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# A Time Duration Optimization Model for the Construction of Piles

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**ABSTRACT-** Time and adequate management of the scheduling of activities are very critical in every construction project. This study formulated a multiple linear regression optimization model to address issues bordering on delays in pile construction operations. A 300mm diameter reinforced concrete pile, 5.4m long, with a plastic casing was used. A total of 32 piles were constructed in a silty soil completely submerged in water at Bonny, Nigeria. The friction piles were constructed serially with a boring method, while the soil was extracted with the piling auger. The volumes of the extracted soil and concrete poured to fill the holes were accounted for, theoretically and actually. The same was done for the reinforcement cages installed in each pile shaft. The model was formulated and tested using Statistical Package for the Social Sciences (SPSS) software. The model was found to be fit, adequate, and highly accurate with an $R^2$ value of 0.874.

**KEYWORDS -** Delays in construction, Pile construction, Multiple Linear Models, Time Optimization Modelling.

## I. INTRODUCTION

There are several types of foundations used in carrying buildings and other structures. They range from pad, raft, pile, strip, strap, and grillage, to mention but a few. They are either shallow or deep foundations. According to [1], a shallow foundation has its depth lesser than or equal to 3 to 4 times its width, otherwise, it is a deep one. Deep foundations are also required among other conditions outlined and cited by [1], when the soil bearing capacity is very low, and the loads transferred to the columns are very large. A typical deep foundation is a pile foundation. It is a long slender column used to carry structures and is either cast-in-situ, bored, or driven [2]. Piles support loads of the superstructure. A pile constructed on soil with a rocky stratum or rocky bed is a point-bearing pile, while that constructed on totally weak soil is a friction pile [1]. Although pile foundations are more expensive than shallow ones [1], they are structurally safer. Piles can be constructed using timber, steel, concrete, Plastic, or composite materials [1], [2], [3], [4]. Pile foundations (especially timber piles) have been in use since the Biblical times in Babylon when man first started to build houses near river banks and shores [3]. However, steel and concrete piles were first used in 1800 and 1900 respectively [3]. The concrete pile may be a cast-in-situ, precast, drilled shaft, or barrette [4]. When it is a drilled shaft pile, the drilled hole is replaced with plain or reinforced concrete. The former is used when consideration is given to compressive structural loads only. The latter is, however, used when consideration is given to moments and/or lateral loads [4]. Plastic piles are made of several materials such as Polyvinyl Chloride (PVC), recycled materials, and polymer composites [4]. The composite piles are very commonly used recently, especially in marine environments where the pile is constantly exposed to excess water, putting it at risk of surface deterioration. According to [3], some composite piles with steel and plastic have been in use since the 1980s. They are also immune to marine and corrosion deterioration risks.

The productivity of construction of pile foundations is dependent on the following factors according to [3] as cited by [5]:

- Type or nature of the soil
- Type of drill and height of drilling equipment;
- Space considerations, method of spoils removal, and size of hauling unit at the construction site;
- Adjustment of pile axis;
- The efficiency of the equipment operator;
- Method and efficiency of concrete pouring;
- Weather conditions;
- Waiting time for other tasks;
- Working conditions on site;
- Pile dimensions; and
- Pile construction cycle time or duration.

To this note, several studies [5], [6], [7], [8] have been conducted to better evaluate pile construction techniques, technology, construction cost optimization, productivity, and construction time optimization. [9] suggested an effective design and construction method of piles, using soil-cement screw piles. In that study, they developed model equations to predict the load capacity for installing and constructing piles in Bangkok. However, the scope of this study was limited to the pile construction time or schedule for a drilled shaft (or bored) concrete pile with PVC casing and steel reinforcement to reduce the effect of settlement. The pile used was a friction pile with a drilled shaft as described by [4] but with PVC. The volumes of soil extracted and concrete poured into the shaft, as well as the weight of reinforcement were of particular interest in the determination of the model in this study.

Every construction project execution obeys the Iron Project Triangle (IPT). The study by [10] to address the construction of the Rivers Monorail which includes the construction of piles, using the Continuous Flight Auger (CFA) method, amongst other items, dwelt immensely on the IPT. This means that the time required to carry out piling construction plays a significant role in piling operations. This goes to show that the last item on the list of factors stated by [5] above is also immensely affected by the rest of the items on that list.

