
ET5	Metalic Profile HP 310x79	25,10	800,00	2200,00	23,24	8,21	15,03
ET6	Metalic Profile HP 310x79	23,60	800,00	2200,00	22,38	3,22	19,16

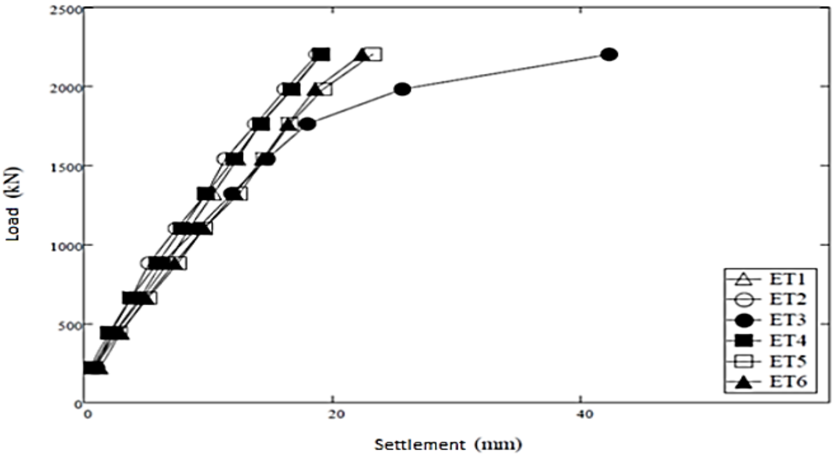

Figure 7: SLT results, load versus settlement diagram

It is not the objective of this work to debate on the DLT, but its results will be used for comparison purposes Table 4 shows the results of the dynamic load tests.

Table 4: DLT results

Tested Pile	Lateral (kN)	Tip (kN)	Total load (kN)
E21	1.962	394	2.356
E24	2.208	240	2.448
E26	2.155	198	2.353
E29	2.301	159	2.460
E53	2.038	176	2.214
E67	2.127	218	2.345
E73	1.804	263	2.067
E77	2.165	215	2.380
E82	2.091	84	2.175
E88	2.091	84	2.175

6. Method of Obtaining the Logistic Adjustment

To adjust and extrapolate the parameters Qu, D and r of the logistic adjustment presented through Equation 16, the Mathcad software was used, which has logistic adjustment, using the “lgsfit” routine present in its library. The input parameters of the “lgsfit” routine are:

- vx, input vector of the independent variable (settlements, S);
- vy, input vector of the dependent variable (loads, Q);
- vg, a starting vector for the values of Qu, D and r – for this study the values of 3,000 kN, 1 and 1 mm -1 were used, respectively.

For comparison purposes, the Van der Veen method generalized by Aoki in [12] was evaluated. And an evaluation of the 3 results was made, SLT with logistic adjustment, SLT with exponential adjustment of Van der Veen and Aoki [12], and DLT.

7. Results and Discussions

From the methodology described, it is possible to obtain the value of the constants: Qu, D and r, for each of the 6 PCEs performed, which are presented in Table 5. It is possible to observe that the load capacity (Qu) varied between values of 2,456 and 2,131 kN with an average of 2,369 kN; the value of the dimensional constant D varied between 7.94 and 5.64, with an average of 6.99; and the value of r (also called intrinsic growth rate) varied between 0.181 and 0.223, with an average equal to 0.2.

Another important fact for observation is that the coefficients of variation found are relatively low for geotechnical parameters. [26] compiled several test results and geotechnical parameters (from resistance parameters to soil characterization results) and found a coefficient of variation of up to 240%. For the present study, values between 5.15 and 12.55% were found.

The most important data to be obtained through this methodology is the load capacity (Qu), which presented the lowest coefficient of variation equal to 5.15%.

Table 5: Results obtained by the methodology

PCE	Qu (kN)	D (-)	r (mm^{-1})
ET1	2.443	7,94	0,215
ET2	2.353	6,57	0,223
ET3	2.131	5,64	0,188
ET4	2.399	6,58	0,210
ET5	2.429	7,50	0,181
ET6	2.456	7,71	0,184
Mean	2.369	6,99	0,200
Coefficient of variation (%)	5,15	12,55	8,98

Where, Qu is the rupture load; D and r are the logistic adjustment parameters.

