Republic of Iraq
Ministry f Higher
Education and Scientific Research
University of Technology
Building and construction Eng. Department

Effect of soil properties and pile dimension on bored pile using Allpile software

Annual project Submitted to Department of Building of and construction Engineering of the university of Technology in partial Fulfillment of Requirements for the Degree of B.Sc. in Road way and Bridge Engineering

Submitted by :

Mustafa Zuhair Abd Alhaleem

Supervised by :

Prof. Qais Taha Shlash

2011

بَسمِ اللهُ الرحمنَ الرحِيمَ

((يَرْفَع اللهُ ٱلَّذِين آمَنُوا مِنكُمْ وَٱلَّذِينَ
أوتُوا العِلمَ دَرَجَاتٍ وَاللهُ بِمَا تَعْمَلونَ
خَبِيرٌ))

صدق الله العظيم

سورة المجادلة آية 11

الاهداء

يامن ضحت بالروح والشباب لاجل عيني ......

ويامن تحملت العناء والحزن والعذاب لاجل عيني ......

ويامن ذرفت الدموع وخاضت الصعاب لاجل عيني ......

لاجل عينيك اهديك ثمرة جهدي وانحني لك حبا واحترام .

(امي الحبيبة ..)

الى من تعشق رؤيتهم عيني ......

وتغرم بأصواتهم أذني ......

وتسعد بلقائهم جوارحي .....

وتطمئن بهم نفسي ......

(اهلي واصحابي ..)

شكر وتقدير

اللهـــــم ربنا لك الحمد حمداً مع دوامك ..

وشكراً لا ينبغي إلا لكَ وحدكَ لاشريك لك

ولا رب سواك .. اللهـــــم كما مننت عليَّ بالنعم

فمنّ عليّ بالشكر لك

اتقدم بجزيل الشكر والامتنان الى الاستاذ الفاضل

أ.د. قيس طه شلاش على انجاز هذا العمل

TABLE OF CONTENTS

CHAPTER ONE: INTRODUCTION

CHAPTER TWO: PILE FOUNDATION

CHAPTER THREE: CALCULATION OF PILE CAPACITY

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

CHAPTER ONE
INRODUCTION

1-1 Definition:

Deep foundation is a Part of a structure used to carry and transfer the load of structure to the bearing ground located at some depth below ground surface. There are two types of deep foundation: Pile foundation and caissons. A pile foundation or a pile is statically indeterminate to a high degree hence empirical methods are used to analyze and solve its capacity.

Piles are used when:

1- When the load imposed by a building cannot he spread sufficiently over the available ground area and exceeding the bearing capacity of the soil .

2- When settlement would be greater than the acceptable values or Unpredictable and hard soil or reek can be reached economically.

3- When the building has to he founded on soils liable to shrinkage and swelling.

4- When building over water.

5- When there are tensional forces lending to overturn or lift the structure.

6- To resist lateral forces.

7- To underpin or strengthening existing foundations such as stiffening bridge, abutments and/ or piers.

1-2 Classification of Piles:

□ **Material:**

1. Steel piles
2. Concrete piles
3. Timber piles
4. Composite piles

□ **Load Transfer Mechanism:**

1. Point (End) bearing piles
2. Friction piles
3. Compaction piles

□ **Effect on Surrounding Soils**

1. Driven piles (displacement piles)
2. Bored piles (non-displacement piles)

1-3 AllPile Software:

is a Windows-based analysis program that handles virtually all types of piles, including steel pipes, H-piles, pre-cast concrete piles, auger-cast piles, drilled shafts, timber piles, jetted piles, tapered piles, piers with bell, micropiles (minipiles), uplift anchors, and shallow foundations.

One of the major advantages AllPile has over other pile software is that it combines most pile analyses in a single program. It calculates compression (with settlement), uplift, and lateral capacity all together. Users only need to input the data once instead of several times in different programs. AllPile makes pile analysis both economical and time-efficient. AllPile is suitable for all engineers, even those without too much pile analysis experience. It helps structural engineers choose soil parameters, and geotechnical engineers choose pile properties.

CHAPTER TWO

PILE FOUNDATION

CHAPTER TWO
PILE FOUNDATION

2-1 Pile Foundations:

Pile foundations are the part of a structure used to carry and transfer the load of the structure to the bearing ground located at some depth below ground surface. The main components of the foundation are the pile cap and the piles. Piles are long and slender members which transfer the load to deeper soil or rock of high bearing capacity avoiding shallow soil of low bearing capacity. The main types of materials used for piles are wood, steel and concrete. Piles made from these materials are driven, drilled or jacked into the ground and connected to pile caps. Depending upon type of soil, pile material and load transmitting characteristic piles are classified accordingly.

2-2 Historical:

Pile foundations have been used as load carrying and load transferring systems for many years. In the early days of civilization , from the communication, defense or strategic point of view villages and towns were situated near to rivers and lakes. It was therefore important to strengthen the bearing ground with some form of piling.

Timber piles were driven in to the ground by hand or holes were dug and filled with sand and stones.

In 1740 Christopher Polhem invented pile driving equipment which resembled to days pile driving mechanism. Steel piles have been used since 1800 and concrete piles since about 1900.

The industrial revolution brought about important changes to pile driving system through the invention of steam and diesel driven machines. More recently, the growing need for housing and construction has forced authorities and development agencies to exploit lands with poor soil characteristics. This has led to the development and improved piles and pile driving systems. Today there are many advanced techniques of pile installation.

2-3 Function of Piles:

As with other types of foundations, the purpose of pile foundations is:

a. to transmit a foundation load to a solid ground
b. to resist vertical, lateral and uplift load

A structure can be founded on piles if the soil immediately beneath its base does not have adequate bearing capacity. If the results of site investigation show that the shallow soil is unstable and weak or if the magnitude of the estimated settlement is not acceptable, a pile foundation may become considered. Further, a cost estimate may indicate that a pile foundation may be cheaper than any other compared ground improvement costs.

In the cases of heavy constructions, it is likely that the bearing capacity of the shallow soil will not be satisfactory, and the construction should be built on pile foundations. Piles can also be used in normal ground conditions to resist horizontal loads. Piles are a convenient method of foundation for works over water, such as jetties or bridge piers.

2-4 Classification of Piles

2-4-1 Classification of pile with respect to load transmission and functional behavior:

- End bearing piles (point bearing piles)
- Friction piles (cohesion piles)
- Combination of friction and cohesion piles
-

1. End bearing piles (point bearing piles)

These piles transfer their load on to a firm stratum located at a considerable depth below the base of the structure and they derive most of their carrying capacity from the penetration resistance of the soil at the toe of the pile (see figure 2.1). The pile behaves as an ordinary column and should be designed as such. Even in weak soil a pile will not fail by buckling and this effect need only be considered if part of the pile is unsupported, i.e. if it is in either air or water. Load is transmitted to the soil through friction or cohesion. But sometimes, the soil surrounding the pile may adhere to the surface of the pile and

causes "Negative Skin Friction" on the pile. This, sometimes have considerable effect on the capacity of the pile. Negative skin friction is caused by the drainage of the ground water and consolidation of the soil. The founding depth of the pile is influenced by the results of the site investigate on and soil test.

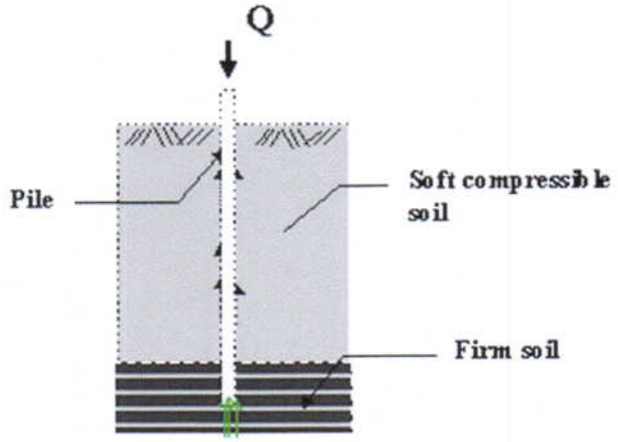


Fig. 2.1 End Bearing Piles

2. Friction piles or Cohesion piles

Carrying capacity is derived mainly from the adhesion or friction of the soil in contact with the shaft of the pile (see figure 2.2).

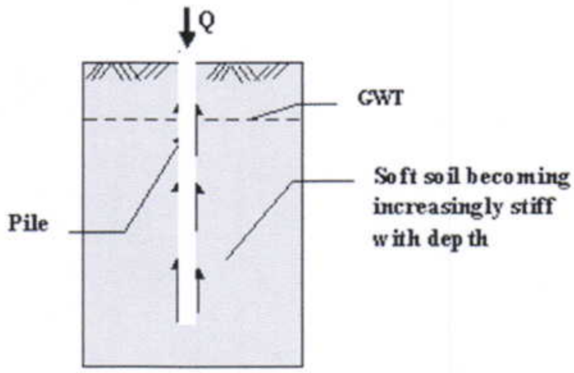


Fig. 2.2 Friction or cohesion pile

Cohesion Piles – these piles transmit most of their load to the soil through skin friction. This process of driving such piles close to each other in groups greatly reduces the porosity and compressibility of the soil within and around the groups. Therefore piles of this category are sometimes called compaction piles. During the process of driving the pile into the ground, the soil becomes molded and, as a result loses some of its strength. Therefore the pile is not able to transfer the exact amount of load which it is intended to immediately after it has been driven. Usually, the soil regains some of its strength three to five months after it has been driven.

Friction Piles – these piles also transfer their load to the ground through skin friction. The process of driving such piles does not compact the soil appreciably. These types of pile foundations are commonly known as floating pile foundations.

3. Combination of friction piles and cohesion piles

An extension of the end bearing pile when the bearing stratum is not hard, such as firm clay. The pile is driven far enough into the lower material to develop adequate frictional resistance. A farther variation of the end bearing pile is piles with enlarged bearing areas. This is achieved by forcing a bulb of concrete into the soft stratum immediately above the firm layer to give an enlarged base. A similar effect is produced with bored piles by forming a large cone or bell at the bottom with a special reaming tool. Bored piles which are provided with a bell have a high tensile strength and can be used as tension piles. (See figure 2.3).

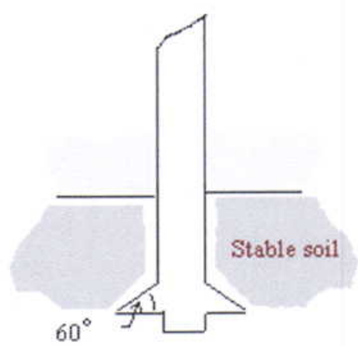


Fig.2-3 *Under-reamed base enlargement to a bore- and-cast-in-situ pile*

2-4-2 Classification of pile with respect to type of material:

1. Timber Piles

Used from earliest record time and still used for permanent works in regions where timber is plentiful. Timber is most suitable for long cohesion piling and piling beneath embankments. The timber should be in a good condition and should not have been attacked by insects. For timber piles of length less than 14 meters, the diameter of the tip should be greater than 150 mm. If the length is greater than 18 meters a tip with a diameter of 125 mm is acceptable. It is essential that the timber is driven in the right direction and should not be driven into firm ground as this can easily damage the pile. Keeping the timber below the ground water level will protect the timber against decay and putrefaction. To protect and strengthen the tip of the pile, timber piles can be provided with toe cover. Pressure creosoting is the usual method of protecting timber piles. (See figure 2.4).

Fig.2.4 *Timber Piles*

2. Concrete Piles

Pre-cast concrete Piles or Pre-fabricated concrete piles: Usually of square, triangle, circle or octagonal section, they are produced in short length in one meter intervals between 3 and 13 meters. They are pre-caste so that they can be easily connected together in order to reach to the required length. This will not decrease the design load capacity. Reinforcement is necessary within the pile to help withstand both handling and driving stresses. Pre stressed concrete piles are also used and are becoming more popular than the ordinary pre cast as less reinforcement is required. (See figure 2.5).

Fig.2.5*Precast Concrete Piles*

3. Steel Piles

Steel / Iron piles are suitable for handling and driving in long lengths. Their relatively small cross-sectional area combined with their high strength makes penetration easier in firm soil. They can be easily cut off or joined by welding. If the pile is driven into a soil with low pH value, then there is a risk of corrosion, but risk of corrosion is not as great as one might think. Although tar coating or cathodic protection can be employed in permanent works.

It is common to allow for an amount of corrosion in design by simply over dimensioning the cross-sectional area of the steel pile. In this way the corrosion process can be prolonged up to 50 years. Normally the speed of corrosion is 0.2-0.5 mm/year and, in design, this value can be taken as 1mm/year. (See figure 2.6).

Fig.2.6 Steel Piles

4. Composite Piles

Combination of different materials in the same of pile. As indicated earlier, part of a timber pile which is installed above ground water could be vulnerable to insect attack and decay. To avoid this, concrete or steel pile is used above the ground water level, whilst wood pile is installed under the ground water level. (See figure 2.7).

