IJET International Journal of Engineering & Technology
CENTRE OF PROFESSIONAL RESEARCH PUBLICATIONS
ISSN 2049-3444

International Journal of Engineering and Technology Volume 3 No. 9, September, 2013

Capacity Analysis of a Bridge Abutment Piles by ICT Modelling Innovation

I. Akiije
Department of Civil and Environmental Engineering
Faculty of Engineering, University of Lagos, Akoka, Lagos, Lagos State, Nigeria

ABSTRACT

The goal of this study is to employ an innovation through Information and Communication Technologies (ICT) of a model-based simulation of the estimation a bridge abutment retaining wall piles capacity. In the process, novel analysis and design while using a general purpose application program that is sound, stable, readily available and adaptable with flexibility has been employed. Before the advent of microcomputer, it was in the culture of professionals, lecturers and students of engineering using the emerging trends of slide rules, four, five and seven figures tables, and pocket calculators while solving computational problems of analysis and design by conventional hand methodology. The advent of microcomputer gave way to the use of high-level programming languages such as FORTAN, C++ and MATLAB to mention very few for computations. One of the problems usually experienced while employing high-level programming languages is coding that is not similarly to the process of computation while solving analysis and design problems by the conventional hand method. The significance of this study is that Excel program has been used as spreadsheet that solved the problems of analysing the lateral, vertical and rotational deflections of the pile foundation, together with the determination of axial loads, shear loads and moments at each of the pile heads similarly with steps taken manually but speedily and economically in an electronics environment that is also amenable to internet.

Keywords: *Retailing Wall, Foundation, Simulation, Deflection, Loads, Spreadsheet, Excel*

1. INTRODUCTION

The use of an electronics calculator that is related to conventional hand approach or employing programming languages or using specific purpose application programs in the cause of determining bridge piles capacity is tedious, and costly. In this study, employing an innovation by Information and Communication Technologies (ICT) of a model-based with simulation of capacity estimation of a bridge abutment piles analysis and design using a general purpose application program that is sound, stable and adaptable with flexibility is introduced. Innovation is the development of new values through solutions that meet new requirements, inarticulate needs, or old customer, market and design needs in value by adding new ways or methodology as in Wikipedia (2013). Also, in the public, private, research and teaching contexts, innovation may be linked to positive changes in efficiency, productivity, quality, competitiveness, market share and design.

Before the advent of microcomputer, it is in the culture of professionals, lecturers and students of engineering using the emerging trends, slide rules, four, five and seven figures tables, and pocket calculators while solving computation of analysis and design problems as in Akiije (2007). Salge and Vera (2012) in their recent research findings highlighted the complementary role of organizational culture in enabling organizations to translate innovative activity into tangible performance improvements. Also, (Tahseen, 2013) claimed that the research on cultural impact and innovation is diverse and no agreed upon theoretical models have been forwarded that assesses the impact of organizational culture on the entire innovation process. Tahseen (2013) further asserted Sarros et al., (2008) for arguing that culture mediates the relationship between transformational leadership and organizational climate for innovation. Tahseen (2013) further declared Dunlop-Hinkler (2010) for pointing out that there is no dominant theory on innovation and by considering new challenges emerging there is an increasing need for more theorizing.

This study aims at an innovation in the modelling of the capacity estimation of a bridge abutment retaining wall piles while accomplishing it through a more effective Information and Communication Technologies (ICT) approach. Innovation refers here is geared towards the use of a spreadsheet program that gives a better result and it is considered a novel method than the use of scientific calculator that are both readily available while utilizing computer. It is pertinent to note that the use of scientific calculator during the capacity estimation of a bridge abutment piles is related to conventional hand methodology. ICT refers to technology that provides access to information through telecommunications and it is similar to information technology (IT), but focuses primarily on communication technologies. This includes the Internet, wireless networks, cell phone and other communication mediums. IT refers to anything related to computing technology, such as networking, hardware, software, the internet, or the people that work with these technologies as in Adedimila and Akiije (2006)

Specifically, the objective of this study includes the determination of vertical, lateral and rotational deflections of the pile foundation together with the axial loads, shear loads and moments at each of the pile heads by employing Microsoft Excel software. The purpose of this study is in the computation of the capacity analysis of a bridge abutment retaining wall piles by using spreadsheet while employing modelling and simulation approach.

Modelling in this study refers to the use of data models to conceptualize, analyse and design a bridge abutment retaining wall piles in ICT environment. In this study data modelling process is used to define and analyze data requirements needed to support the determination of the capacity estimation of a bridge abutment piles. In the process data modelling defines data models and their related analysis and design of structures. Simison and Witt (2005) claimed that conceptual, logical and physical data models are normally produced while progressing from requirements to the actual database of an information system development. Conceptual data model is essentially a set of technology independent specifications about the data and is used to discuss initial requirements. Logical data model can be implemented in databases to transform into documents of structures. Physical data model organizes the data into tables, and accounts for access, performance and storage details.

Simulation is the representation of physical systems and phenomena by computers, models, and other equipment as in Chambers (2007). Most engineering simulations entail mathematical modelling and computer assisted investigation. Benedettini and Tjahjono (2008) claimed that simulation can be used to predict the performance of an existing or planned system and to compare alternative solutions for a particular design problem. Banks et al., (2005) declared an important goal of simulation which is to quantify system performance through the effectiveness of scheduling and control systems. Key issues in simulation include acquisition of valid source information about the relevant selection of key characteristics and behaviours, the use of simplifying approximations, assumptions, fidelity and validity of the outcomes as in Sokolowski and Banks (2009).