In this way, it is also possible to use the proposed Equation 16 to obtain the adjusted graph of the Logistic Curve to the data measured in each SLT. A typical result is shown in Figure 8, referring to the test on the ET5 pile. It is observed that the curve has an S shape (sigmoidal) as expected, starting from an initial value (Qo) to a limit value (Qu). Qo is implicit in the value of the constant D, as shown in Equation 16. The logistic curves, qualitatively, fit very well to the points obtained in the tests.

Note that the curve presents a behavior close to the exponential until around the fifth point of the curve (settlement of the order of 10 mm), where from this stage, it begins to present asymptotic behavior around the load capacity Qu.

It is also important to note that, for settlements close to 0, the initial value Qo is slightly different from the first stage of the Static Load Test. It is in this section that the largest error associated with the adjustment was found.

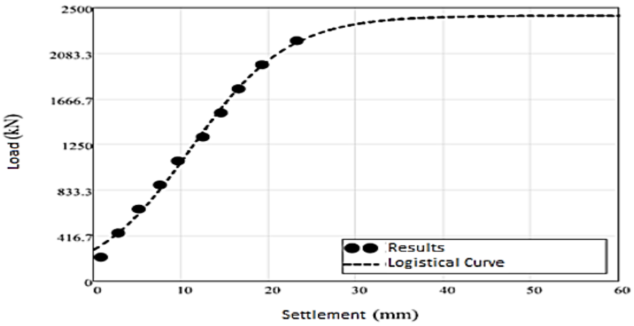

Figure 8: Typical result found for SLT – ET5

All this described behavior is repeated for the other curves that are shown in Figure 9 (a) to (f). In order to maintain the scale effect, all SLTs are presented with the same upper limit on the axes of the 2500 kN loads; and the same upper limit for the axis of the settlements of 60 mm.