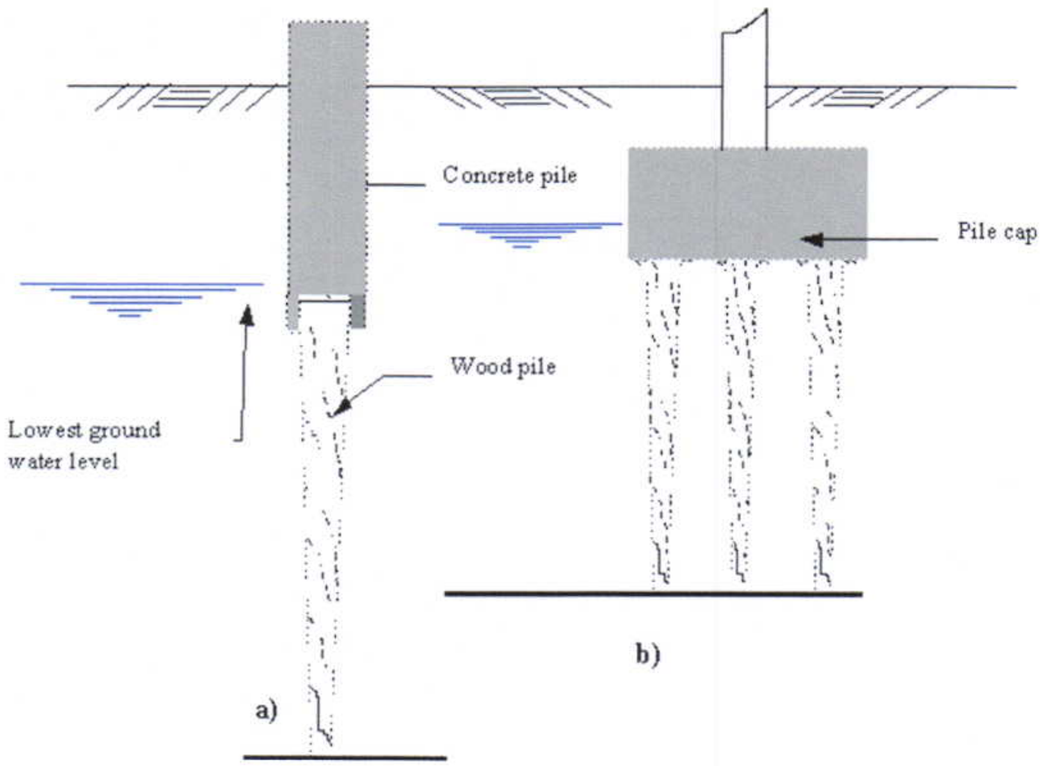


Fig2-7 Protecting timber piles from decay: a) by pre-cast concrete upper section above water level. b) By extending pile cap below water level

2-4-3Classification of pile with respect to effect on the soil:

1. Driven Piles

Driven piles are considered to be displacement piles. In the process of driving the pile into the ground, soil is moved radially as the pile shaft enters the ground. There may also be a component of movement of the soil in the vertical direction. (See figure 2.8).

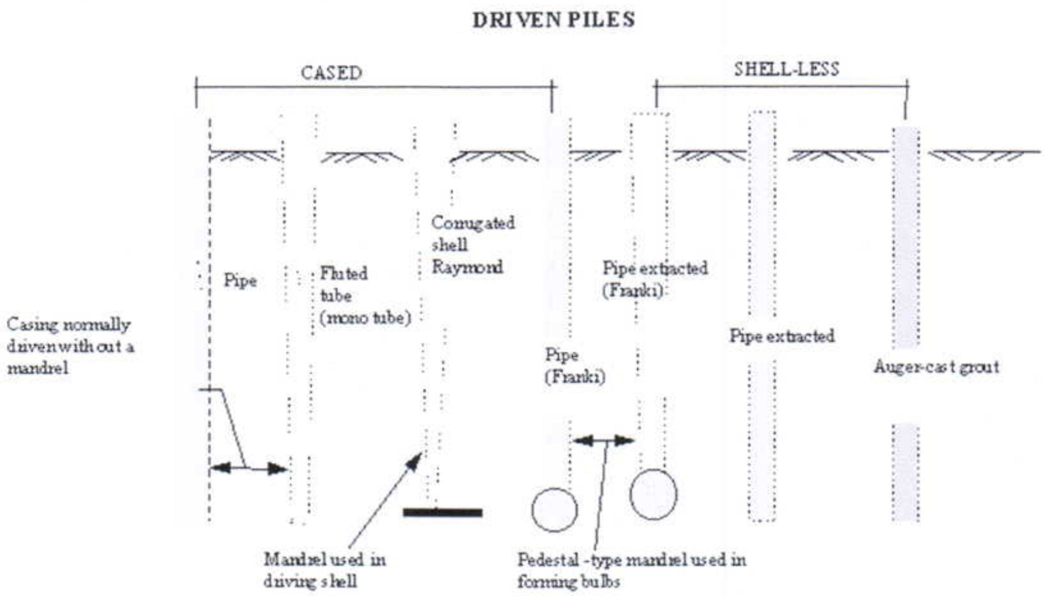


Fig2.8 Driven Piles

2. Bored Piles

Bored piles (Replacement piles*)* are generally considered to be non-displacement piles a void is formed by boring or excavation before piles is produced (see figure 2.9)... Piles can be produced by casting concrete in the void. Some soils such as stiff clays are particularly amenable to the formation of piles in this way, since the bore whole walls do not requires temporary support except cloth to the ground surface. In unstable ground, such as gravel the ground requires temporary support from casing or bentonite slurry. Alternatively the casing may be permanent, but driven into a hole which is bored as casing is advanced. A different technique, which is still essentially non-displacement, is to intrude, a grout or a concrete from an auger

which is rotated into the granular soil, and hence produced a grouted column of soil.

There are three non-displacement methods: bored cast- in - place piles, particularly pre-formed piles and grout or concrete intruded piles. (See figure 2.10).

The following are replacement piles:

a. Augured
b. Cable percussion drilling
c. Large-diameter under-reamed
d. Types incorporating pre caste concrete unite
e. Drilled-in tubes
f. Mini piles

Fig.2.9 Bored Piles

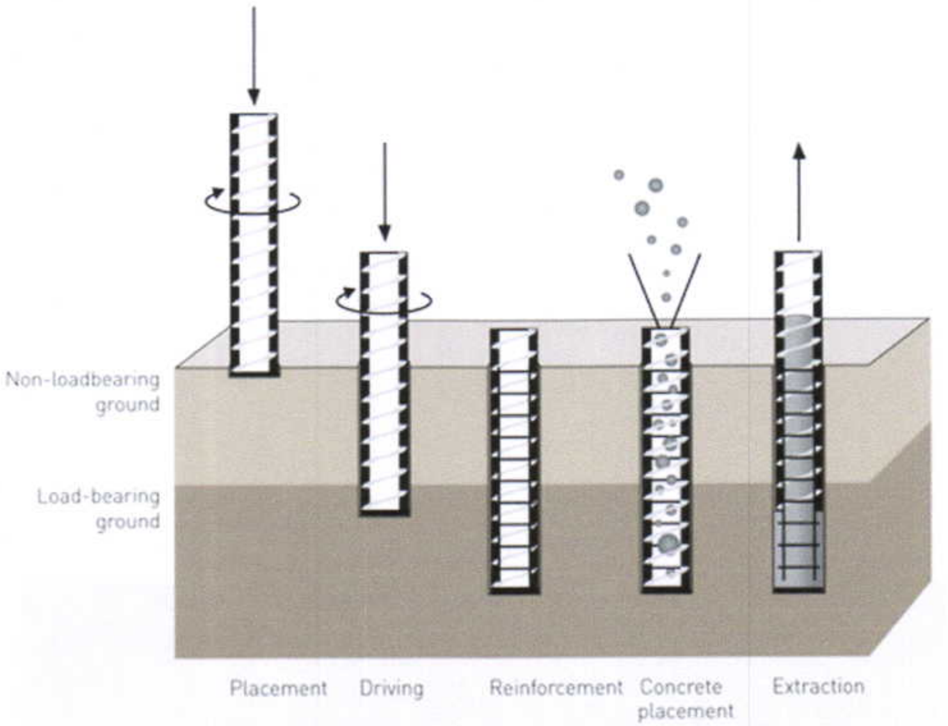


Fig.2.10 Non displacement method

2-5 Aides to Classification of Piles

Figure 2.11.For a quick understanding of pile classification, a hierarchical representation of pile types can be used as shown below:

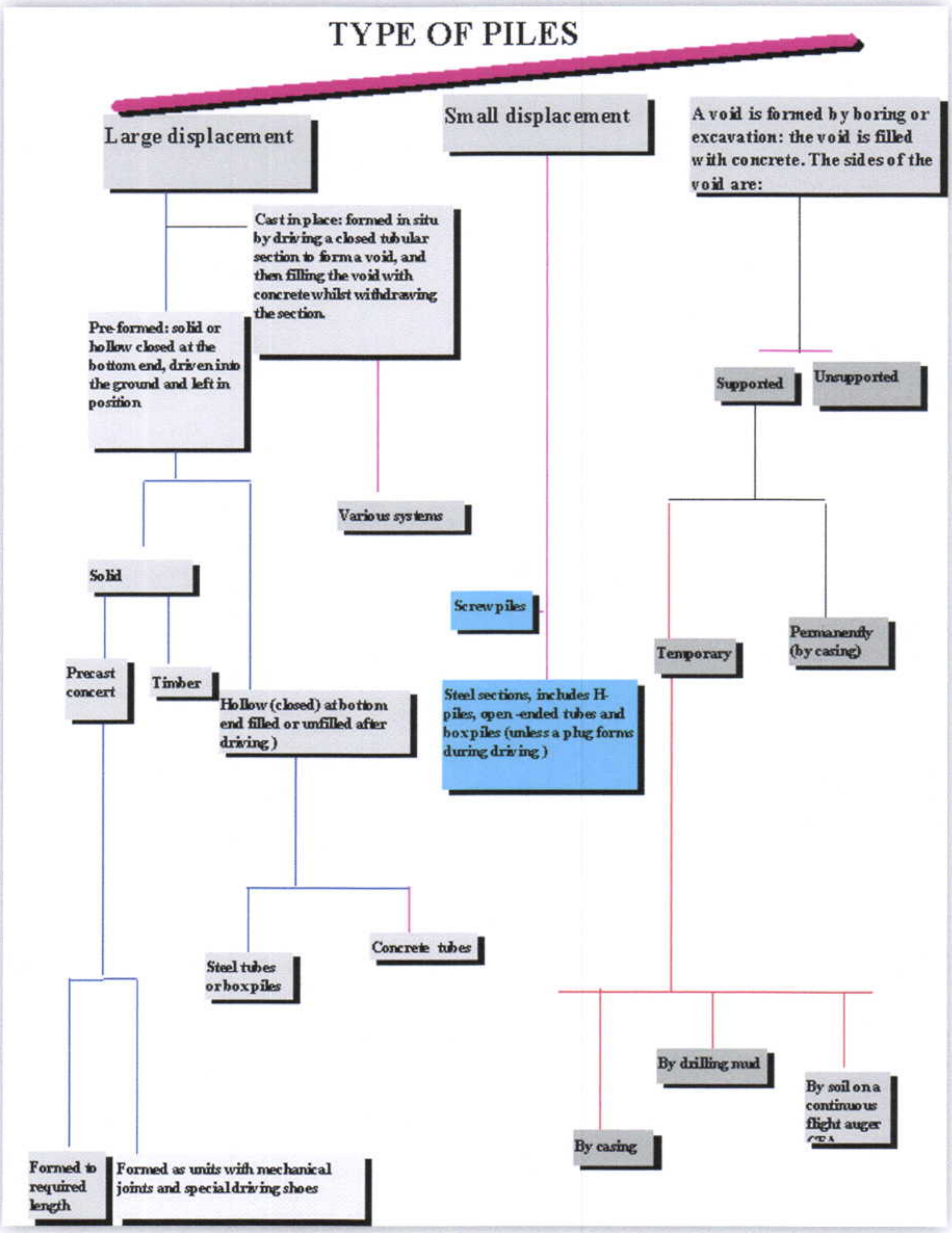


Fig.2.11 Hierarchical representation of pile types

2-6 Advantages and disadvantages of different pile material

❖ *Wood piles*

\+ The piles are easy to handle

\+ Relatively inexpensive where timber is plentiful.

\+ Sections can be joined together and excess length easily removed.

-- The piles will rot above the ground water level. Have a limited bearing capacity.

-- Can easily be damaged during driving by stones and boulders.

-- The piles are difficult to splice and are attacked by marine borers in salt water.

❖ *Prefabricated concrete piles (reinforced) and pre stressed concrete piles. (Driven) affected by the ground water conditions.*

\+ Do not corrode or rot.

\+ Are easy to splice. Relatively inexpensive.

\+ The quality of the concrete can be checked before driving.