Adequate time management during piling operations will ensure the timely delivery of the overall project in question. The success stories of adequate planning and scheduling are imminent in the development of the Polaris Fleet Ballistic Missile (FBM) program in 1957 by the United States Navy [11]. Oftentimes, the nature of soils, challenges encountered during the piling operations, time to prepare for the next pile installation, the quantities of materials to be used, and the rest of the factors listed by [3], have caused several problems hinging on delays. This study will evaluate some key variables for piling operations; develop a mathematical regression model; and justify the importance of scheduling and time management to address the problem of delays in pile construction operations.

The study was carried out on a building construction project in Bonny, a small oil-rich town in Nigeria. The building was designed to sit on a raft foundation. The building has a ground floor and two suspended floors made of reinforced concrete structural elements and hollow block walls. The soil was found by the geotechnical team to be mostly of silty sand. The terrain is water-logged with a relatively flat topography. The soil was later reclaimed with medium loose sand to a height of 500mm. For this reason, the structural design team recommended the introduction of single settlement piles, with pile caps, to cushion the effect of consolidation settlement on the foundation.

## II. METHODS

The type of pile designed by the structural design team was a friction pile. As stated earlier, it was composed of plastic (PVC) casing with reinforced concrete. The method of installation was boring with the use of a manually handled auger drill-bit of diameter 300mm. The materials used were soil, concrete, steel reinforcement, water, and PVC pipes. The equipment used were a 6m boring auger and a surface pump for dredging with its accessories.