Piles are relatively long and slender members used to transfer loads of a vertical or a lateral or a combination of same through weak soil or water to deeper soil or rock strata having a high bearing capacity as in (Tomlinson and Boorman, 2007) and (Murthy, 2008). Piles are also used in normal ground-conditions to resist heavy uplift forces and horizontal forces as in foundations of multi-storeyed buildings, transmission line towers, retaining walls, bridge abutments and dolphins as in Saran (2010). There are different types of piles according to (Saran, 2010) with the name derived from the related soil bearing stratum and their bearing end location. Bearing piles are the ones that pass through poor soil material with their tips getting to and penetrating a small distance into a stratum of good bearing capacity. Friction piles are installed in a deep stratum of limited supporting ability for the piles to develop their carrying capacity by friction on their sides. End bearing-friction piles get their load carrying capacity from the combination of point resistance and skin friction. Tension piles are used to resist upward forces or anchor down the structures such as building with basements below groundwater table, or buried tanks that are subject to uplift. Batter piles driven at an angle to the vertical are useful in case of large lateral loads. Short piles driven into ground compact loose granular soil deposits are called compaction piles. Piles passing through a swelling or consolidating layer are subjected to skin friction in the upward direction and are termed as negative skin friction piles.

There are five methods of installing piles according to (Tomlinson, 2007) besides Vibrated, Jetted and Tremie being mentioned by (Kaniraj, 2011) as follows:

1. Driven piles of preformed units, usually in timber, concrete, or steel are driven into the soil by the blows of a hammer.
2. Driven and cast-in-place piles formed are by driving a tube with a closed end into the soil, and filling the tube with concrete which may or may not be withdrawn.
3. Jacked piles are steel or concrete units that are jacked into the soil.
4. Bored and cast-in-place piles are formed by boring a hole into the soil and filling it with concrete.
5. Composite piles are combinations of two or more of the preceding methods of installation, or combinations of different materials in the same pile methodology.

The first three of the above types are sometimes called displacement method of installation. In all forms of bored piles, and in some forms of composite piles, the soil is first removed by boring a hole into which concrete is placed or various types of precast concrete or other proprietary units are inserted. This basic difference between displacement and non-displacement piles requires a different approach to the problems of calculating carrying capacity.

The conventional hand methodology of solving computational problem is tedious, time consuming and prone to errors due to fatigue. MATLAB, Maple, Mathematica, and MathCad are commercially available, sophisticated mathematical computation tools. Despite what their proponents may claim, no single one of these tools is the best as claimed in Moore (2007). It may be claimed that MATLAB is now replacing high-level languages such as C, C++ or FORTRAN in particular area of matrix computation, yet its use involves performing many programming tasks. Microsoft Excel is an electronic spreadsheet program in use with flexibility for storing, organizing and manipulating data such as formulas to perform mathematical calculations, matrix in particular, together with graphing in scientific, engineering and statistical analysis and design even with large numbers. An opened Excel document is a workbook with many worksheets laid out in columns of vertical and rows of horizontal cells to accept any data such as a large amount of texts, dates, numbers and formulas. While working with the workbook, formatting individual cell is possible in relationship to variable colour, varieties of size and type for border line and font.

The scope of work in this study is to investigate displacement method of installation of vertical and batter driven concrete piles supporting a bridge abutment in form of a retaining wall as shown in Figure 1.

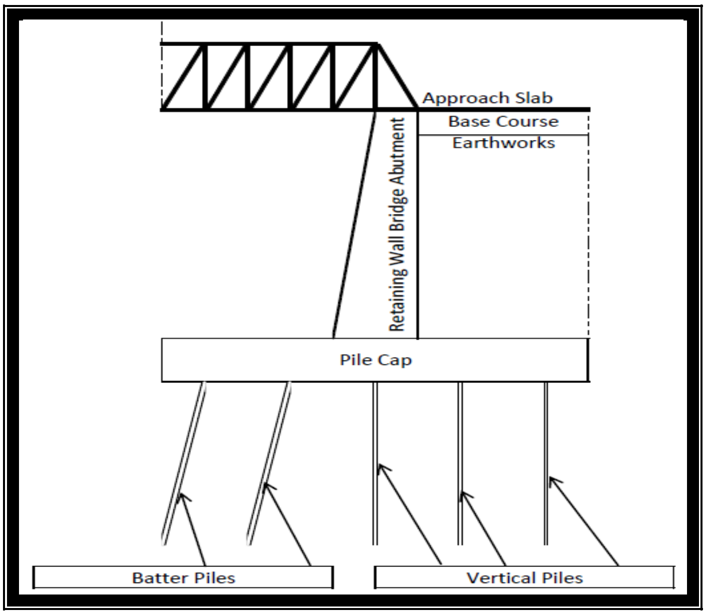

Figure 1: Bridge Abutment Retailing Wall Piles

This involves the capacity estimation computation of the bridge abutment piles of a cluster or group of piles to provide safe and economical foundation using Excel spreadsheet. It is important to note that the significance of this study is in the development of templates that are useful models to guide professional, scholars and readers while analysing and designing related bridge pile foundation projects in the cause of providing safe transportation system. The developed templates make similar computations easy and optimally while identifying, conceptualising, analysing and designing alternative solutions to measure favourably with standard specifications and of due economy.