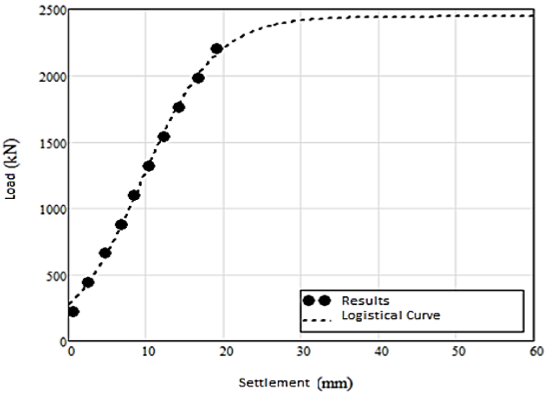

Figure 9(a): ET1

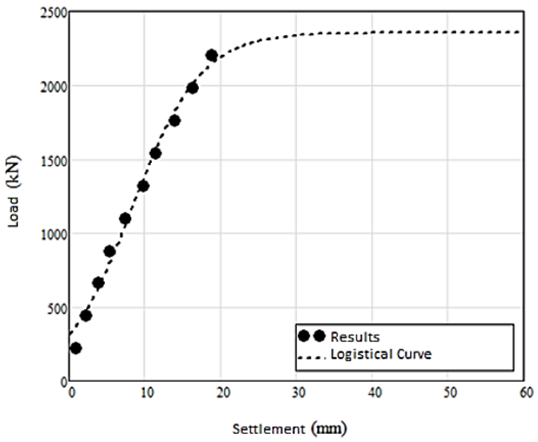

Figure 9(b): ET2

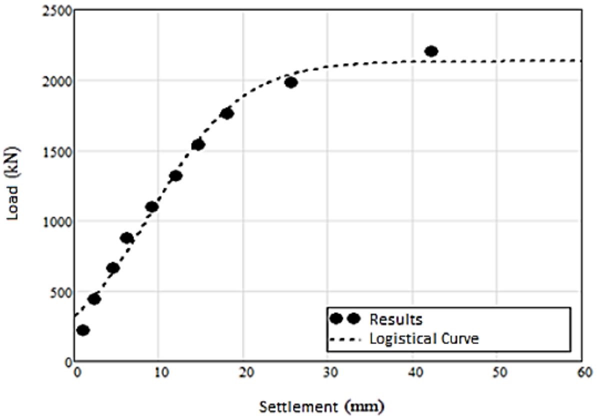

Figure 9(c): ET3

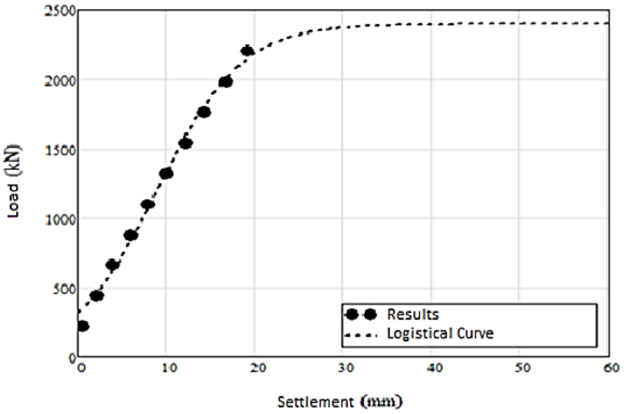

Figure 9(d): ET4

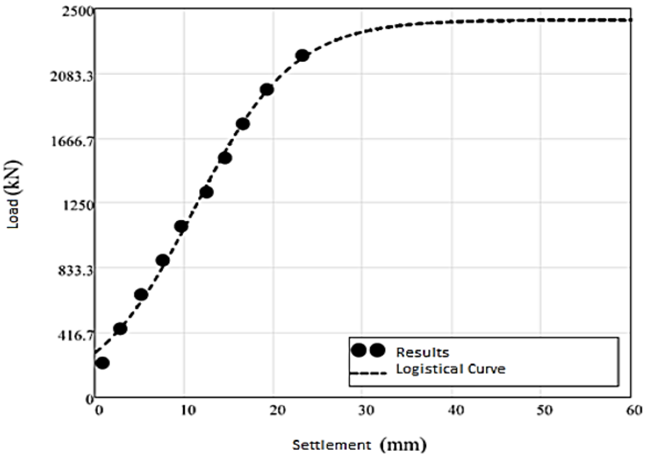

Figure 9(e): ET5

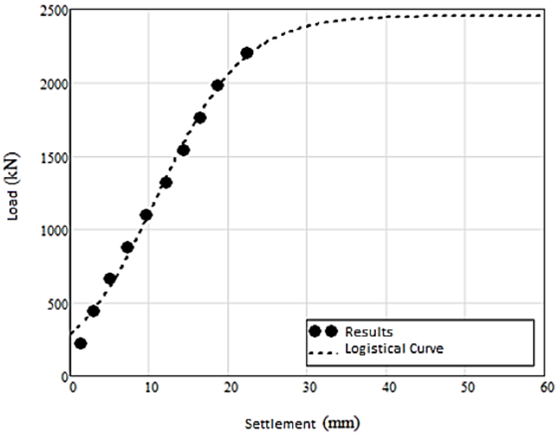

Figure 9(f): ET6

Figure 9: Adjustment results for all SLTs

Therefore, it can be easily observed that the SLT ET3, shown in Figure 9 (c), presents an inferior performance to the other PCEs. In the first aspect, it is the only test that presents displacements (settlements) greater than 30 mm. For this level of settlements, the inclination of the curve is much lower than the other stages. However, even so, the adjustment is interesting, suggesting that from this level of displacement (30 mm, around 10% on the side of the 310 mm pile) the load capacity value would already be obtained.

This data is consistent with the results and criteria of other researchers who point out that for displacements above 10% of the diameter/side of the pile, the referring load should already be considered the ultimate load. This displacement criterion is presented by [14], and is called the conventional criterion, for which a conventional ultimate load is obtained.

In Figure 10, all 6 SLTs are presented, as well as their respective adjustments through Equation 16.