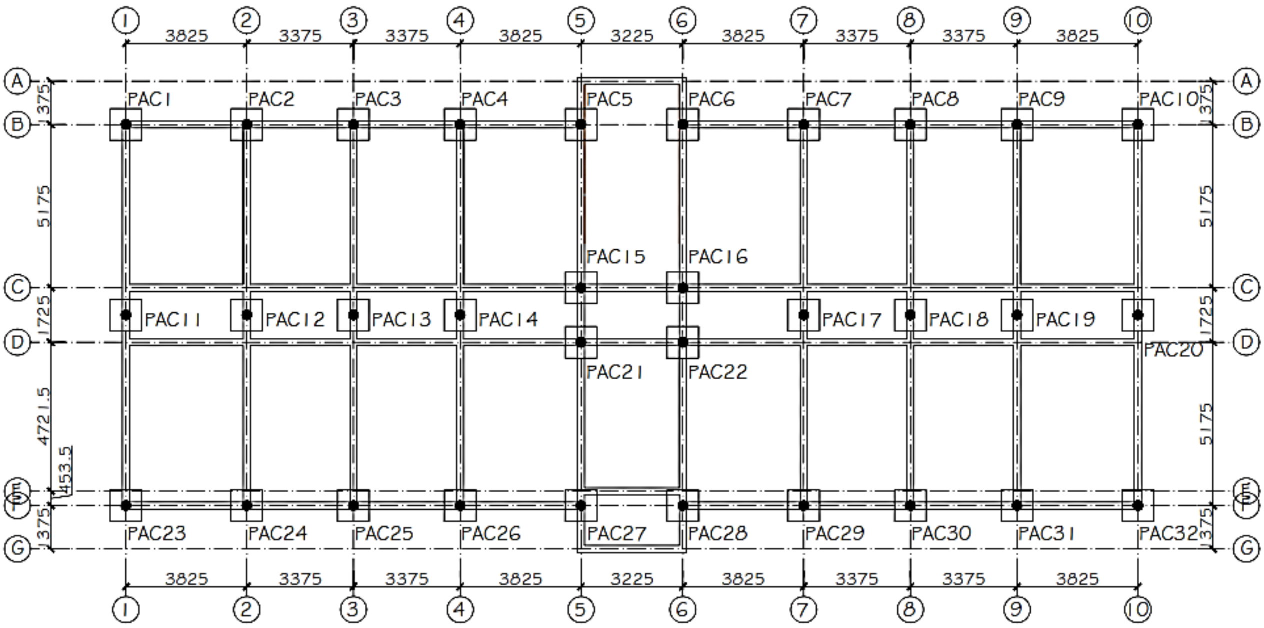



Figure 1: Layout showing piles, pile caps, and raft beam layout

The $406.1625m^2$ building had 32 piles with pile caps as shown in Fig. 1. The Piles and Caps (PAC) were annotated accordingly. The concrete was batched and ready for pouring before the drilling was done. The reinforcement cages for the 32 piles were also ready before drilling. This would enable the reinforcement and concrete to be installed immediately after the drilling, and auger is withdrawn, to avoid collapse and backfill of soil into the shaft from underneath. The total time taken for the entire cycle was recorded. The process was repeated for the rest of the piles. Fig. 2. shows details of the soil profile and structural details of the pile respectively.

| BOREHOLE LOG | | | STANDARD PENETRATION TEST | | | | |
|---|---|---|---|---|---|---|---|
| BOREHOLE NO.: | 1 | | | | | | |
| TOTAL DEPTH (m): | 15 | | | BLOW COUNT | | | |
| GROUND WATER LEVEL (m): | 0.3 | | | | | | |
| DATE: | 29/8/2021 | | | | | | |
| DEPTH (m) | DESCRITION | SOIL PROFILE | SPT DEPTH (m) | 0 - 150mm | 150 - 300mm | 300 - 450mm | SPT (N) 30 |
| 0.3 | Black Silty Sand, top soil | | | | | | |
| 1 | Loose dark greyish brown highly Silty fine Sand | | | | | | |
| 2 | Loose dark greyish brown highly Silty fine Sand | | | | | | |
| 3 | Loose dark greyish brown highly Silty fine Sand | | -3 | 6 | 7 | 8 | 15 |
| 4 | Loose to medium dense greyish m.caceous fine Sand | | | | | | |
| 5 | Loose to medium dense greyish m.caceous fine Sand | | | | | | |
| 6 | Loose to medium dense greyish m.caceous fine Sand | | -6 | 8 | 14 | 10 | 24 |
| 7 | Loose to medium dense greyish m.caceous fine Sand | | | | | | |
| 8 | Loose to medium dense greyish m.caceous fine Sand | | | | | | |
| 9 | Soft to stiff dark greyish peaty clay | | | | | | |
| 10 | Soft to stiff dark greyish peaty clay | | | | | | |
| 11 | Soft to stiff dark greyish peaty clay | | | | | | |
| 12 | Soft to stiff dark greyish peaty clay | | -12 | 15 | 22 | 30 | 52 |
| 13 | Medium dense to dense light greyish fine sand with pockets of stiff peaty clay | | | | | | |
| 14 | Medium dense to dense light greyish fine sand with pockets of stiff peaty clay | | -14 | 15 | 25 | 31 | 56 |
| 15 | Medium dense to dense light greyish fine sand with pockets of stiff peaty clay | | | | | | |

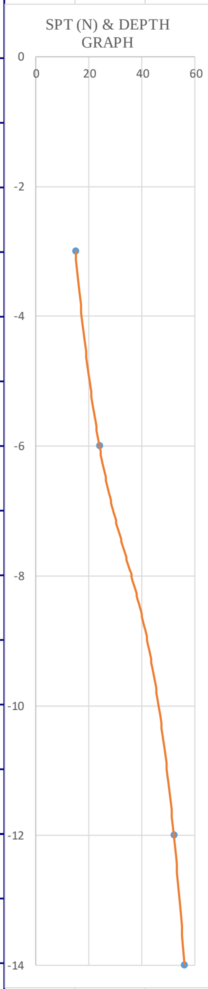



Figure 2: Soil Profile

The volume of soil dredged or drilled is theoretically equal to the volume of concrete required to fill the shaft. This was determined from eq. (1). Similarly, eq. (2) was used to determine the theoretical weight of the reinforcement cage required for each pile.

$$V_{st} = V_{ct} = \pi D_p^2 L_p / 4 \quad (1)$$

$$W_{rt} = \pi D_{16}^2 \rho_s / 4 + \pi D_{10}^2 \rho_s / 4 \quad (2)$$

where;

$V_{st}$, $V_{ct}$, $W_{rt}$, $D_p$, $D_{16}$, $D_{10}$, $L_p$, and $\rho_s$ are the theoretical volume of soil, the theoretical volume of concrete, the theoretical weight of the reinforcement cage, diameter of pipe, diameter of 16mm reinforcement, diameter of 10mm reinforcement, length of pipe, and density of steel respectively. The symbols, $\pi$ and $\rho_s$ are constants, with values of 3.142 and 7850kg/m$^3$ respectively. However, the actual volume of soil, concrete, and weight of reinforcement cage were measured on-site. The loads were transmitted from the columns to the raft beams, which were translated to shear forces, V on the raft beams. Figs. 3 and 4 show details of the typical pile's structural drawings and its penetration depth.