2. MATERIALS

Figure 2 represents a foundation comprising vertical and batter piles. Hrennikoff (1950) suggested a method for analysis of pile foundations with vertical and batter piles subjected to external forces such as vertical load V, lateral load H, and moment M in relationship to Figure 2. The method of analysis in relationship to Figure 2 is that group 1 comprises n_l piles making an angle θ_1 with the foundation base. Also, group 2 comprises n_2 piles at an angle θ_2 while group 3 comprises n_3 piles at angle θ_3 and so on. Considering the total number of pile groups to be N then the any angle θ is measured from the positive direction of the X-axis clockwise to the given pile. Saran (2010) wrote on Assumptions, Pile Constants, Foundation Constants, Equations for Foundation Constants and Equilibrium of the Footing, Pile Displacements, and Pile Loads considered during the analysis put forward by Hrennikoff (1950).

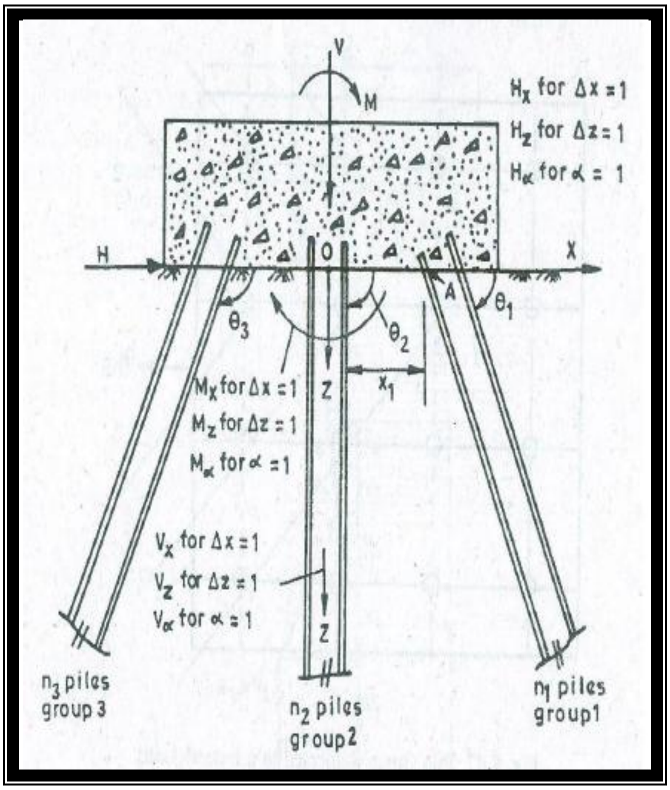

Figure 2: Pile Group Foundation

Source: Saran (2010)

Assumptions made are the following:

1. The pile cap in which the pile heads are rigidly embedded.
2. All piles behave alike with regards to the load deformation relation. The load carried by each pile is proportional to the displacement of pile head which consists of three components, namely, (a) the axial displacement δ_a, (b) the transverse displacement y_t and (c) the rotational displacement α.
3. The pile cap movements are small.
4. The problem is two-dimensional, that is, the piles, as well as the external forces, are arranged in planes transverse to the length of the foundation and they are symmetrical with regard to the transverse middle plane.

There are five pile constants that defined the forces with which the pile acts on the foundation when pile head is given a unit displacement. The five pile constants (K_a, m_t, K_t, m_α, K_α) are associated with the displacements δ_a , y_t and α . By Betti's reciprocal theorem as in Rajasekaran and Sankarasubramanian (2009) K_α = m_t resulting to only four independent constants characterising the load deformation relating to a pile when embedded in a footing. The four pile constants can be evaluated using the following equations.

$$K_a = \frac{AE}{L} \text{ for point bearing piles} \quad (1)$$

$$K_a = \frac{2AE}{L} \text{ for friction piles} \quad (2)$$

$$K_t = \frac{2.56EI}{A_y T^3} \quad (3)$$

$$m_t = \frac{2.35EI}{A_y T^2} \quad (4)$$

$$K_\alpha = \frac{3.54EI}{A_y T^2} \quad (5)$$

In the equations according to Saran (2010), A is the cross sectional area of the circular pile, E is the reinforced concrete pipe material modulus of elasticity assumed as $1.4\times10^7 kN/m^2$, I is moment of inertial of pile section the deflection coefficient A_y at ground level is 2.435 and T is relative stiffness factor.

$$T = \left(\frac{EI}{\eta_h}\right)^{\frac{1}{5}} \quad (6)$$

In Equation 6, the constant of modulus of subgrade reaction η_h is 3×10^4 kN/m^3 according to Saran (2010).

The foundation constants (H_x, V_x, M_x), (H_z, V_z, M_z), and (H_α V_α , M_α) are obtained by giving the foundation pile cap displacement $\Delta_x = 1$, $\Delta_z = 1$ and $\alpha = 1$ as shown in Figure 2. Only six independent constants are taken out of nine, based on Betti's reciprocal theorem for $H_z = V_z$, $H_\alpha = M_x$ and $M_z = V_\alpha$.