\+ Stable in squeezing ground, for example, soft clays, silts and peats pile material can be inspected before piling.

\+ Can be re driven if affected by ground heave. Construction procedure unaffected by ground water.

\+ Can be driven in long lengths. Can be carried above ground level, for example, through water for marine structures.

\+ Can increase the relative density of a granular founding stratum.

-- Relatively difficult to cut.

-- Displacement, heave, and disturbance of the soil during driving.

-- Can be damaged during driving. Replacement piles may be required.

-- Sometimes problems with noise and vibration.

-- Cannot be driven with very large diameters or in condition of limited headroom.

❖ *Driven and cast-in-place concrete piles*

Permanently cased (casing left in the ground)

Temporarily cased or uncased (casing retrieved)

+ Can be inspected before casting can easily be cut or extended to the desired length.

+ Relatively inexpensive.

+ Low noise level.

+ The piles can be cast before excavation.

+ Pile lengths are readily adjustable.

+ An enlarged base can be formed which can increase the relative density of a granular founding stratum leading to much higher end bearing capacity.

+ Reinforcement is not determined by the effects of handling or driving stresses.

+ Can be driven with closed end so excluding the effects of GW

-- Heave of neighboring ground surface, which could lead to re consolidation and the development of negative skin friction forces on piles.

-- Displacement of nearby retaining walls. Lifting of previously driven piles, where the penetrations at the toe have been sufficient to resist upward movements.

-- Tensile damage to unreinforced piles or piles consisting of green concrete, where forces at the toe have been sufficient to resist upward movements.

-- Damage piles consisting of uncased or thinly cased green concrete due to the lateral forces set up in the soil, for example, necking or wasting. Concrete cannot be inspected after completion. Concrete may be weakened if artesian flow pipes up shaft of piles when tube is withdrawn.

-- Light steel section or precast concrete shells may be damaged or distorted by hard driving.

-- Limitation in length owing to lifting forces required withdrawing casing, nose vibration and ground displacement may a nuisance or may damage adjacent structures.

-- Cannot be driven where headroom is limited.

-- Relatively expensive.

-- Time consuming. Cannot be used immediately after the installation.

-- Limited length.

❖ *Bored and cast in -place (non -displacement piles)*

+ Length can be readily varied to suit varying ground conditions.

+ Soil removed in boring can be inspected and if necessary sampled or in- situ test made.

+ Can be installed in very large diameters.

+ End enlargement up to two or three diameters is possible in clays.

+ Material of piles is not dependent on handling or driving conditions.

+ Can be installed in very long lengths.

+ Can be installed without appreciable noise or vibrations.

+ Can be installed in conditions of very low headroom.

+ No risk of ground heaves.

-- Susceptible to "wasting" or "necking" in squeezing ground.

-- Concrete is not placed under ideal conditions and cannot be subsequently inspected.

-- Water under artesian pressure may pipe up pile shaft washing out cement.

-- Enlarged ends cannot be formed in cohesion less materials without special techniques.

-- Cannot be readily extended above ground level especially in river and marine structures.

-- Boring methods may loosen sandy or gravely soils requiring base grouting to achieve economic base resistance.

-- Sinking piles may cause loss of ground I cohesion-less leading to settlement of adjacent structures.

❖ Steel piles (Rolled steel section)

+ The piles are easy to handle and can easily be cut to desire length.

+ Can be driven through dense layers. The lateral displacement of the soil during driving is low (steel section H or I section piles) can be relatively easily spliced or bolted.

+ Can be driven hard and in very long lengths.

+ Can carry heavy loads.

+ Can be successfully anchored in sloping rock.

+ Small displacement piles particularly useful if ground displacements and disturbance critical.

-- The piles will corrode,

-- Will deviate relatively easy during driving.

-- Are relatively expensive.

CHAPTER THREE

CALCULATION OF PILE CAPCITY

CHAPTER THREE
CALCULATION OF PILE CAPACITY

3-1 Capacity of individual pile

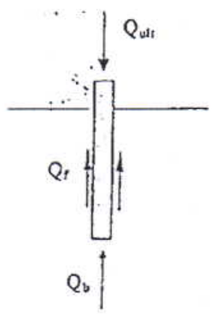
The capacity of a pile consists of two components the sum of which gives the load which can be carried by' .the pile just before failure. These components are:

a) End-bearing of the fip of the pile (Qb) which is derived from the soil surrounding the tip and lying beneath it and it is not mobilized unless the pile penetrates this soil for a reasonable depth (3×D).
b) Skin friction along the length of the pile *(Qf)* which is derived from the friction mobilized between the soil surrounding the pile and the pile material.

The two components are mobilized in any pile but their quantities depend on soil properties, length and diameter of pile, type of pile and its method of installation
hence:

$$(Q_p)ult. = Q_b + Q_f$$

$$(Q_p)all. = \frac{Q_{ult.}}{F.S} = \frac{Q_b}{F.S} + \frac{Q_f}{F.S}$$



3-2 Pile capacity from static formula:

All static pile capacity depends on the soil properties and the ultimate capacity of a single pile computed from the summation of the ultimate shaft resistance (Q_f) and ultimate base resistance (Qb) .

In general

$$(Q_p)ult. = Q_b + Q_f$$

Q_b : *bearing capacity*
Q_f: *shaft resistance*

3-2-1 Bearing capacity of pile in sand :

Qb value is calculated from the following equations :

1- Berezantzev equation (1961):

$$Q_b = \grave{q}.N\grave{q}.Ab$$

$\grave{q}$: *Effective over burden pressure at the tip of pile .*

Ab: *bearing area of tip of pile .*

$N\grave{q}$: *bearing factor from fig.(a) ,(b). These values should not be used unless $h_b \geq 5 \times D$ so that full mobilization reached . for fig (b)the ∅angle should be modified*

$$\emptyset = \frac{\emptyset_1 + 40}{2} \; For\ driven\ pile$$

$$\emptyset = \emptyset_1 - 3 \; For\ bored\ pile$$

$\emptyset_1$: *angle of internal friction*

2- <u>Meyerhof equation (1976):</u>

$$Q_b = [C.Nc + \dot{q}.N\dot{q}].Ab \text{ (used for all types of soil)}$$

$Nc, N\dot{q}$: From fig (16-14)

Procedure:

- Compute $R_1 = \frac{hb}{B} = \frac{L}{B}$ $(for\ uniform\ layer)$
- Obtain $R_2 = \frac{Lc}{B} = \frac{(hb)c}{B}$ $(from\ fig. 16-14.)$
- If $R_1 \geq 0.5\ R_2\ and\ \emptyset \leq 30\ use\ N\grave{c}\ , N\dot{q} from\ upper\ curves$
- If $R_1\ \leq 0.5\ R_2 and\ \emptyset \leq 30\ \ use\ interpolation$
  $N\ddot{q} = Nq + (N\dot{q} - Nq).(\frac{R_1}{0.5\ R_2})$
  $N\ddot{c} = Nc + (N\grave{c} - Nc).(\frac{R_1}{0.5\ R_2})$
  Where : Nq and Nc taken from lower curves
  Nq̇ and Nc̀ taken from upper curves
  Nq̈ and Nc̈ used in eq. of Qb
- If $\emptyset > 30°\ use\ reduced\ curves\ for\ appropriate\ R_1$
- If $R_1 \leq R_2\ and\ \emptyset = 0\ , c = 0\ (cohesionless\ soils)$
  $Q_b = \dot{q}.N\dot{q}.Ab$
- If $R_1 > R_2$ then the penetration exceeds the critical and limitation is applied for the $N\dot{q} - term$:
  $Q_b = q.N\dot{q}.Ab\ \leq 50N\dot{q}\tan\emptyset Ab$

<u>Note</u>: $(Q_b)bored = \frac{(Q_b)driven}{3}$

3-2-2Shaft Resistance for pile in sand (cohesionless) :

In general

$$(Q_f)ult. = \acute{\sigma}_{av.}.Ks \tan\delta \; As = f \; As$$

f : *unit friction along the shaft (kpa)*
As: *surface area of pile within the sand layer*
$\acute{\sigma}_{av.}$: *average overburden pressure on shaft*

The $(Ks \tan\delta)$ term can be determined using one of the following for piles in sand :

1- Brom's: for driven piles in sand use the table below :

	Ks		δ
Type	loose	Dense	
Steel	0.5	1.0	20°
Concrete	1.0	2.0	3\4 ∅°
Timber	*1.5*	*4*	2\3∅°

- *This table is used for sandy soils only*
- *For bored pile use (Ks)loose for all types of soil*

2- Vesic's and Meyerhof :

For driven piles vesic gave a figure to determine $(Ks \tan\delta)$ (see fig 4- b)

- In using fig 4 $\grave{\sigma}_{av.}$ Has limiting value depending on penetration into the sand layer (Z_c) below which $\grave{\sigma}_{av.}$ Reches a constant value Z_c/D is given in Fig 4-a .

- For layered soils the critical depth Z_c refers to the position of pile embedded in the sand .

- For bored piles in sand vesic's figure for $(Ks \tan\delta)$ cannot be used .use Meyerhof 's figure (fig 4-c)

- In fig 4 $\emptyset_a{}^\circ = \delta^\circ$

- In using this figure $\emptyset_1$ is the given angle of friction $\emptyset^\circ$is calculated for fig 4-a-b as:

$\emptyset^\circ = \frac{3}{4}\emptyset_1 + 10$ $\quad$ $(for\ driven\ pile\ )\ (for\ fig\ 4 - a\ and\ b)$

$\emptyset^\circ = \emptyset_1 - 3$ $\quad$ $(for\ fig\ 4 - a\ for\ bored\ piles\ )$

$\emptyset^\circ = \emptyset_1$ $\quad$ $(for\ bored\ piles\ )$

3- Terzaghi's : Terzaghi assumes :

$$(Q_f)ult. = \ \grave{\sigma}_{av.}.Ks \tan\delta\ As = f\ As$$

Where $\delta = \emptyset$ *and*

K = 1 for bored piles $\qquad$ *k = 3 for driven piles*

3-2-3 Bearing capacity of pile in clay:

$$Q_b = Cu.N\grave{c}.Ab$$

Where:

Cu: undrained shear strength of clay

Nc̀: End bearing factor = 9 for $\emptyset = 0$ and penetration $h_b > 5D$

If $h_b < 5D$ Nc̀ = 5.4 -8.5

Ab: bearing area of pile

For drained condition in stiff clay ($\emptyset > 0$) use :

$$(Q_b)ult = (Cu.N\grave{c} + q.N\grave{q})Ab$$

Nc̀ , Nq̀: From Meyerhof's curve (fig. 16-14)

3-2-4 Shaft Resistance for pile in clay (cohesive soil) :

$$(Q_f)ult. = (\grave{\sigma}_{av.}.Ks\tan\delta + \alpha c_u)\ As$$

$$(generally\ if\ c\ and\ \emptyset\ exists)$$

$\grave{\sigma}_{av.}$: average overburden pressure along the shaft length

$$\delta = \frac{2}{3}\emptyset$$

Ks = k_o for driven pile in normally consolidated clay

= 1.5 k_o for driven piles in stiff clay

K_s for bored pile = ½ k_s for driven pile

$$K_o = (1 - \sin\emptyset)\sqrt{OCR}$$

For saturated clay ($\emptyset = 0$) the first term = 0

$$(Q_f)ult. = \alpha. c_u. As$$

Cu: undrained shear strength of clay
As: surface area of pile within the clay layer

α : Adhesion factor of clay can be obtained for driven piles from the following :

1- Using Fig.5 by choosing one of the curves for different researchers. This curve could be used for any clay soil (i.e c- soil or c - Ø soils).

2- Using Fig. 6 by Tomlinson for piles in clay. To use this figure-(table or curves) we first obtain the penetration ratio into the clay layer $R = \frac{hf}{D}$, then if R≤ 20 use table choosing the correct case from the three cases shown in the figure. If R > 20 use curves choosing the correct case.