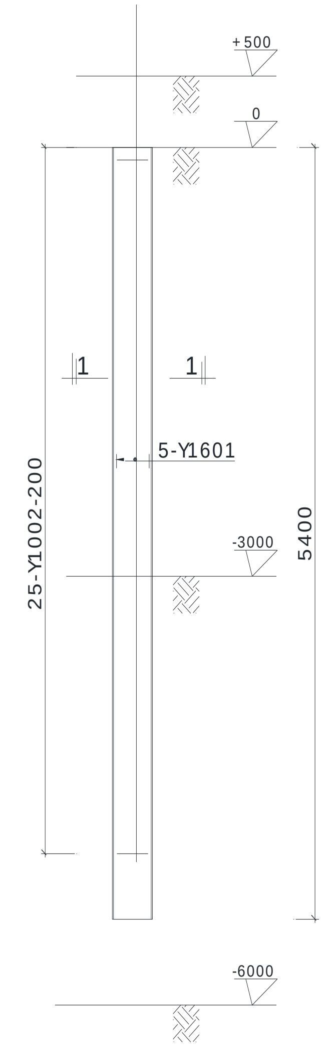



Figure 3: Pile Sectional Elevation

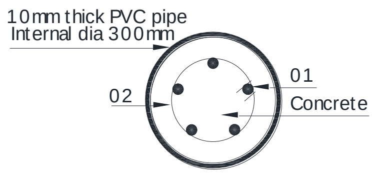



Figure 4: Pile Section 1-1

## III. RESULTS AND DISCUSSIONS

The soil investigation and structural analysis/designs were carried out before the commencement of the construction of the building. This is the usual practice globally. Some results were extracted from the structural analysis report, some from the soil report, and others were determined on-site. Table 1 shows the time durations of pile operation for the 32 piles. This includes time to position the equipment, drill the shaft, install the pipe, install the reinforcement cage, pour the already mixed concrete, and move the equipment to the next point for piling. The entire operation took 6 days to complete. Table 2 shows results of the theoretical and actual values of the volume of soil dredged or removed, volume of concrete poured, and weight of reinforcement cage. Eq. (3) is the governing equation or objective function for the time duration of the piling operation. It is a multiple linear regression model.

$$t_p = \lambda + \psi V_{sa} + \vartheta V_{ca} + \omega W_{ra} \quad (3)$$

where;

$t_p$ is the predicted time it would take to complete the construction of one pile, in minutes, while $\boldsymbol{\lambda}$, $\boldsymbol{\psi}$, $\boldsymbol{\vartheta}$, and $\boldsymbol{\omega}$ are the model constants with units of minutes, minutes/m$^3$, minutes/m$^3$, and minutes/kg respectively. In addition, $V_{sa}$, $V_{ca}$, and $W_{ra}$ are the actual volume of soil removed, actual volume of concrete poured, and actual weight of reinforcement cage, in m$^3$, m$^3$, and kg respectively.