For full fixity of piles in the footing, equations for foundation constants considered are the following:

$$H_x = -\sum n\left(K_a \cos^2\theta + K_t \sin^2\theta\right) \quad (7)$$

$$H_z = -\frac{1}{2}(K_a - K_t)\sum n \sin 2\theta \quad (8)$$

$$H_\alpha = -\frac{1}{2}(K_a - K_t)\sum n\bar{x}\sin 2\theta + m_t\sum(n\sin\theta) \quad (9)$$

$$V_z = -\sum n\left(K_a \sin^2\theta + K_t \cos^2\theta\right) \quad (10)$$

$$M_z = -\sum\left(K_a \sin^2\theta + K_t \cos^2\theta\right)n\bar{x} - m_t\sum(n\cos\theta)) \quad (11)$$

$$M_\alpha = -\sum\left[\left(K_a \sin^2\theta + K_t \cos^2\theta\right)\sum x^2\right] - 2m_t\sum n\bar{x}\cos\theta - m_\alpha\sum n \quad (12)$$

After the determination of the foundation constants, the component displacements of the footing which are axial Δ_x, lateral Δ_z, and rotational α are determined from the following equations.

$$H_x\Delta_x + H_z\Delta_z + H_\alpha\alpha + H = 0 \quad (13)$$

$$H_z\Delta_x + V_z\Delta_z + V_\alpha\alpha + V = 0 \quad (14)$$

$$H_\alpha\Delta_x + V_\alpha\Delta_z + M_\alpha\alpha + M = 0 \quad (15)$$

Equations 13, 14 and 15 could be solved by matrix inversion approach thus.

$$[A]\{x\} = [B] \quad (16)$$

Where,

$$[A] = \begin{bmatrix} H_x & H_z & H_\alpha \\ H_z & V_z & V_\alpha \\ H_\alpha & V_\alpha & M_\alpha \end{bmatrix} \quad (17)$$

$$\{x\} = \begin{bmatrix} \Delta_x \\ \Delta_z \\ \Delta_\alpha \end{bmatrix} \quad (18)$$

$$[B] = \begin{bmatrix} H \\ V \\ M \end{bmatrix} \quad (19)$$

$$\{x\} = [A]^{-1}[B] \quad (20)$$

Matrix inversion $[A]^{-1}$ in Equation 20 used in the solution of the simultaneous equations for the determination of the component displacements could be obtained by several methods. Adjoint, Gauss-Jordan, Partitioning and Cholesky's methods were put forward by (Ural, 1973) for matrix inversions application claiming that Adjoint method among them only resulting to academic value more than a practical one while employing computer for solving simultaneous equations. He further claimed that Adjoint methodology is not meant to be incorporated in sophisticated computer programs. Moaveni (2008) discussed a procedure for solving matrix inversion based on the Lower Triangular, Upper Triangular (LU) Decomposition Method. He claimed that Gauss-Jordan would not handle any changes in the loads matrix much more efficiently like LU.

In this study, matrix inversion problem is solved while employing Microsoft Excel for the solution of the generated simultaneous equations while solving computation of pile foundation analysis and design. The methodology gave results of component displacements for both academic and practical values faster and easier than all methods put forward by Ural (1973) and Moaveni (2008). The determination of component displacements then leads to the computation of the displacements of the individual pile heads together with the axial, lateral and rotational pile loads. The downward longitudinal displacement δ_a of the pile head can be obtained using the following equation.

$$\delta_a = \Delta_x \cos\theta + \Delta_z \sin\theta + \alpha x \sin\theta \quad (21)$$

The transverse displacement y_t of the pile head to the right can be obtained using the following equation.

$$y_t = \Delta_x \sin\theta - \Delta_z \cos\theta - \alpha x \cos\theta \quad (22)$$

In the two equations angle θ is measured from the positive direction of the X-axis in clockwise way to the given pile.

The axial load of pile in compression V_g , can be obtained using the following equation.

$$V_g = K_a \delta_a \quad (23)$$

The transverse load H_g , acting on the foundation to the right can be obtained using the following equation.

$$H_g = -K_t y_t + m_t \alpha \quad (24)$$

The moment M_g , acting on a foundation clockwise can be obtained using the following equation.

$$M_g = -m_t y_t + m_\alpha \alpha \quad (25)$$

3. METHODOLOGY

In this study, the method of analysing the lateral, vertical and rotational deflections of the pile cap of a group of piles, together with the determination of axial loads, shear loads and moments at each of the pile heads is considered via the use of Excel. In line to the stated problems, Saran (2010) considered bridge abutment retaining wall supported on foundation comprising vertical and batter piles that are rigidly fixed to the cap as shown in Figure 3.

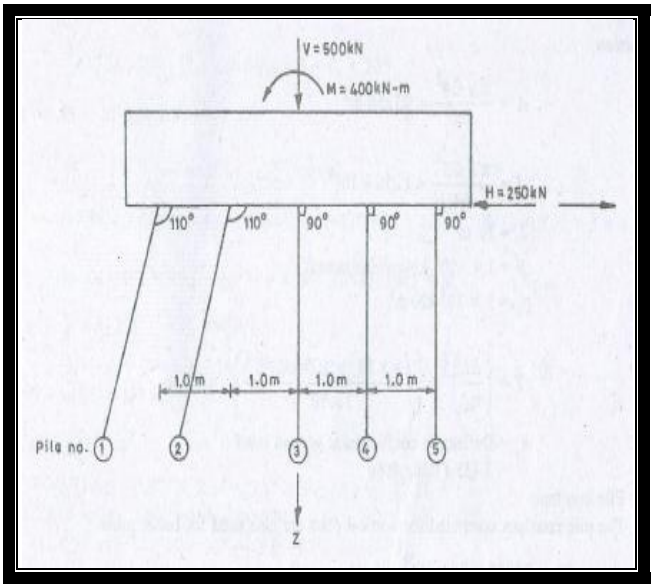

Figure 3: Pile Foundation

Source: Saran (2010)

The pile foundation per unit length of wall is subjected to vertical load V = 500 kN, horizontal load H = 250 kN and moment M = 400 kN m. The piles are spaced 1.0 m apart parallel to the face of wall. The number of piles per metre length of wall is five as shown in Figure 3. The piles are reinforced concrete piles of 400 mm diameter of length 10 m driven in medium dense sand. The constant of modulus of subgrade reaction η_h is given as $3 \times 10^4\ kN/m^3$.