** If these cases do not apply use Fig.5 for α •
** For bored piles $\alpha = 0.45$

** For soft clay and sensitive clays $\alpha = 1$ even for bored piles.
** Use Fig.5 for H- piles
** For under-reamed bored piles $\alpha = 0.3$

3-2-5 Bearing capacity in c- Ø soils:

Drained condition of clay and other types of soil showing both friction and cohesion characteristics
In general

$$Q_{ult} = Q_b + Q_f$$

$(Qb)_{ult} = (CNc' + qN_q')\ Ab$

use Meyerhof's curves (Fig.3) for Nc' and Nq' as described.

$$(Q_f)ult. = (\acute{\sigma}_{av.}.Ks\tan\delta + \alpha c_u)As$$

use K_s and δ as for clay for the first term and use α from fig. 5 for driven piles

** For bored piles α = 0.45

3-2-6 Allowable capacity of individual pile :

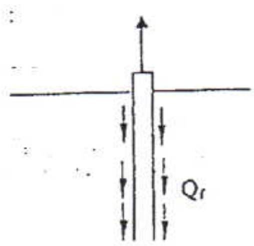
$$Q_{all} = \frac{Q_{ult}}{F.S} = \frac{Q_b + Q_f}{F.S} \qquad F.S = 2.5 - 3$$

$$if\ F.S = 2.5\ then\ check \rightarrow\ Q_{all} = \frac{Q_b}{3} + \frac{Q_f}{1.5}$$

3-3 Uplift pile :

If the net force on individual pile is a tension force then the pile must resist the tension which is done by the pile weight and the shaft resistance of the pile hence:

$$(Q_{uplift})_{ult} = (Q_f)_{ult} + w_p$$

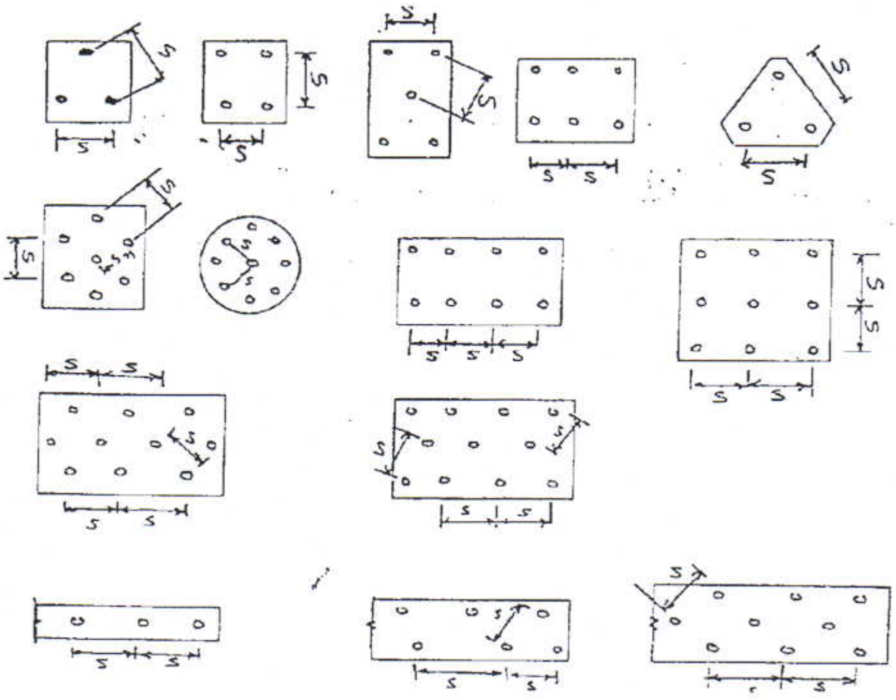


$$(Q_{uplift})_{all} = \frac{(Q_{uplift})_{ult}}{F.S} \qquad F.S \geq 3$$

Q_f is calculated as stated previously for compression piles.

3-4 Pile group :

A piled foundation usually consists. of a group of pile installed fairly close together and joined by a slab, known as the pile cap cast on top of the piles. Typical arrangements of piles are shown below



Suggested minimum spacing between piles of a group

Pile condition	Minimum spacing c/c
Point bearing piles on hard or dense stratum	2.5D or 80cm
Friction piles	*3D or 110 Cm*

There are two types of pile groups:

1- A free standing group in which the pile cap is not in contact with the underlying soil.
2- A piled foundation in which the pile cap is in contact with the underlying soil.

For both types it is customary to relate the ultimate load capacity of the group to the load capacity of a single pile through an efficiency factor (Eg) since the capacity of a group is not necessarily .

equal the sum of the capacities of the piles in the group but sometimes its less or greater as will be seen later. Hence in general:

$$Eg = \frac{ultimate\ load\ capacity\ of\ group}{sum\ of\ ultimate\ load\ capacity\ of\ individual\ piles}$$

$$= \frac{(Q_u)group}{(Q_u)pile\ \times n}$$

n= number of piles in the group

The efficiency (Eg) is influenced by:

a-· The sequence and number of soil strata.
b- Nature of soil (sand or clay).
c- Load per pile
d- Spacing of piles.
e- Number or-piles in the group.
f- Method of installation including sequence of pile construction.

3-4-1 Pile groups in clay :

For pile groups in clay (i.e friction piles) the efficiency is unity at relatively large spacing but decreases as the spacing decreases because of overlapping in the bulb of stress of the closely spaced piles. And since the installation of piles in clay decreases the
shear strength of surrounding soil (driven and bored) .

Hence the efficiency (E_g) of a pile group in clay is less than (1) for spacing less than 3D and increases as(S> 3D) until it reaches unity. The efficiency can be calculated as:

1- The Converse Labarre Formula

$$Eg = 1 - \frac{\theta}{90}\left[\frac{(n-m)m+(m-n)n}{Mn}\right]$$ for rectangular configuration

where

n = number of piles in a row.

m = number of rows.

mn = number of piles in the group

$$\theta = tan^{-1}\frac{D}{s} \ (in\ degrees)$$

D = pile diameter

s = *pile* spacing (all spacing must be equal)

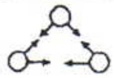
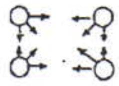
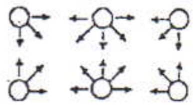
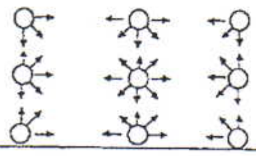
** It may be concluded that higher efficiency factors can be obtained for:

a- Piles having smaller length- diameter ratios.

b- Larger spacing.

c- Smaller numbers of piles in the group.

2- <u>The Feld efficiency factor (Eg):</u> Feld assumed that each pile reduces the capacity of the adjacent pile by (1/16) .

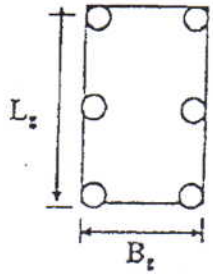
2		$\frac{2}{2}\times\frac{15}{16}$ or 0.938
3		$\frac{3}{3}\times\frac{14}{16}$ or 0.875
4		$\frac{4\times\frac{13}{16}}{4}$ or 0.815
6		$\frac{4\times\frac{13}{16}+2\frac{11}{16}}{6}$ or 0.77
9		$\frac{4\frac{13}{16}+4\frac{11}{16}+\frac{8}{16}}{9}$ or 0.722

This empirical formula can be used for any configuration.

To estimate the group - load capacity in clay as stated by Terzaghi and Peck the group capacity is the lesser of a or b below:

a- Block failure: if the spacing is very small (less than the critical 3D) the group will fail as a block i.e as a large pile having the dimension of the pile group (see Fig.) since the clay within the piles will slip with the piles and the capacity of this block can be estimated as follows :

$$(Q_{group}) = Q_b + Q_f$$
$$= B_g.l_g.c.Nc + 2(B_g + l_g)L\grave{c}$$



where:
c = undrained cohesion at base of group.
L = length of piles.
$B_g . l_g$ = length and width of group.
N_c = bearing capacity factor = 9
$\grave{c}$ = average cohesion between surface 'and depth L.

As the spacing increases this failure will not occur and the piles in the group will fail individually and type b will be more probable.

b- The group capacity is the sum of the ultimate capacities of individual piles in the group (taking E_g into consideration).

$$(Q_{group})_{ult} = (Q_p)_{ult} \, . n \, . Eg$$

n = number of piles , E_g = efficiency

** The efficiency is less than (1) for piles in clay or for friction piles (Qf > Qb) and must be found by one of the formulae.

The allowable capacity of a group can be determined using a suitable *F.S* (2.5 - 3)

$$(Q_{group})_{all} = \frac{(Q_{group})_{ult}}{F.S}$$

3-4-2 Pile groups in sand :

When installing piles so that it penetrates through a soft soil into a sandy or gravely soil the major part of the capacity comes from the bearing component (end bearing piles) and the skin friction is small. For such groups the efficiency of the group will be sometimes greater than (1) and for safety is taken (1). The maximum efficiency is obtained at (s= 2D to 3D) and ranges from 1.3 and 2 because the driving of the piles will cause compaction of the sand surrounding the piles and the group capacity is greater than the sum of the individual pile capacities.

$$(Q_{group})_{ult} = (Q_p)_{ult} \,.\, n \,.\, Eg \qquad (Eg = efficiency)$$

*$(Q_p)_{ult}$ = capacity of single pile

** There is no block failure in Sand.

** E_g = 1 for piles completely in sand or resting in sand or granular soils (bearing piles).

** E_g should be calculated for piles completely in clay.

3-5 Pile dynamic formulae :

General Notes:

1- *To* be used with sand, gravel and hard clay

2- Resistance to driving α Pile capacity (end bearing Q_b) .To find Q_s assume Q_s=0.1 to 0.2 Qb

3- The total downward energy is consumed by work done in penetrating the pile and by certain losses.

4- Soil resistance to dynamic penetration of pile is the same as the penetration of pile under static or sustained loading.

General Equation

Energy Input = Energy Used +Energy Lost

$(W)(h)(\eta) = (R)(S) + (R)(C)$

where

W : weight of hammer (or ram)

h : effective height of fall

H : Tote: height of fall

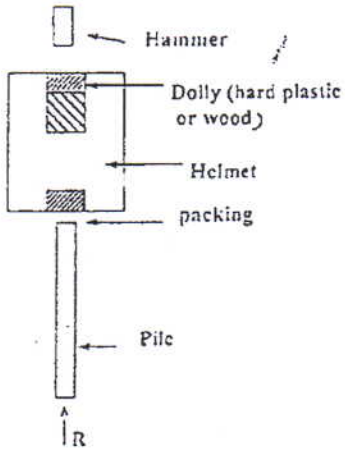
K : energy reduction factor

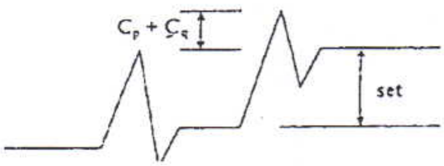
η : efficiency of blow of hammer

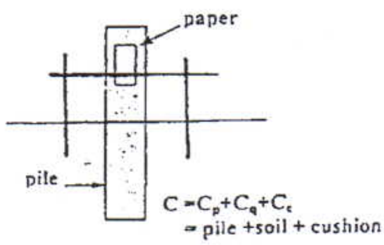
R : soil resistance $=Q_b$

S : set per blow

C : elastic compression of pile, soil, and cushion.







Energy News Formula:

$$R_a = \frac{2E}{S+C}$$

R_a : allowable pile capacity

E : energy of hammer per blow = W x h x η

C : 0.1 inch

S : set per blow (inch)

Boston Building Code Formula

$$R_a = \frac{1.7E}{s + 0.1\sqrt{\frac{w_p}{w_r}}}$$

w_p : weight of pile
w_r : weight of ram (hammer)
min $w_p / w_r \geq 1.0$

Hilev Formula :

$$R_u = \frac{w \times h \times \eta}{s + \frac{c}{2}}$$

w : weight of ram or hammer
h : effective height of fall = K * H
K :cocfficicnt (type of hammer)
H : actual height of blow
η : efficiency of blow (graph GI)
= depends on e and p/w
e : coefficient of restitution (table G2)
p : weight of pile + helmet + dolly + packing etc.
S : set per blow
C : C_c - C_p +C_q
C_c : temporary compression of dolly and packing (graph G2)
C_p : temporary compression of pile (graph G 3. G4. G5)
C_q: temporary compression of ground (quake) (graph G6)

3-6 Charts and Figures :

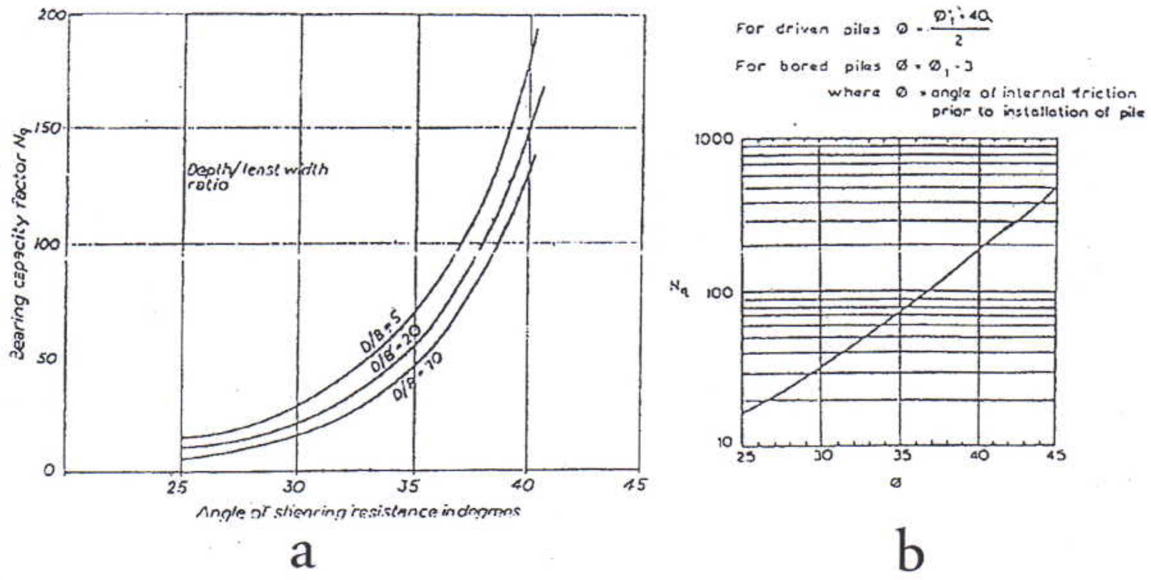


Fig 1 .Bearing capacity, Nq (Berezantsev's)