Table 1: Actual Time taken for piling operations

| Day | Date | Pile point | Duration, t (minutes) |
|---|---|---|---|
| 1 | 25/05/2023 | PAC1 | 55 |
| | | PAC2 | 62 |
| | | PAC3 | 52 |
| | | PAC4 | 57 |
| | | PAC5 | 55 |
| 2 | 26/05/2023 | PAC6 | 65 |
| | | PAC7 | 50 |
| | | PAC8 | 61 |
| | | PAC9 | 51 |
| | | PAC10 | 59 |
| | | PAC11 | 57 |
| 3 | 27/05/2023 | PAC12 | 50 |
| | | PAC13 | 40 |
| | | PAC14 | 59 |
| | | PAC15 | 57 |
| | | PAC16 | 52 |
| 4 | 29/05/2023 | PAC17 | 59 |
| | | PAC18 | 50 |
| | | PAC19 | 55 |
| | | PAC20 | 46 |
| | | PAC21 | 55 |
| | | PAC22 | 55 |
| 5 | 30/05/2023 | PAC23 | 50 |
| | | PAC24 | 40 |
| | | PAC25 | 52 |
| | | PAC26 | 55 |
| 6 | 31/05/2023 | PAC27 | 53 |
| | | PAC28 | 44 |
| | | PAC29 | 49 |
| | | PAC30 | 56 |
| | | PAC31 | 54 |
| | | PAC32 | 58 |

Table 2 is a detailed information of the piles, volume of soil extracted, volume of concrete poured, and weight of reinforcement cage. The weights of reinforcement cage were calculated with a length of 6m for the main bars. The data in Table 2 along with the durations in Table 1 were subjected to the SPSS regression analysis tool.

Table 2: Piling Details

| Pile Hole | Pile diameter, $D_p$ (m) | Pile length, $L_p$ (m) | Theoretical volume of soil removed, $V_{st}$ ($m^3$) | Actual volume of soil removed, $V_{sa}$ ($m^3$) | Theoretical volume of concrete poured, $V_{ct}$ ($m^3$) | Actual volume of concrete poured, $V_{ca}$ ($m^3$) | Theoretical weight of reinforcement cage, $W_{rt}$ (kg) | Actual weight of reinforcement cage, $W_{ra}$ (kg) |
|---|---|---|---|---|---|---|---|---|
| PAC1 | 0.3 | 5.4 | 0.382 | 0.399 | 0.382 | 0.350 | 59.680 | 58.350 |
| PAC2 | 0.3 | 5.4 | 0.382 | 0.443 | 0.382 | 0.365 | 59.680 | 58.000 |
| PAC3 | 0.3 | 5.4 | 0.382 | 0.410 | 0.382 | 0.377 | 59.680 | 58.200 |
| PAC4 | 0.3 | 5.4 | 0.382 | 0.375 | 0.382 | 0.342 | 59.680 | 59.100 |
| PAC5 | 0.3 | 5.4 | 0.382 | 0.389 | 0.382 | 0.380 | 59.680 | 59.340 |
| PAC6 | 0.3 | 5.4 | 0.382 | 0.421 | 0.382 | 0.394 | 59.680 | 59.720 |
| PAC7 | 0.3 | 5.4 | 0.382 | 0.380 | 0.382 | 0.378 | 59.680 | 58.910 |