Although the use of scientific calculator can solve the stated problem by conventional hand method, this study put forward the use of Microsoft Excel as ICT methodology in an electronics office. In the process, templates were created in form of modules in the opened book sheet while employing single or multiple cells for modelling and simulation paradigm thereby creating logical data models. Also, the templates created allow for the development and upgrading of physical data models. Created, analyzed and upgraded physical data models are automatically simulated in one second as the required results which are then used as foundation pile design while employing the developed templates. Tables 1 to 9 are the templates created by modelling approach for the purpose of analysing and designing piles for bridge abutment retailing wall comprising vertical and batter ones as shown in Figure 3. Table 1 exemplified length, diameter, arrangements, number location and moment of inertial of piles. Table 2 is illustrating the four forces of independent pile constants $K_a, K_t, m_\alpha, K_\alpha$, characterising the load deformations when piles are embedded into the footing. Table 3 demonstrated pile angle arrangements while Table 4 established pile distance arrangements. Table 5 is on the set up for the foundation constants forces whilst Table 6 showed footing component displacements modelling. Table 7 is on piles longitudinal displacements while Table 8 described piles transverse displacements. Table 9 expressed piles axial loads and Table 10 gave piles transverse forces. Finally, Table 11 instituted piles moments.

Table 1: Section Properties Modelling

	B	C	D
5	LABEL	MODELLING	UNIT
6	Pile Diameter, d	0.4	m
7	Pile Length, L	10	m
8	Modulus of Elasticity of Pile, E	14000000	kN/m^2
9	Constant of Subgrade Reaction, η_h	30000	kN/m^3
10	Deflection Coefficient for Lateral Load, A_y	2.435	
11	Area of Cross Section of Pipe, $A = \pi d^2 \div 4$	=PI()*C6^2/4	m^2
12	Moment of Inertial of Pipe, $I = \pi d^4 \div 64$	=PI()*C6^4/64	m^4
13	Relative Stiffness Factor, T = (EI/η_h)^0.2	=((C8*C12)/C9)^0.2	m
14	Number of Batter Piles	2	
15	Number of Vertical Piles	3	
16	Mean Distance of Batter Piles	=-(1+2)/2	m
17	Mean Distance of Vertical Piles	=(0+1+2)/3	m

Table 2: Pile Constants Modelling

	B	C	D
25	LABEL	MODELLING	UNIT
26	$K_a = (AE)/L$	=C11*C8/C7	kN/m
27	$K_t = (2.56\ EI)/(A_yT^3)$	=(2.56*C8*C12)/(C10*C13^3)	kN/m
28	$m_t = (2.35EI)/(A_yT^2)$	=(2.33*C8*C12)/(C10*C13^2)	kN m/m
29	$m_\alpha = (3.54EI)/(A_yT)$	=(3.54*C8*C12)/(C10*C13)	kN m/radians

Table 3: Pile Angle Arrangements Modelling

	B	C	D
35	LABEL	MODELLING	UNIT
36	Radian 110°	=22/7/180*110	Radians
37	Sin 110°	=SIN(C36)	Radians
38	Sin^2 110°	=SIN(C36)^2	Radians
39	Sin 2(110°)	=SIN(2*C36)	Radians
40	Cos 110°	=COS(C36)	Radians
41	Cos^2 110°	=COS(C36)^2	Radians
42	Radian 90°	=22/7/180*90	Radians
43	Sin 90°	=SIN(C42)	Radians
44	Sin^2 90°	=SIN(C42)^2	Radians
45	Sin 2(90°)	=SIN(2*C42)	Radians
46	Cos 90°	=COS(C42)	Radians
47	Cos^2 90°	=COS(C42)^2	Radians

Table 4: Pile Distance Arrangements Modelling

	E	F	G
49	LABEL	MODELLING	UNIT
50	Second left hand pile location, x_1	-2	m
51	First left hand pile location, x_2	-1	m
52	Centre pile location, x_3	0	m
53	First right hand pile location, x_4	1	m
54	Second right hand pile location, x_5	2	m

Table 5: Foundation Constants Modelling

	B	C	D
55	LABEL	MODELLING	UNIT
56	$H_x = -\sum n(K_a \cos^2\theta + K_t \sin^2\theta)$	=-(C14*(C26*C41+C27*C38) +C15*(C26*C47+C27*C44))	kN
57	$H_z = V_x = -½(K_a - K_t)\sum n \sin 2\theta$	=(-0.5*(C26-C27))* (C14*C39+C15*C45)	kN
58	$H_\alpha = M_x = -½ (K_a - K_t) \sum(n\, \bar{u} \sin 2\theta) + mt \sum(n \sin\theta)$	=-0.5*((C26-27)*(C14*C16*C39) +(C15*C17*C45))+C28* (C14*C37+C15*C43)	kN m/m
59	$V_z = -\sum n(K_a \sin^2\theta + K_t \cos^2\theta)$	=-(C14*(C26*C38+C27*C41) +C15*(C26*C44+C27*C46))	kN
60	$M_z = V_\alpha = -\sum(K_a \sin^2\theta + K_t \cos^2\theta)n\bar{u} - mt \sum(n \cos\theta)$	=-(((C26*C38+C27*C41)*C14*C16) +((C26*C44+C27*C47)*C15*C17)) -(C28*(C14*C40)+(C15*C46))	kN m
61	$M_\alpha = -\sum[(K_a \sin^2\theta + K_t \cos^2\theta)\sum x] - 2m_t \sum n\bar{u} \cos\theta - m_\alpha \sum n$	=-(C26*C38+C27*C41)*((-2)^2 +(-1)^2+(0)^2+(1)^2+(2)^2) -(2*C28*(2*C16*C40+3*1*0))-(C29*5)	kN m/ radians