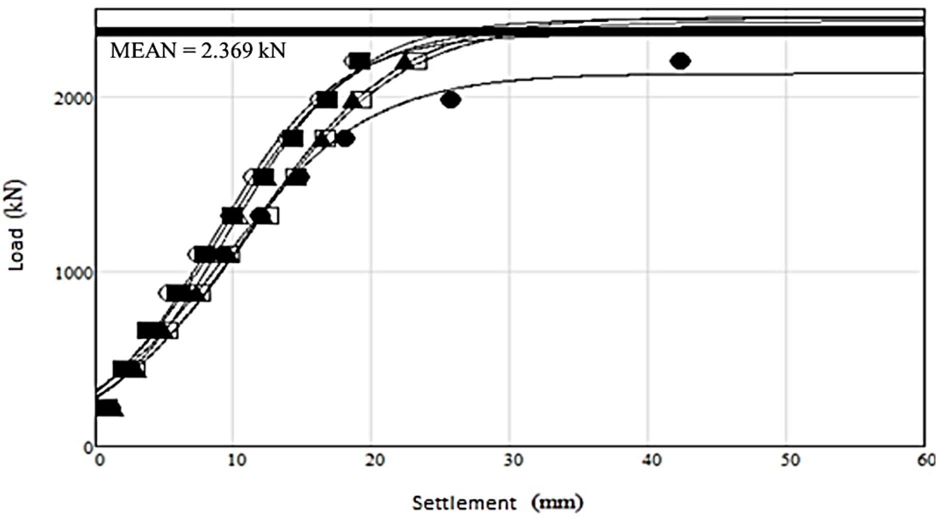

Figure 10: Global result found for all SLTs, highlighting the average load capacity

It is possible to notice the convergence of the results around the average, which explains the low coefficient of variation found for the load capacities (5.15%). It is also possible to observe the sigmoidal and asymptotic behavior of all curves. The difference in behavior mentioned for ET3 can still be highlighted.

Another important fact to note is that for the settling value of 10% on the pile side (around 30 mm), the curves already meet the average load capacity, with the exception of the test performed on the ET6 pile. This means that there was a convergence of the results obtained for the load capacities with the adjustment of the Logistic Curve and the conventional rupture criterion, presented by [14].

A comparison between the results obtained from alternative field measurements Dynamic Load Test (DLT), with two methods of extrapolation of the results from the Static Load Test (SLT) is presented: the first method widely used in Brazil (the Van der Veen method) [11] and the second refers to the methodology proposed here that uses the logistic curve adjustment. The methods of Décourt [14] and Chin [13], presented in Table 1, were not used, because according to [6], these methods present coefficients of variation at least 50% higher than those of Van der Veen [11][12]. Comparisons will be made for ultimate load, or load capacity (logistic adjustment).

Therefore, adjustments are made considering the Van der Veen equation generalized by Aoki [12]. As a result of this method, 3 constants are obtained, Qu, a and b. Qu would be the ultimate load extrapolated by the method (similar to the load capacity of the logistic adjustment) while “a” and “b” are constants obtained from the iterations. The method by Van der Veen [11,12] is probably one of the most used in Brazil, and it is not the purpose of this work to discuss its details. For more information, consult [6]. The results obtained for the Van Der Veen method generalized by Aoki [12] are presented in Table 6.

Table 6: Results for the Van Der Veen method generalized by Aoki [12]

PCE	Qu (kN)	a (mm^{-1})	b (-)
ET1	7.370	0,018	0,01
ET2	3.800	0,044	0,015
ET3	2.370	0,063	0,063
ET4	4.240	0,036	0,021
ET5	7.470	0,015	0,013
ET6	7.660	0,015	0,01
Mean	5.485	0,032	0,022
Coefficient of variation (%)	41,82	61,15	93,15

Where, Qu is the rupture load; a and b are the logistic adjustment parameters.

Table 7 presents a comparison between the results obtained for the Van der Veen method generalized by Aoki [12], the results of the dynamic load tests (DLT) and the results obtained with the adjustment of the Logistical Curve, as well as the comparison between the ranges of variation of each result, means and coefficients of variation.

Table 7: Summary of the results obtained for the extrapolation of the ultimate load by different methods

Analysis method	Ultimate Load or Load Capacity* (kN)			Coefficient of variation (%)
	Max	Min	Average	
Dynamic Loading Test (ECD)	2.460	1.951	2.263	6,85
Adjustment of the Logistics Curve	2.456	2.131	2.369	5,15
Van der Veen generalized by Aoki	7.660	2.370	5.485	41,82

* Ultimate load is the name used for the maximum load that the soil-pile system can support, usually extrapolated by methods such as Van der Veen [11], whereas the load capacity is a nomenclature for the limit growth of the logistical adjustment. Although with different nomenclatures, they have the same physical meaning in this work.