| Pile Hole | Pile diameter, $D_p$ (m) | Pile length, $L_p$ (m) | Theoretical volume of soil removed, $V_{st}$ ($m^3$) | Actual volume of soil removed, $V_{sa}$ ($m^3$) | Theoretical volume of concrete poured, $V_{ct}$ ($m^3$) | Actual volume of concrete poured, $V_{ca}$ ($m^3$) | Theoretical weight of reinforcement cage, $W_{rt}$ (kg) | Actual weight of reinforcement cage, $W_{ra}$ (kg) |
|---|---|---|---|---|---|---|---|---|
| PAC8 | 0.3 | 5.4 | 0.382 | 0.450 | 0.382 | 0.430 | 59.680 | 59.150 |
| PAC9 | 0.3 | 5.4 | 0.382 | 0.386 | 0.382 | 0.385 | 59.680 | 59.000 |
| PAC10 | 0.3 | 5.4 | 0.382 | 0.370 | 0.382 | 0.367 | 59.680 | 60.040 |
| PAC11 | 0.3 | 5.4 | 0.382 | 0.395 | 0.382 | 0.389 | 59.680 | 59.550 |
| PAC12 | 0.3 | 5.4 | 0.382 | 0.368 | 0.382 | 0.365 | 59.680 | 58.990 |
| PAC13 | 0.3 | 5.4 | 0.382 | 0.381 | 0.382 | 0.388 | 59.680 | 57.940 |
| PAC14 | 0.3 | 5.4 | 0.382 | 0.388 | 0.382 | 0.364 | 59.680 | 59.420 |
| PAC15 | 0.3 | 5.4 | 0.382 | 0.399 | 0.382 | 0.400 | 59.680 | 59.680 |
| PAC16 | 0.3 | 5.4 | 0.382 | 0.350 | 0.382 | 0.356 | 59.680 | 59.600 |
| PAC17 | 0.3 | 5.4 | 0.382 | 0.400 | 0.382 | 0.398 | 59.680 | 59.790 |
| PAC18 | 0.3 | 5.4 | 0.382 | 0.391 | 0.382 | 0.387 | 59.680 | 58.780 |
| PAC19 | 0.3 | 5.4 | 0.382 | 0.386 | 0.382 | 0.382 | 59.680 | 59.440 |
| PAC20 | 0.3 | 5.4 | 0.382 | 0.385 | 0.382 | 0.382 | 59.680 | 58.360 |
| PAC21 | 0.3 | 5.4 | 0.382 | 0.383 | 0.382 | 0.383 | 59.680 | 59.570 |
| PAC22 | 0.3 | 5.4 | 0.382 | 0.389 | 0.382 | 0.386 | 59.680 | 59.380 |
| PAC23 | 0.3 | 5.4 | 0.382 | 0.374 | 0.382 | 0.399 | 59.680 | 59.540 |
| PAC24 | 0.3 | 5.4 | 0.382 | 0.382 | 0.382 | 0.420 | 59.680 | 58.590 |
| PAC25 | 0.3 | 5.4 | 0.382 | 0.392 | 0.382 | 0.400 | 59.680 | 59.220 |
| PAC26 | 0.3 | 5.4 | 0.382 | 0.397 | 0.382 | 0.381 | 59.680 | 59.060 |
| PAC27 | 0.3 | 5.4 | 0.382 | 0.415 | 0.382 | 0.395 | 59.680 | 58.550 |
| PAC28 | 0.3 | 5.4 | 0.382 | 0.402 | 0.382 | 0.400 | 59.680 | 57.970 |
| PAC29 | 0.3 | 5.4 | 0.382 | 0.394 | 0.382 | 0.400 | 59.680 | 58.860 |
| PAC30 | 0.3 | 5.4 | 0.382 | 0.387 | 0.382 | 0.380 | 59.680 | 59.490 |
| PAC31 | 0.3 | 5.4 | 0.382 | 0.390 | 0.382 | 0.391 | 59.680 | 59.350 |
| PAC32 | 0.3 | 5.4 | 0.382 | 0.384 | 0.382 | 0.383 | 59.680 | 59.860 |

After the analysis, eq. (4) was formulated. It is called “the Oba’s equation of time taken to construct a pile”.

$$t_p = -476.788 + 270.873V_{sa} - 185.411V_{ca} + 8.381W_{ra} \quad (4)$$

The model summary in Table 3 shows an $R^2$ value of 0.874, which indicates that the model has high goodness of fit and high predictive capabilities. The Analysis of Variance (ANOVA) in Table 4 confirms that the model is adequate. Finally, the unstandardized coefficients in Table 5 are the model coefficients that resulted from the model calibration.

Table 3: Model Summary

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | | Durbin-Watson |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change | |
| 1 | .935 | .874 | .861 | 2.300 | .874 | 64.742 | 3 | 28 | .000 | 1.618 |

Table 4: Analysis of Variance

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 1027.717 | 3 | 342.572 | 64.742 | .000 |
| | Residual | 148.158 | 28 | 5.291 | | |
| | Total | 1175.875 | 31 | | | |

Table 5: Coefficients

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | 95.0% Confidence Interval for B | |
|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Lower Bound | Upper Bound |
| 1 | (Constant) | -476.788 | 47.076 | | -10.128 | .000 | -573.219 | -380.356 |
| | $V_{sa}$ | 270.873 | 24.302 | .868 | 11.146 | .000 | 221.092 | 320.654 |
| | $V_{ca}$ | -185.411 | 24.936 | -.552 | -7.435 | .000 | -236.491 | -134.332 |
| | $W_{ra}$ | 8.381 | .749 | .797 | 11.183 | .000 | 6.846 | 9.916 |