Table 6: Footing Component Displacements Modelling

	B	C	D	E	F
81	LABEL		MODELLING		UNIT
82		=C56	=C83	=C84	
83	[A] =	=C57	=C59	=D84	
84		=C58	=C60	=C61	
85		=MINVERSE(C82:E84)	=MINVERSE(C82:E84)	=MINVERS E(C82:E84)	
86	$[A]^{-1}$ =	=MINVERSE(C82:E84)	=MINVERSE(C82:E84)	=MINVERS E(C82:E84)	
87		=MINVERSE(C82:E84)	=MINVERSE(C82:E84)	=MINVERS E(C82:E84)	
88			250		
89	[B] =		-500		
90			400		
91	LABEL		MODELLING		UNIT
92		Δ_x =	=MMULT(C85:E87,C88:C90)		m
93	$\{x\} = [A]^{-1}[B]$ =	Δ_z =	=MMULT(C85:E87,C88:C90)		m
94		α =	=MMULT(C85:E87,C88:C90)		radians

Table 7: Piles Longitudinal Displacements Modelling

	H	I	J	K	L	,
99	LABEL	Pile No.	$\Delta_x \cos\theta$ (m)	$\Delta_z \sin\theta$ (m)	$\alpha x \sin\theta$ (m)	δ_a (m)
100	MODELLING	1	=D92*C40	=D93*C37	=D94*F50*C37	=SUM(J100:L100)
101		2	=D92*C40	=D93*C37	=D94*F51*C37	=SUM(J101:L101)
102		3	=D92*C46	=D93*C43	=D94*F52*C43	=SUM(J102:L102)
103		4	=D92*C46	=D93*C43	=D94*F53*C43	=SUM(J103:L103)
104		5	=D92*C46	=D93*C43	=D94*F54*C43	=SUM(J104:L104)

Table 8: Piles Transverse Displacements Modelling

	H	I	J	K	L	M
110	LABEL	Pile No.	$\Delta_x \sin\theta$ (m)	$\Delta_z \cos\theta$ (m)	$\alpha x \cos\theta$ (m)	y_t (m)
111	MODELLING	1	=D92*C37	=D93*C40	=D94*F50*C40	=SUM(SUM(J111:L111))
112		2	=D92*C37	=D93*C40	=D94*F51*C40	=SUM(SUM(J112:L112))
113		3	=D92*C43	=D93*C46	=D94*F52*C46	=SUM(SUM(J113:L113))
114		4	=D92*C43	=D93*C46	=D94*F53*C46	=SUM(SUM(J114:L114))
115		5	=D92*C43	=D93*C46	=D94*F54*C46	=SUM(SUM(J115:L115))

Table 9: Piles Axial Loads Modelling

	H	I	J	K	L
119	LABEL	Pile No.	K_a (kN/m)	δ_a (m)	$K_a\delta_a$ (kN)
120	MODELLING	1	=C26	=M100	=J120*K120
121		2	=C26	=M101	=J121*K121
122		3	=C26	=M102	=J122*K122
123		4	=C26	=M103	=J123*K123
124		5	=C26	=M104	=J124*K124

Table 10: Piles Transverse Modelling

	H	I	J	K	L	M	N
130	LABEL	Pile No.	K_t (kN/m)	y_t (m)	m_t (kNm/m)	α (radians)	$(-K_t\,y_t + m_t\,\alpha)$
131	MODELLING	1	=C27	=M111	=C28	=D94	=-J131*K131+L131*M131
132		2	=C27	=M112	=C28	=D94	=-J132*K132+L132*M132
133		3	=C27	=M113	=C28	=D94	=-J133*K133+L133*M133
134		4	=C27	=M114	=C28	=D94	=-J134*K134+L134*M134
135		5	=C27	=M115	=C28	=D94	=-J135*K135+L135*M135

Table 11: Piles Modelling

	H	I	J	K	L	M	N
140	LABEL	Pile No.	m_t (kN m/m)	y_t (m)	m_α (kN m/m)	α (radians)	$(m_t\,y_t - m_\alpha\,\alpha)$
141	MODELLING	1	=C28	=M111	=C29	=D94	=J141*K141-L141*M141
142		2	=C28	=M112	=C29	=D94	=J142*K142-L142*M142
143		3	=C28	=M113	=C29	=D94	=J143*K143-L143*M143
144		4	=C28	=M114	=C29	=D94	=J144*K144-L144*M144
145		5	=C28	=M115	=C29	=D94	=J145*K145-L145*M145

4. RESULTS

Obviously, results obtained while employing spreadsheet approach introduced in this study were simulated automatically and instantly as modelling is finishing. Tables 6 to 11 modelling modules gave simulations of Tables 12 to 17 as the results of rotational deflection α , vertical displacement δ_a , lateral displacement y_t , axial load, transverse load and moments at each of the pile heads.