Fig 4

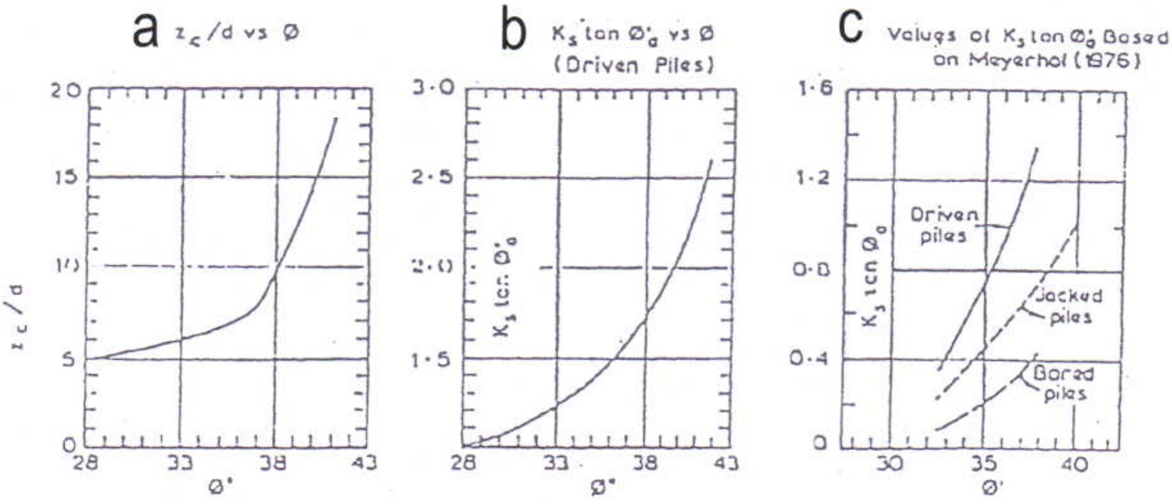


Fig 4 . for determine Zc\D , $Ks \tan \delta$ (Vesic's & Meyerhof's)

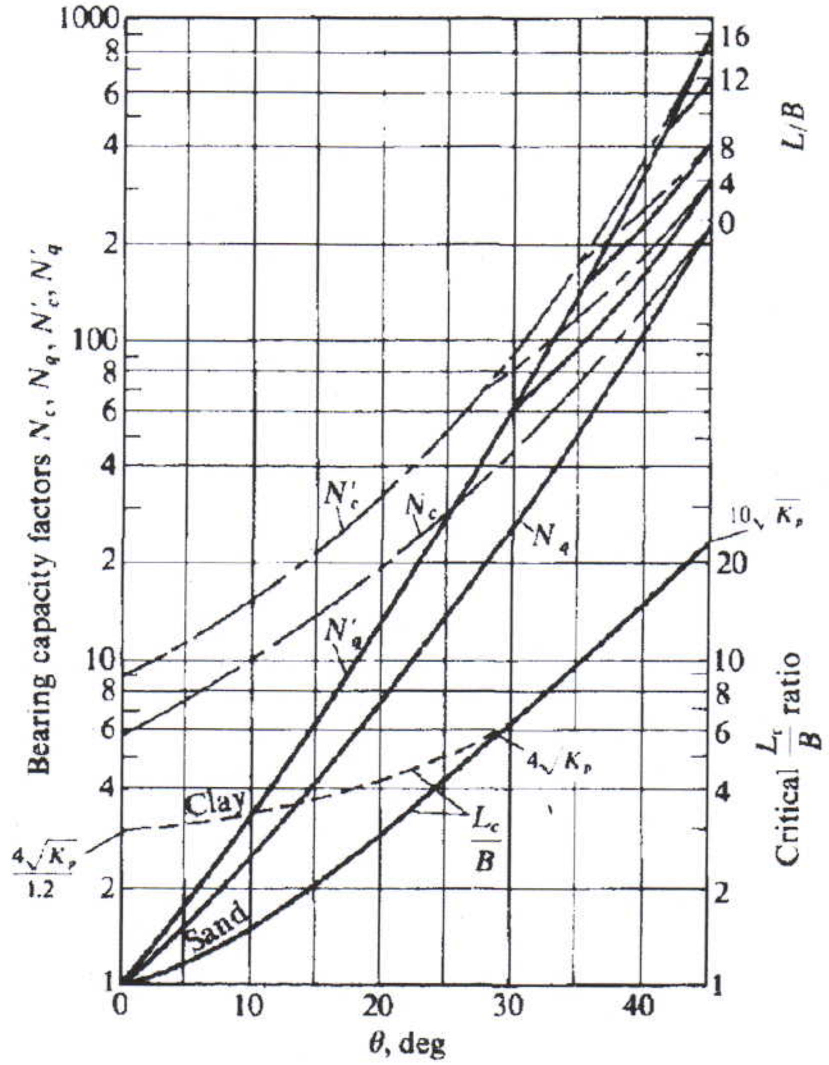


FIGURE 16-14
Bearing-capacity factors for deep foundations. [*After Meyerhof (1976).*]

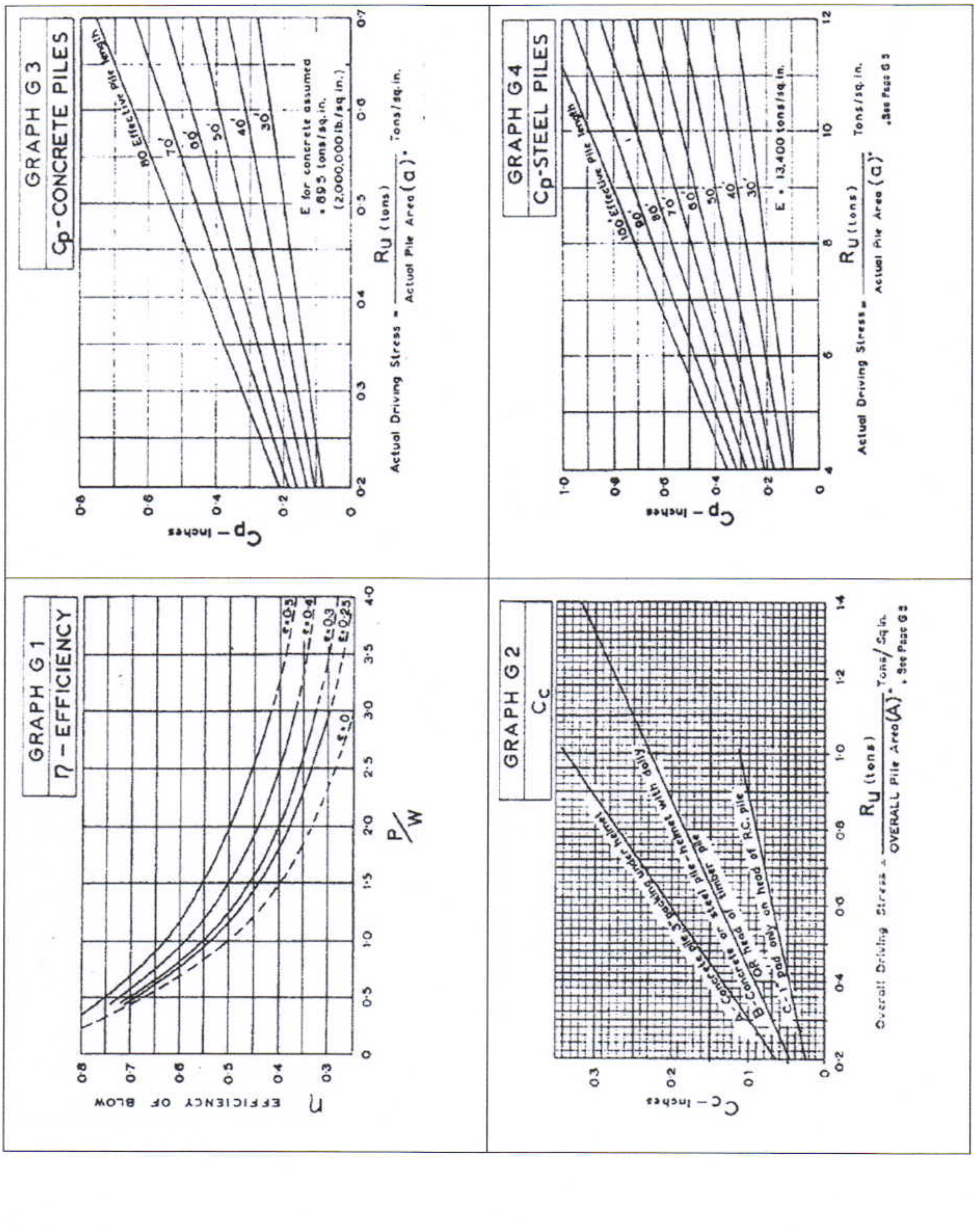
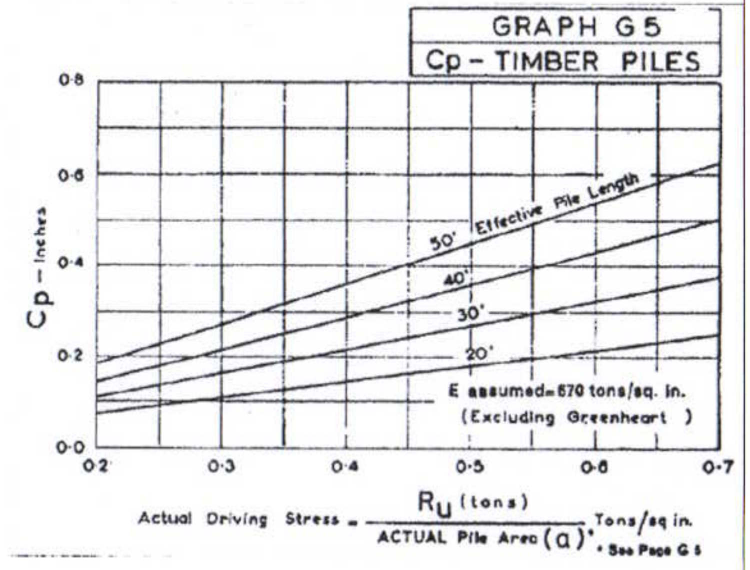
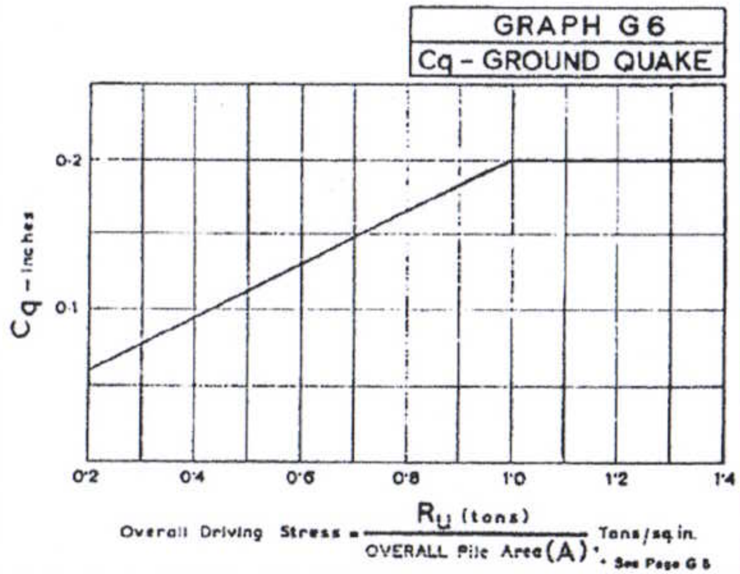

GRAPH G 1
η - EFFICIENCY
EFFICIENCY OF BLOW
P/W
GRAPH G 2
C_c
C_c – Inches
A - Concrete pile 3" packing under helmet
B - Concrete or steel pile helmet with dolly OR head of timber pile
C - 1" pad only on head of R.C. pile
Overall Driving Stress = Ru (tons) / OVERALL Pile Area (A) Tons/Sq.in.
GRAPH G 3
C_p - CONCRETE PILES
C_p – Inches
E for concrete assumed = 893 tons/sq.in. (2,000,000 lb/sq.in.)
Actual Driving Stress = Ru (tons) / Actual Pile Area (a) Tons/sq.in.
GRAPH G 4
C_p - STEEL PILES
C_p – Inches
E = 13,400 tons/sq.in.
Actual Driving Stress = Ru (tons) / Actual Pile Area (a) Tons/sq.in.