## IV. CONCLUSION

The piling operation in this study has several variables, but the key variables considered were volume of soil extracted, volume of concrete poured, and weight of reinforcement cage. These quantities have been calculated theoretically and measured as used. It is believed that the volume of soil extracted will be equal to the volume of concrete used to replace it. However, it is not always so in actual sense. There are sometimes disparities between the theoretical and actual values. For this study, the disparities between them were as a result of the following:

i. The soil is granular with no cohesion and is therefore caving beyond the required diameter during drilling. This continues after drilling, thereby reducing the depth of drilled hole.
ii. The soil is totally submerged in water. This also makes the granular soil unstable within a void, thereby causing erosion on the walls of the drilled hole.
iii. The reinforcement cage was immediately inserted but could not completely fill the theoretical length as it has already been reduced by the above circumstances. However, the length was longer in very few cases. This was as a result of areas that were drilled beyond the required depth as a result of persistent drilling due to the continuous caving-in of extra soil.
iv. The same reasons for the reinforcement also apply to the concrete.

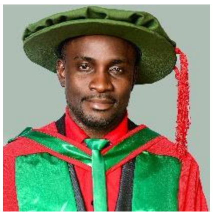
The entire operation encountered pockets of delays, which gave room for more disparities to occur. These disparities in turn negatively affected the durability, structural integrity, and safety of the piles. The formulated model will be used to optimize the time in order to overcome the problems of delay in pile construction operations. This justifies the objectives of this study. Additionally, the formulated model, now call “the Oba’s equation of time taken to construct a pile” was found to be fit, adequate, and have a high predictive accuracy.

It is recommended that the model developed in this study be used when planning and scheduling pile construction activities. The study was limited to the three variables considered above. It is, therefore, also recommended that further studies be carried out with other relevant key variables for pile construction operations.

## REFERENCES

[1] B. M. Das, Principles of Foundation Engineering, 7th ed. Stamford: Cengage Learning, 2011.
[2] V. N. S. Murthy, Geotechnical Engineering: Principles and practices of soil mechanics and foundation engineering. New York : Marcel Dekker Inc., 2002.
[3] R. L. (Robert L. Peurifoy, C. J. Schexnayder, and Aviad. Shapira, Construction planning, equipment, and methods. McGraw-Hill Higher Education, 2006.
[4] M. Budhu, Soil Mechanics and Foundations, 3rd ed. Danvers: John Wiley & sons incorporated, 2011.
[5] T. M. Zayed and D. W. Halpin, “Productivity and Cost Regression Models for Pile Construction,” J Constr Eng Manag, vol. 131, no. 7, pp. 779–789, 2005, doi: 10.1061/ASCE0733-93642005131:7779.
[6] T. M. Zayed, “Assessment of productivity for concrete bored pile construction,” Ph.D Thesis, Purdue University, West Lafayette, 2001.
[7] T. M. Zayed and D. Halpin, “Simulation of bored pile construction,” in Proceedings of the 2001 Winter Simulation Conference, B. A. Peters, D. J. Smith, J. S. Medeiros, and M. W. Rohrer, Eds., 2001, pp. 1495–1503.
[8] E. K. Zavadskas, S. Sušinskas, A. Daniunas, Z. Turskis, and H. Sivilevičius, “Multiple criteria selection of pile-column construction technology,” Journal of Civil Engineering and Management, vol. 18, no. 6, pp. 834–842, 2012, doi: 10.3846/13923730.2012.744537.
[9] C. Srijaroen, M. Hoy, S. Horpibulsuk, R. Rachan, and A. Arulrajah, “Soil–Cement Screw Pile: Alternative Pile for Low- and Medium-Rise Buildings in Soft Bangkok Clay,” J Constr Eng Manag, vol. 147, no. 2, Feb. 2021, doi: 10.1061/(ASCE)CO.1943-7862.0001988.
[10] K. M. Oba, “Cost, Time, and Quality factors: A case Study of the Rivers Monorail Construction Project,” IOSR Journal of Mechanical and Civil Engineering, vol. 15, no. 1, pp. 12–17, 2018.
[11] U.S. Dept. of the Navy, “Program Evaluation Research Task, Summary Report, Phase 1,” Washington DC, 1958.

## ABOUT THE AUTHOR



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