Table 12: Footing Component Displacements Simulation

	B	C	D	E	F
81	LABEL	SIMULATION			UNIT
82	[A] =	-162734.081	97172.153	-43652.374	
83		97172.153	-844248.692	-38736.887	
84		-43652.374	-38736.887	-1767694.515	
85	$[A]^{-1}$ =	-0.0000067	-0.0000008	0.0000002	
86		-0.0000008	-0.0000013	0.0000000	
87		0.0000002	0.0000000	-0.0000006	
88	[B] =	250			
89		-500			
90		400			
91	LABEL		SIMULATION		UNIT
92	$\{x\} = [A]^{-1}[B]$ =	Component Axial Displacement, Δ_x =	-0.001204267		m
93		Component Transverse Displacement, Δ_z =	0.000463116		m
94		Pile rotation, α =	-0.000206693		radians

Table 13: Piles Longitudinal Displacements Simulation

	H	I	J	K	L	M
99	LABEL	Pile No.	$\Delta_x \cos\theta$ (m)	$\Delta_z \sin\theta$ (m)	$\alpha x \sin\theta$ (m)	δ_a (m)
100	SIMULATION	1	0.00041	0.00044	0.00039	0.00124
101		2	0.00041	0.00044	0.00019	0.00104
102		3	0.00000	0.00046	0.00000	0.00046
103		4	0.00000	0.00046	-0.00021	0.00026
104		5	0.00000	0.00046	-0.00041	0.00005

Table 14: Piles Transverse Displacements Simulation

	H	I	J	K	L	M
110	LABEL	Pile No.	$\Delta_x \sin\theta$ (m)	$\Delta_z \cos\theta$ (m)	$\alpha x \cos\theta$ (m)	y_t (m)
111	SIMULATION	1	-0.00113	-0.00016	-0.00014	-0.00143
112		2	-0.00113	-0.00016	-0.00007	-0.00136
113		3	-0.00120	0.00000	0.00000	-0.00120
114		4	-0.00120	0.00000	0.00000	-0.00120
115		5	-0.00120	0.00000	0.00000	-0.00120

Table 15: Piles Axial Loads Simulation

	H	I	J	K	L
119	LABEL	Pile No.	K_a (kN/m)	δ_a (m)	$K_a\delta_a$ (kN)
120	SIMULATION	1	175929.18860	0.00124	217.47829
121		2	175929.18860	0.00104	183.31751
122		3	175929.18860	0.00046	81.60963
123		4	175929.18860	0.00026	45.24625
124		5	175929.18860	0.00005	8.88288

Table 16: Piles Transverse Simulation

	H	I	J	K	L	M	N
130	LABEL	Pile No.	K_t (kN/m)	y_t (m)	m_t (Kn m/m)	α (radians)	$(-K_t\,y_t + m_t\,\alpha)$
131	SIMULATION	1	25477.03669	-0.00143	20840.50302	-0.00021	32.16891
132		2	25477.03669	-0.00136	20840.50302	-0.00021	30.36404
133		3	25477.03669	-0.00120	20840.50302	-0.00021	26.38102
134		4	25477.03669	-0.00120	20840.50302	-0.00021	26.37769
135		5	25477.03669	-0.00120	20840.50302	-0.00021	26.37437

Table 17: Piles Moments Simulation

LABEL	Pile No.	m_t (kN m/m)	y_t (m)	m_α (kN m/m)	α (radians)	$(m_t\,y_t - m_\alpha\,\alpha)$
SIMULATION	1	20840.50302	-0.00143	28457.63909	-0.00021	-23.95619
	2	20840.50302	-0.00136	28457.63909	-0.00021	-22.47978
	3	20840.50302	-0.00120	28457.63909	-0.00021	-19.22163
	4	20840.50302	-0.00120	28457.63909	-0.00021	-19.21891
	5	20840.50302	-0.00120	28457.63909	-0.00021	-19.21618

5. DISCUSSION

The results obtained by using manual approach while utilising calculator as in Saran (2010) and that of using Excel spreadsheet of ICT methodology of this study compared favourably to each other as shown in Tables 18 to 21.

Table 18: Pile Rotational Deflections

LABEL	MANUAL (SARAN, 2010)	EXCEL (THIS STUDY)	UNIT
Component Axial Displacement, Δ_x =	-0.001198	-0.001204267	m
Component Transverse Displacement, Δ_z =	0.0004656	0.000463116	m
Pile rotational deflection, α =	-0.0002311	-0.000206693	radians

Table 19: Foundation Pile Displacements

Pile No	Vertical Displacement, δ_a		Lateral Displacement, y_t		UNIT
	MANUAL (SARAN, 2010)	EXCEL (THIS STUDY)	MANUAL (SARAN, 2010)	EXCEL (THIS STUDY)	
1	0.00128	0.00124	-0.00144	-0.00143	m
2	0.00106	0.00104	-0.001364	-0.00136	m
3	0.00047	0.00046	-0.00120	-0.00120	m
4	0.00023	0.00026	-0.00120	-0.00120	m
5	0.00003	0.00005	-0.00120	-0.00120	m

Table 20: Foundation Pile Loads

Pile No	Axial Loads, $K_a\delta_a$		Shear Loads, $(-K_t\, y_t + m_t\, \alpha)$		UNIT
	MANUAL (SARAN, 2010)	EXCEL (THIS STUDY)	MANUAL (SARAN, 2010)	EXCEL (THIS STUDY)	
1	225.376	217.47829	31.82	32.16891	kN
2	187.051	183.31751	25.60	30.36404	kN
3	81.85	81.60963	25.60	26.38102	kN
4	41.22	45.24625	25.60	26.37769	kN
5	0.60	8.88288	25.60	26.37437	kN

Table 21: Foundation Pile Moments

Pile No	Moments, $(m_t\, y_t - m_\alpha\, \alpha)$		UNIT
	MANUAL (SARAN, 2010)	EXCEL (THIS STUDY)	
1	-23.60	-23.95619	kN m
2	-21.95	-22.47978	kN m
3	-18.48	-19.22163	kN m
4	-18.48	-19.21891	kN m
5	-18.48	-19.21618	kN m