Table G2—Values of ***e***

Type of Pile	Head Condition	Single-Acting or Drop-Hammer or Diesel Hammers	Double-Acting Hammer
REINFORCED CONCRETE	Helmet with Composite Plastic or Greenheart Dolly, and Packing on top of pile	0·4	0·5
	Helmet with Timber Dolly,* and Packing on top of pile	0·25	0·4
	Hammer directly on pile with pad only	—	0·5
STEEL	Driving Cap with Composite Plastic or Greenheart Dolly	0·5	0·5
	Driving Cap with Timber* Dolly	0·3	0·3
	Hammer directly on pile	—	0·5
TIMBER	Hammer directly on pile	0·25	0·4

* Not Greenheart





CHAPTER FOUR

PILE TESTING

CHAPTER FOUR
PILE TESTING

4-1 Dynamic Load testing:

1. Application:

Dynamic load testing is suitable for all types of pile, but is most frequently employed on pre-cast concrete or tubular steel driven piles. This method is also ideally suited to small contracts, e.g. mini-piles or underpinning, which cannot justify the relatively large investment of static load testing.

The technique determines the load bearing characteristics of the pile including skin friction and end bearing. There are numerous other parameters which can be determined including pile hammer energy transfer, pile integrity, pile stresses, driving and load displacement behavior.

2. Description:

In order to dynamically test a pile, the pile must be rest ruck using a pile hammer. Two strain transducers and accelerometers are firmly attached to the face of the pile near to the head. As the pile is rest ruck the equipment measures the force and the acceleration of the pile.

This information is relayed to the pile driving analyser, which gives information on the CASE method pile capacity to an experienced test operator. As the test only takes a matter of minutes per pile, a large number can be tested in one site visit.

Once a series of blows have been struck on the test pile, the data is digitally stored and relayed back to our offices for further analysis.

A stress wave analysis is conducted on the data in the RB test department. This includes computer generation of a theoretical pile and soil model, which is compared with the recorded data. The aim of the method is to produce a model that resembles as closely as possible that which would be required to replicate the recorded data. To this end, the model is continually updated and altered until the measured data is matched. Once this has been achieved, the model gives shaft friction distribution, bearing capacity and load settlement behaviour, together with additional information as required.

3. Equipment:

In order to carry out this technique, pile driving analyser hardware from Pile Dynamics Incorporated and the modeling programmer CAPWAP provided by GRL Inc. are used.
Both organizations are responsible for the theories behind this technique and are acknowledged as market standard, reliable and accurate procedures.

Fig 4-1 Pile prepared for testing on site

Fig 4-2 Pile driving analyser for collection and analysis of test data

4-3 Static Load testing:

1. *Application:*

Static load testing is the method by which the load displacement characteristics of a pile can be determined.
All piles are suited to testing in this way.
The designed and purpose-built static load testing frames can accommodate loads of up to 4000 kN.
Additionally, specialist equipment for low headroom or restricted access locations is available.

2. *Description:*

In order to apply a known load to the test pile some form of reaction is necessary. The most commonly used methods are kentledge or tension pile reaction, dependent upon ground conditions.
Other methodologies can be adopted according to site requirements e.g. in areas of restricted access or headroom. Once adequate reaction has been provided, the testing is carried out using a hydraulic jack and calibrated digital load cell to a previously agreed procedure.
Time, load, temperature and displacement data are usually recorded. The data is stored electronically, to analyzer's test department for processing. The information is then presented in conventional graphical and tabular format

.

3. *Equipment:*

Reaction loading frames and kentledge assemblies allow tests of up to 4000kN to be carried out.
Measurement of pile response to load is measured by digital load cells and electronic linear variable displacement transducers.
Larger capacity tests can be accommodated on request.

Fig 4-3 **Kentledge test-frame on site**

Fig 4-4 **Pilehead measurement**

4-2 Sonic integrity:

1. *Application:*

Integrity testing is primarily used on continuous flight auger (CFA) or RB continuous helical displacement (CHD) and other wet bored piling techniques.
The method is fast and reliable, allowing a large number of piles to be tested in a single site visit.
The technique is used to determine the reliability, morphology and quality of construction of the piling method.

2. *Description:*

The pile to be tested must be sufficiently cured, free of latence and trimmed to sound concrete, preferably to final cut-off level.
Using a small hand-held hammer, a series of low strain acoustic shock waves are passed down the pile.
As it does so, the wave rebounds where changes in impedance occur. This rebound or echo is then recorded by a small accelerometer, held against the pile head.
The response is stored digitally and a graphical representation displayed and plotted, usually against time, for immediate inspection.

3. *Equipment:*

The sonic testing equipment is supplied by both Pile Dynamics (USA) and TNO-Profound (Holland).
They are battery powered and can be operated by one engineer to give an indication of integrity on site.

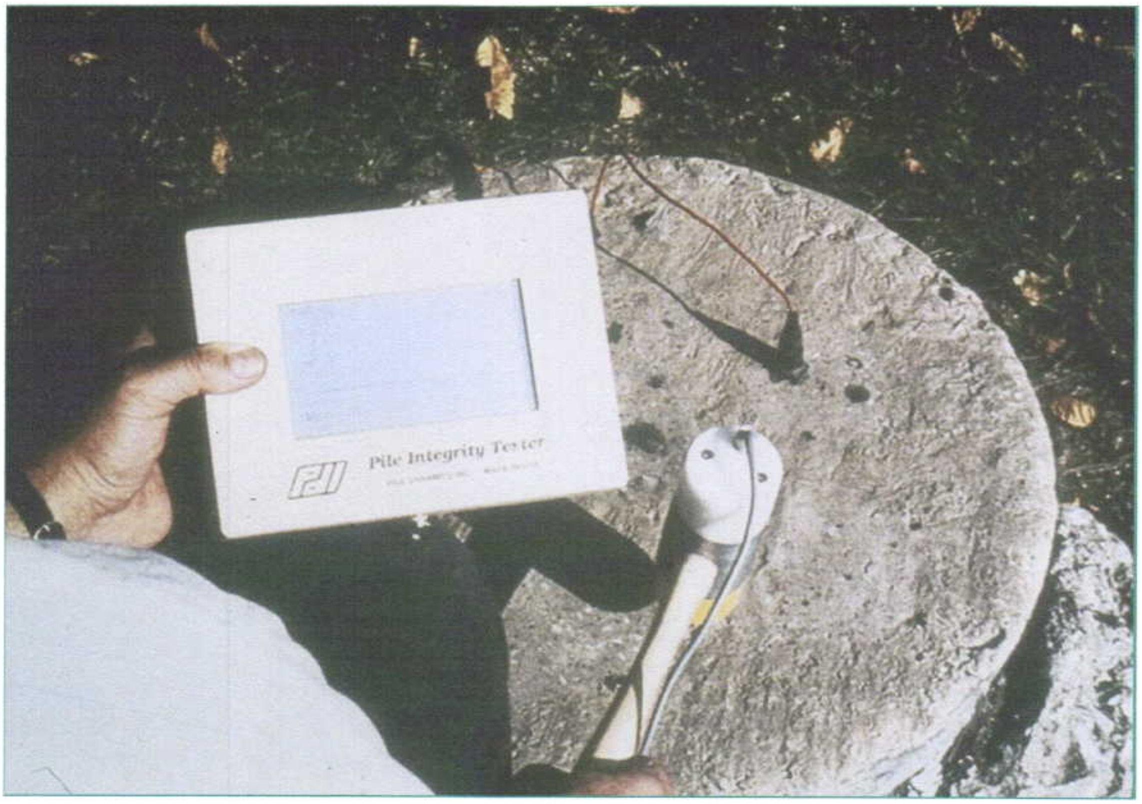


Fig 4-5 **Sonic Integrity testing equipment**

CHAPTER FIVE

ANALYSIS PILE USING ALLPILE PROGRAM

CHAPTER FIVE
ANALYSIS PILE USING ALLPILE PROGRAM

5-1 About AllPile

The program AllPile analyzes pile load capacity efficiently and accurately. AllPile can handle all types of piles: drilled shaft, driven pile, auger cast
pile, steel pipe pile, H-pile, timber pile, tapered pile, bell pile, shallow foundation, etc. You can define new pile types and input customized parameters based on local practices and experience. The program is capable
of performing the following calculations:

- Lateral capacity and deflection
- Vertical capacity and settlement
- Group vertical and lateral analysis
- FHWA SHAFT program
- Static and cyclic conditions
- Negative and zero friction
- Shallow footing
- Tower foundation

5-2 Pile Type Page:

As shown in (Figure 5.1), you can select the pile type that best suits your condition and design criteria. There are twelve different pile types to choose
from the pile type list.

1. Drilled pile diameter less than or equal to 24 inches, such as auger cast
2. Drilled pile diameter is more than 24 inches, such as drilled shaft or pier
3. Shaft using US FHWA SHAFT methods of analysis
4. Driving steel pile with opened end, such as H-pile or open-end pipe.
5. Driving steel pipe with closed end, including pipe with shoe on the tip
6. Driving concrete pile, such as pre-cased circular or square concrete pile.

7. Driving timber pile, tapered pile with small tip and large top
8. Driving jetted pile, soils are jetted during driving
9. Micropile, is a pressure-grouted small-diameter pile, also called mini-pile.
10. Uplift anchor, frictionless steel bar with grouted ends (uplift only)
11. Uplift plate, frictionless steel bar with concrete or steel plates at the end (uplift only)
12. Shallow footing, spread footing for shallow foundations

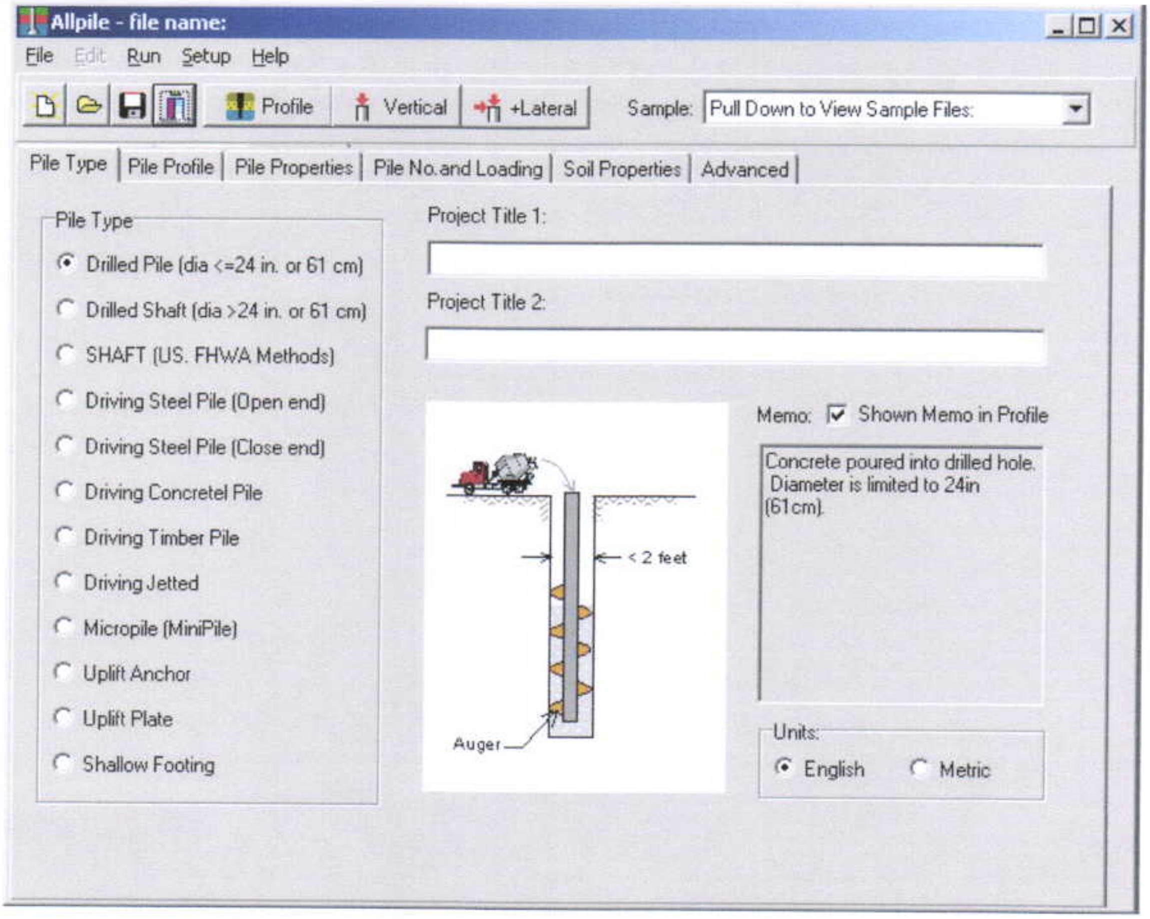


Fig.5.1 pile type page in AllPile program

5-3 Pile Profile Page:

This page presents pile profile information as shown in (Figure 5.2). The diagram on the left side reflects the information you input on the right side.