The results of the logistic adjustment are very close to the dynamic load test (DLT), and quite divergent from the Van der Veen generalized by Aoki [12]. Note that the average van der Veen ultimate load is more than twice the load capacity obtained by adjusting the logistic curve. The same is true between Van der Veen and the DLT.

The logistic adjustment and the DLT are very similar, with almost equal maximum results, and an average 5% higher than that obtained by the DLT. Another relevant point is the evaluation of the Coefficient of Variation. According to the author in [6] who studied a construction with 40 PCEs, in continuous helix piles, as the displacements obtained in the test increase, there is a tendency for the coefficient of variation of the extrapolations to decrease. The author notes that from displacements of the order of two percent of the pile diameter (2% D), the coefficients of variation tended to stabilize. As the settlements obtained in the SLT for the present study are greater than 6% on the pile side, it is inferred that the coefficients of variation are already stable, given that the extrapolated ultimate load no longer depends on the settlement level obtained.

It is possible to notice that the coefficient of variation of the Van der Veen method is almost seven times greater than that found for the DLT. And the lowest coefficient of variation found was that of the logistic curve adjustment, which is very close to the one found for the DLT.

Comparing the methods, it is possible to observe that the values obtained by Van Der Veen 3 times higher than those obtained by the logistic curve adjustment, which are in the same order of magnitude as the results obtained with Dynamic Load Test. The results presented between the DLT and the Logistic Adjustment were coherent with each other, from the range of rupture loads obtained, as well as the average ultimate load, and the coefficients of variation.

8. Final Considerations

Historically, for the extrapolation of the ultimate loads of the foundation pieces, basically two models are used: exponential adjustments [11,12] and hyperbolic adjustments [13,14]. The present study proposed another possibility using a logistic adjustment. Expanding the range of models that can be used to adjust the performance of engineering pieces. It considers the method of Extrapolation by the Logistic Curve (ELC) adopting the postulates for the load-settlement diagram, finding the value of Load Capacity of the soil-pile system. The proposal is tested in a building supported by 822 metallic piles in the Metropolitan Region of Recife-PE, Brazil, using six Static Load Tests (SLT) and nine Dynamic Load Tests (DLT) results, showing excellent results.

Within the area of geosciences, the estimation of the performance of materials and systems of buildings and geotechnical constructions is executed from parameters that are obtained from field and/or laboratory tests. However, due to the high degree of uncertainty involving natural materials of different genesis such as soil, very high dispersions of these parameters are obtained. On the order of 240% in relation to the average. So there is a great motivation for geotechnical studies to adjust the available models for a better adherence to physical phenomena, in order to reduce these dispersions. One of the main conclusions of the work is that the coefficient of variation found for the estimation of rupture loads by the proposed Logistic Adjustment method was of the order of 5%. Much lower than that practiced and obtained in investigations of this nature. For this same test site, using established methods such as that of Van der Veen, coefficients of variation of 42% were obtained.

Such high estimation variability values are no longer admissible in the contemporary world where measurements and information are increasingly tiny and transcend the nanometer scale.

The main questions that must be asked and answered in future works are the doubts that still remain about the application of the method for other types of foundations, for settlements of greater magnitudes and for piles with low value of residual driving tensions. It is also important to note that, for settlements close to 0, the initial value Qo is slightly different from the first stage of the Static Load Test. It is in this section that the largest error associated with the adjustment was found. But it can also indicate a residual tension measurement. However, other methodologies do not present these tensions in their deformability diagrams. Although, the present study showed that the method was efficient for displacements less than 20 mm, as well as for displacements greater than 40 mm.

It is possible that the geosciences community is facing a moment of change in perception and paradigms about the behavior of materials, since the estimation of the maximum support capacity of a piece is the most important argument for ultimate limit state verifications, and the uncertainty inherent to the methodologies used significantly hampers the ability to optimize the process.

The authors of the work believe that it is possible to extrapolate this suggestion of logistical adjustment to other construction methodologies for foundations and to other materials such as reinforced concrete, soil, rocks, among others. Therefore, it is convenient that new studies are performed to prove its usefulness and evidence of the reduction of the coefficients of variation obtained.

Finally, it is important to highlight that these results are the first to use the Logistic Adjustment, and recommended that other studies be analyzed to consolidate the proposal in other types of piles and soils to create a database of studied and extrapolated results, and an accumulated experience.

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