Considering footing component displacements simulation of Table 12, inverse matrix obtained is symmetrical which conformed to Maxwell-Betti theorem. Also, it is to be noted that the same theoretical steps were used for the foundation solutions to rotational deflection α, vertical displacement δ_a, lateral displacement y_t, axial load, transverse load and moments acting on piles while employing conventional hand approach and the use of Excel of ICT approach introduced in this study. The methodology introduced in this study requires no coding tasks as in programming languages before getting required results. However, the methodology introduced in this study favours speedy iteration process than the conventional hand method when optimization of design is in progress. This is particularly obvious when changing the values of vertical load, horizontal load, moment and size of the diameter of the pile is required urgently that is always a frequent characteristic to analysis and design of structures. Also, the minimum diameter pile size could be speedily obtained while optimising among various available piles.

6. CONCLUSION & RECOMMENDATIONS

The results obtained while employing Microsoft Excel spreadsheet that compared favourably with the conventional hand approach has shown that the methodology introduced here is a potential and useful improvement over manual means that are being taught in the universities and other institutions of higher learning. The improvement in accuracy of the required results, reduction in processing time and cost of computation as elicited by the new methodology introduced here while determining rotational deflection α, vertical displacement δ_a, lateral displacement y_t, axial load, transverse load and moments of bridge abutment retailing wall piles is meritorious. The simplification of creating modules that can be saved as template for further iterations and correcting computations of analysis and design as shown in this study is creditable and worthy of recommendation. The methodology introduced in this study is highly recommended to lecturers, students in the universities and higher institutions of learning, as well as professionals for it allows for improvement in designers' productivity as well as amenable to electronics offices and internet.

REFERENCES

[1] Wikipedia, (2013): 'Innovation.' The Free Encyclopedia, http://en.wikipedia.org/wiki

[2] Akiije, I. (2007): 'An Analytical and Autographic Method for Highway Geometric Design, Ph.D. Thesis.' School of Postgraduate Studies, University of Lagos, Akoka, Lagos

[3] Salge, T.O. and Vera, A. (2012): Benefiting from Public Sector Innovation: The Moderating Role of Customer and Learning Orientation.' Public Administration Review, Vol. 72, Issue 4, pp. 550-560

[4] Tahseen, A. A. (2013): 'Can Organizational Culture Influence Innovation? an Empirical Study on Organizational Culture

Characteristics and Innovative Intensity.' Scottish Journal of Arts, Social Sciences and Scientific Studies, Volume 10, Issue II: 2-17

[5] Sarros, J.C. Cooper, B.K. and Santora, J.C. (2008): 'Building a Climate for Innovation through Organizational Leadership and Organizational Culture.' Journal of Leadership and Organizational Studies, 15 (2) 145-158

[6] Dunlop-Hinkler, D. Mudambi, R. and Kotabe, M. (2010): A Story of Breakthrough and Incremental Innovation.' Strategic Entrepreneurship Journal, Discussion Paper, 1105-10

[7] Adedimila, A. S. and Akiije, I. (2006): 'National Capacity Development in Highway Geometric Design.' Nigerian Society of Engineers, V.I., Lagos

[8] Simison, G. C. and Witt, G. C. (2005): 'Data Modeling Essentials.' 3rd Edition, Morgan Kauffman Publishers

[9] Chambers. (2007): 'Dictionary of Science and Technology.' General Editor; Lackie, J., Chambers Harrap Publishers Ltd, 7 Hopetoun Crescent, Edinburgh, EH7 4AY

[10] Benedettini, O. and Tjahjono, B. (2008): 'Towards an Improved Tool to Facilitate Simulation Modelling Of Complex Manufacturing Systems.' International Journal of Advanced Manufacturing Technology 43 (1/2): 191-199

[11] Banks, J., Carson J., Nelson, B.L. and Nicol, D. (2005): 'Discrete-Event System Simulation.' 4th Edition, Pearson Prentice Hall, Upper Saddle River, NJ

[12] Sokolowski, J.A. and Banks, C.M. (2009): 'Principles of Modeling and Simulation.' Hoboken, NJ. Wiley

[13] Tomlinson, M. J. and Boorman, I. R. (2007): 'Foundation Design and Construction.' 8th edition, Pearson, Prentice Hall

[14] Murthy, V. N. S. (2008): 'Text Book of Soil Mechanics and Foundation Engineering.' CBS Publishers and Distributors, New Delhi

[15] Saran, S. (2010): Analysis and design of substructures limit state design, Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi, India

[16] Kaniraj, S. R. (2011): Design Aids in Soil Mechanics and Foundation Engineering.) Tata McGraw Hill Education Private Limited, New Delhi

[17] Moore, H. (2007): MATLAB for Engineers.' Pearson Prentice Hall, Pearson Education, Inc. Upper Saddle River, New Jersey

[18] Hrennikoff, A. (1950): Analysis of Pile Foundations with Batter Piles.' Transactions of American Society of Engineers, Vol. 115, Paper No.2401, p. 351

[19] Rajasekaran, S. and Sankarasubramanian, G. (2009): Computational Structural Mechanics.' PHI Learning Private Limited, M-97, Connaught Circus, New Delhi

[20] Ural, O. (1973): Finite Element Method.' Intext Educational Publishers, 257 Park Avenue South, New York

[21] Moaveni, S. (2008): 'Finite Element Analysis Theory and Application with ANSYS.' Pearson Education, Inc., Pearson Prentice Hall. Upper Saddle River, NJ