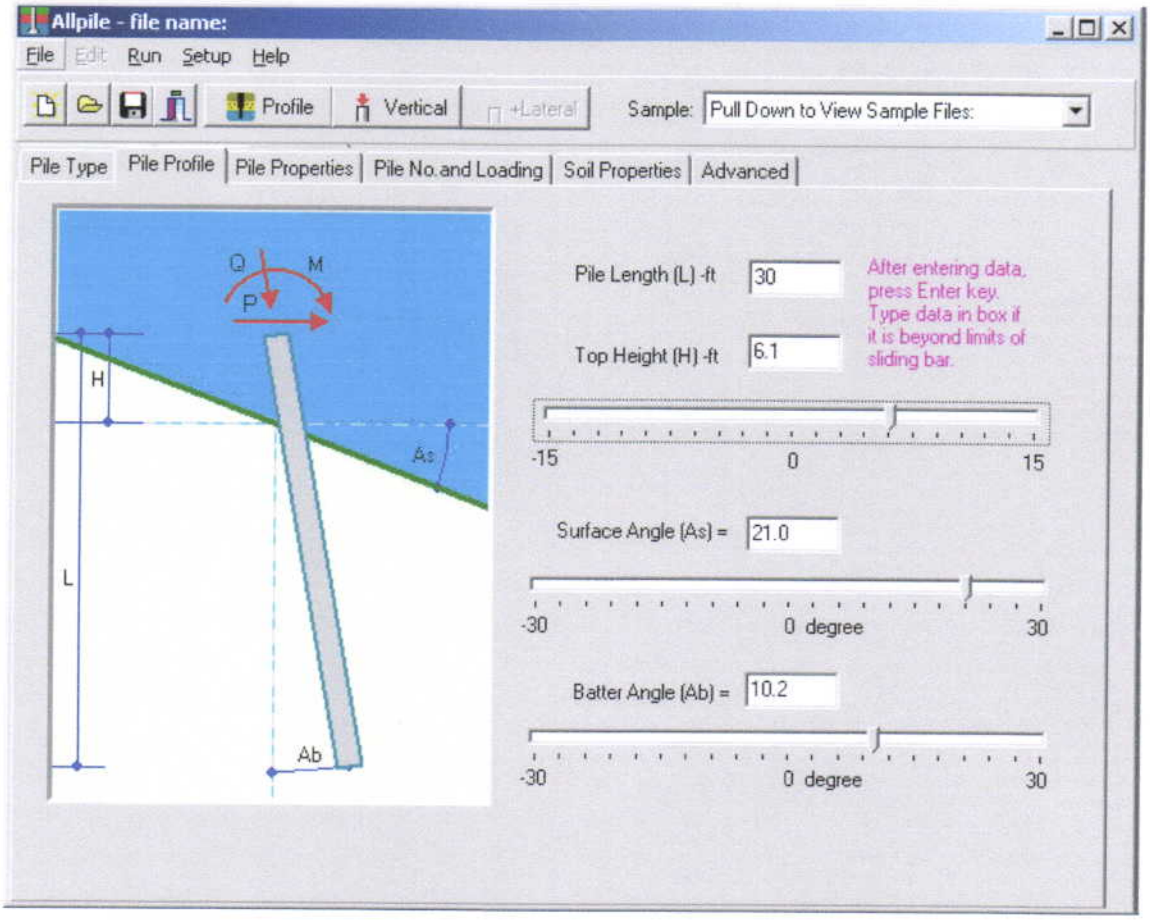
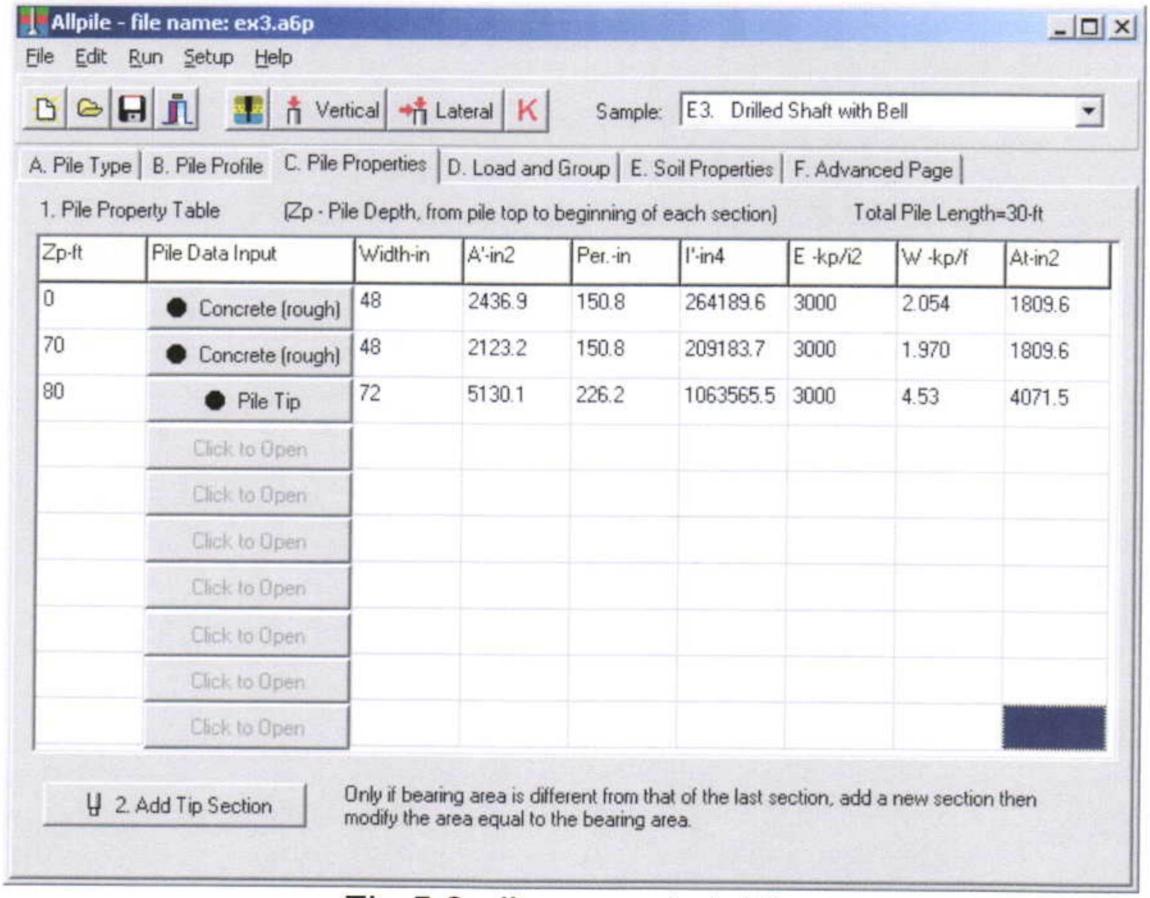


Fig. 5.2 pile profile page

P is horizontal load at top of pile.
Q is vertical load at pile top. For batter pile, Q is axial load.
M is moment load at top of pile.
L is projected length of pile in vertical direction.
H is top height above ground *.
As is surface angle , limited up to 30 degree.
Ab is batter angle of pile , limited up to 30 degree

5-4Pile Property Table

The table on the Pile Properties Page allows you to choose the pile property. Ten different sections can be defined along the length of the pile. If the
pile has a uniform section, you only need to input the first row. You should input
all the data through the Pile Section Screen as shown in (Figure 5.3).



Zp-ft	Pile Data Input	Width-in	A'-in2	Per.-in	I'-in4	E -kp/i2	W -kp/f	At-in2
0	● Concrete (rough)	48	2436.9	150.8	264189.6	3000	2.054	1809.6
70	● Concrete (rough)	48	2123.2	150.8	209183.7	3000	1.970	1809.6
80	● Pile Tip	72	5130.1	226.2	1063565.5	3000	4.53	4071.5
	Click to Open							
	Click to Open							
	Click to Open							
	Click to Open							
	Click to Open							
	Click to Open							
	Click to Open							

Fig.5.3 pile property table

Zp – Pile Depth

Input the distance from the top of the pile to the start of the following section having different pile properties (NOT from the ground surface). The first row is always zero.

Pile Data Input
Press the button in this column to select details from the Pile Section screen . You should input all the pile property data on the Pile Section screen instead of on the Pile Properties table.
Width Width of the pile section, or the pile diameter for a circular pile.
A' Effective area of the pile section.
Perimeter Perimeter of the pile section.
Inertia Effective moment of inertia of the pile.
E Elastic modules of outside materials.
W Weight of the pile section for uplift calculation. It is per foot or meter.
At Total or Gross Area of the pile section.

5-5 Load and Group:

You can start off by selecting the pile configuration that most fits the analysis.
Select **single pile** , **group pile** or **tower foundation** analysis from the tabs on the left side of the panel. as shown in (Figure 5.5).

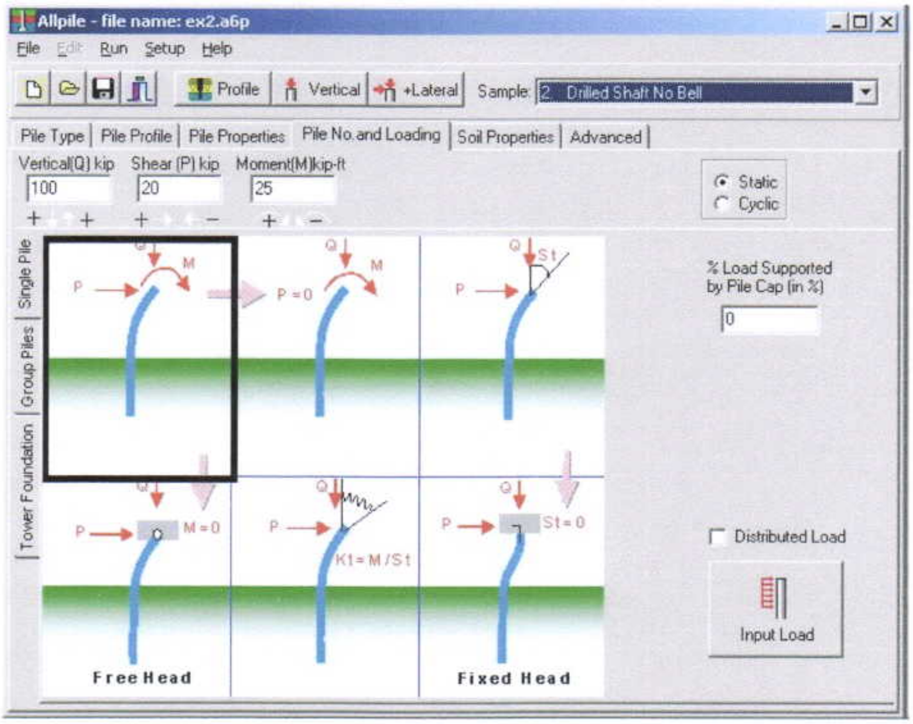
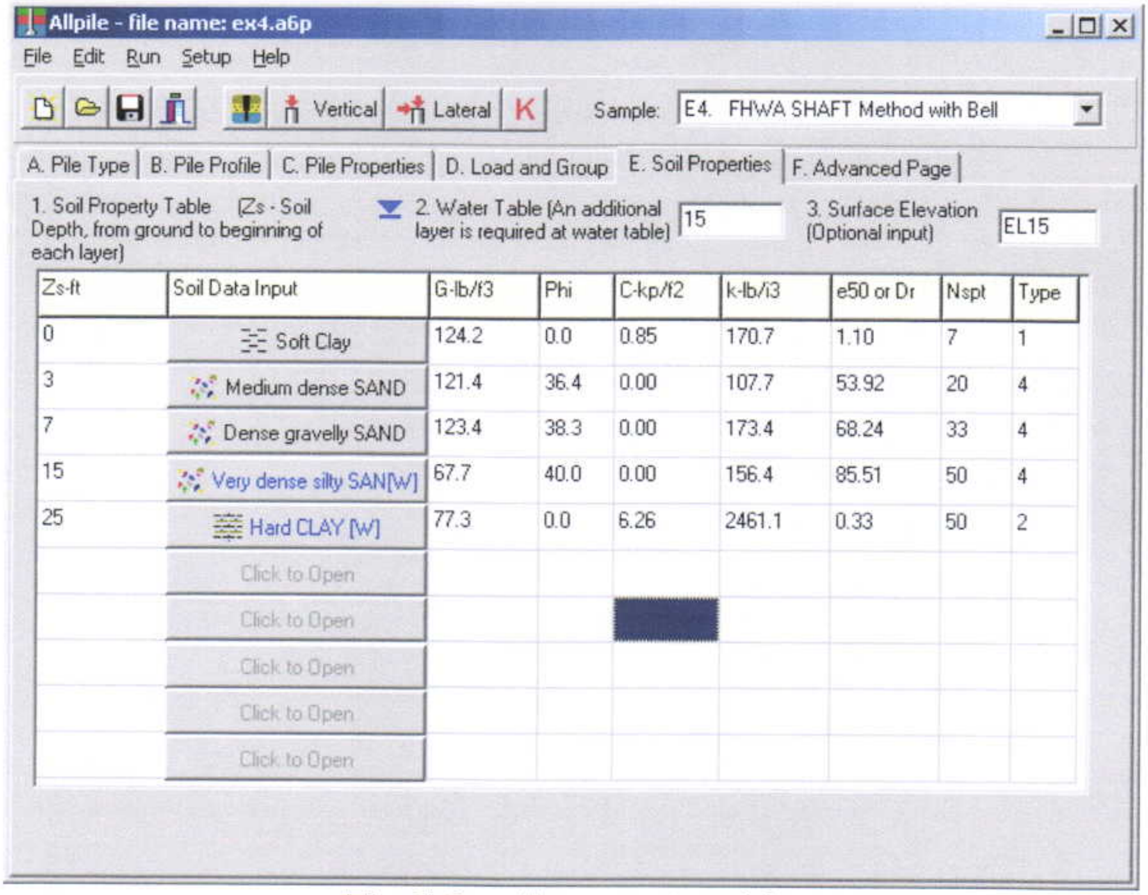


Fig.5.5 load and Group

5-6 Soil Property Table:



Zs-ft	Soil Data Input	G-lb/f3	Phi	C-kp/f2	k-lb/i3	e50 or Dr	Nspt	Type
0	Soft Clay	124.2	0.0	0.85	170.7	1.10	7	1
3	Medium dense SAND	121.4	36.4	0.00	107.7	53.92	20	4
7	Dense gravelly SAND	123.4	38.3	0.00	173.4	68.24	33	4
15	Very dense silty SAN[W]	67.7	40.0	0.00	156.4	85.51	50	4
25	Hard CLAY [W]	77.3	0.0	6.26	2461.1	0.33	50	2
	Click to Open							
	Click to Open							
	Click to Open							
	Click to Open							
	Click to Open							

Fig.5.6 soil property table

Step 1: Ground Water Table (GWT)

First, users need to input depth of ground water table (GWT). The depth is
the distance from ground surface to GWT. If the water table is deeper than
the pile tip or at great depth, leave the box blank.

HINT: Input the water table depth before completing the Soil Property table. Leave the box blank if there is no water or water is at great depth.

Step 2: Soil Property Input

You can input up to ten layers, if the GWT exist within a layer, you must break
the layer into two layers at the water table location. The total unit weight should be use for soil above the GWT, but the buoyant unit weight should be
used for soil below the GWT. You should input all the data through the Soil Parameter

Zs-Soil Depth Input the top depth of the soil layer. The top is the distance
from ground surface to the top of the layer. The depth of the first row (layer) is zero. The top of the second layer is the bottom of the first layer. The top depth of the last layer is defined as the last row. The bottom depth of the last layer is undefined, assuming it extends to a great depth.

Soil Data Input

Press the [Click to Open] button in the cell to open the Soil Parameter screen (see next section).

G Unit weight of soil. If the soil is under the water table, buoyant weight must be input. (This is why it is necessary to divide a layer into two if the GWT sits within this layer.) Buoyant weight is the total unit weight of the soil minus the unit weight of the water.

HINT: Input total unit weight above GWT and buoyant weight below GWT.

***Phi** Friction angle of soil.

***C** Cohesion of soil.

***K** Modulus of Subgrade Reaction of soil (for lateral analysis only). If you only run vertical analysis, you don't have to input this value (Refer to Ch.8 for description).

***e_{50} or Dr** If soil is silt, rock, or clay, e_{50} is strain at 50% deflection in p-y curve (only used for cohesive soil in lateral analysis) (Refer to Ch.8). If soil is sand, Dr is the relative density from 0 to 100 (%). It is for reference only and is not used in the analysis.

Nspt Standard Penetration Test (SPT) value or N value is the number of blows to penetrate 12 inches in soil (304.8 mm) with a 140-lb (622.72 N) hammer dropping a distance of 30 inches (0.762 m).
Type Number of Soil Type defined in **Soil Parameter screen**

Step 3 Surface Elevation
It is optional to input a value in this field. If an elevation is inputted, the depth
of the pile is shown on the left side and the elevation is shown on the right side
of the chart.

5-7 Profile screen:

The **Profile** function provides the pile profile and soil conditions (Figure 5.7).
This report also presents soil parameters as well as foundation material properties input by users. The report can be printed for references.

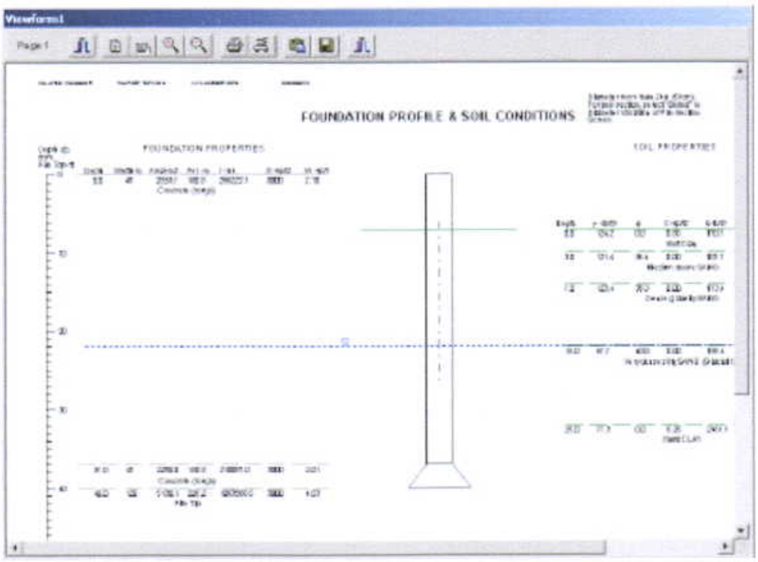


Fig.5.6 profile screen

5-8 Vertical Analysis Results

Clicking on **[Vertical Analysis]** will display a panel that allows you to choose the different types of result from the analysis. For this analysis all lateral load components are ignored and only vertical load is considered. (Figure 5.7) shows the several choices available for vertical analysis.

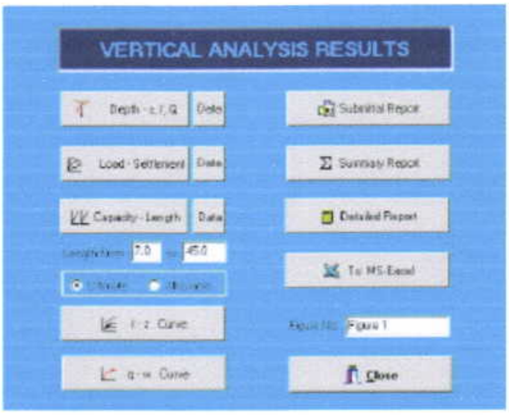


Fig 5.7 vertical analysis results

5-9 Lateral Analysis Results:

The lateral analysis results panel (Figure 5.8) provides several choices.

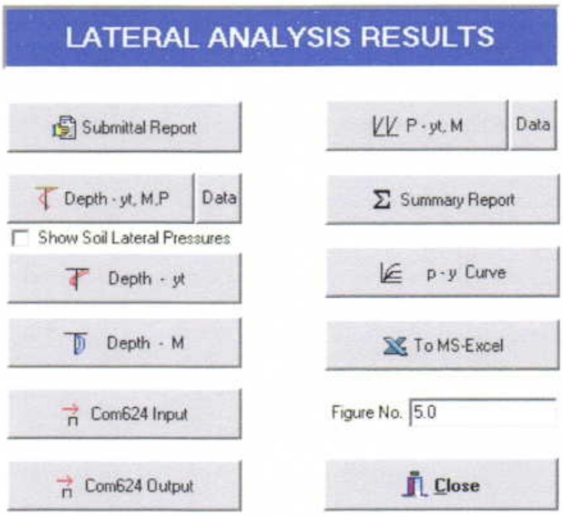


Fig.5.8 lateral analysis results

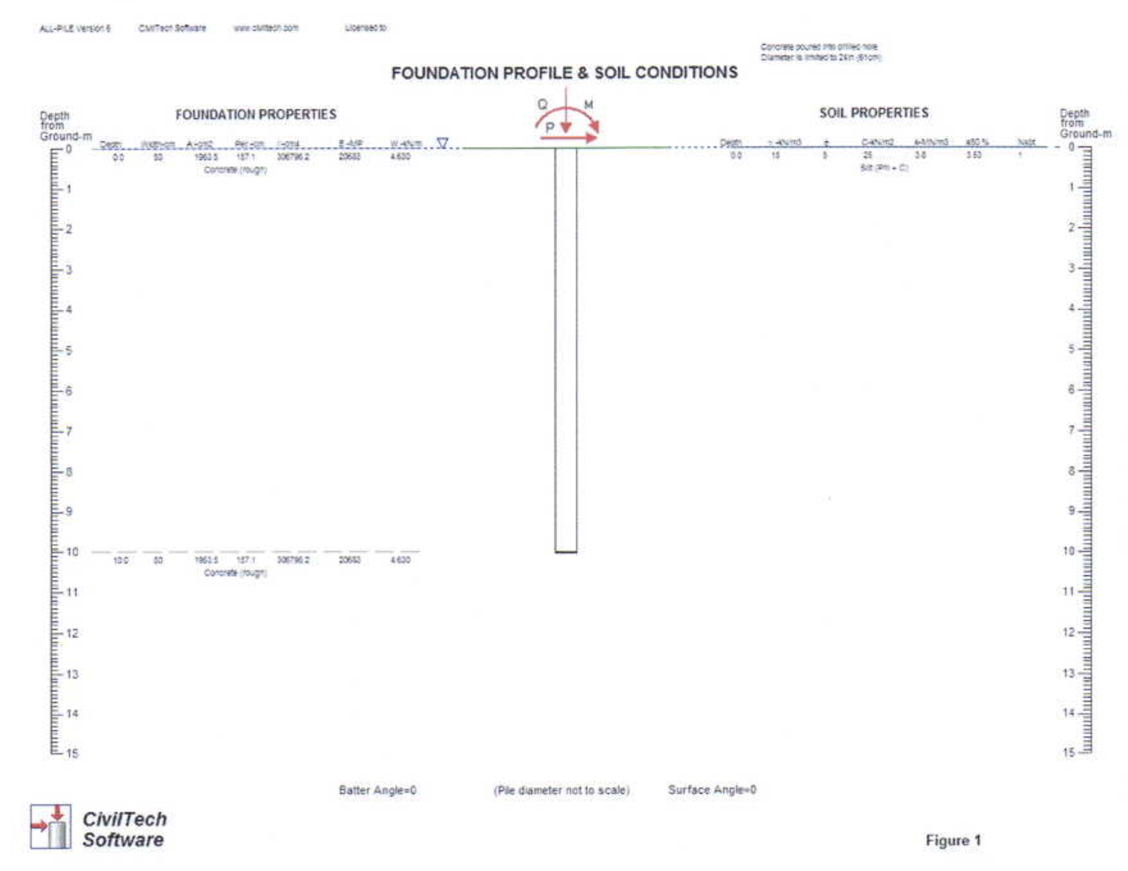
5-10 Analysis variable for bored pile using Allpile program :

For example when using variables as **basic problem**

No.	Dia. Cm	length	C	Ø	γ	load
1	50	10	25	5	15	1000

we get the following results

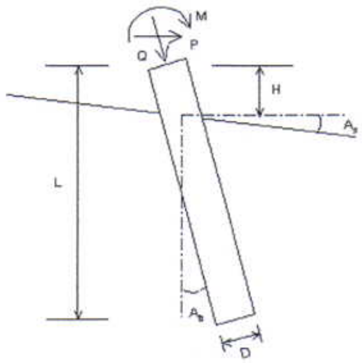
1- Profile of soil



2- Vertical analysis

VERTICAL ANALYSIS

Figure 1



Drilled Pile (dia <=24 in. or 61 cm)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 1000.0 -kN
Shear Load, P= 0.0 -kN
Moment, M= 0.0 -kN-m

Profile:
Pile Length, L= 10.0 -m
Top Height, H= 0 -m
Slope Angle, As= 0
Batter Angle, Ab= 0

Soil Data:

Depth -m	Gamma -kN/m3	Phi	C -kN/m2	K -MN/m3	e50 or Dr %	Nspt
0	15	5	25	3.8	3.53	1
30	15	5	25	85.0	0.87	10

Pile Data:

Depth -m	Width -cm	Area -cm2	Per. -cm	I -cm4	E -MP	Weight -kN/m
0.0	50	1963.5	157.1	306796.2	20683	4.630
10.0	50	1963.5	157.1	306796.2	20683	4.630

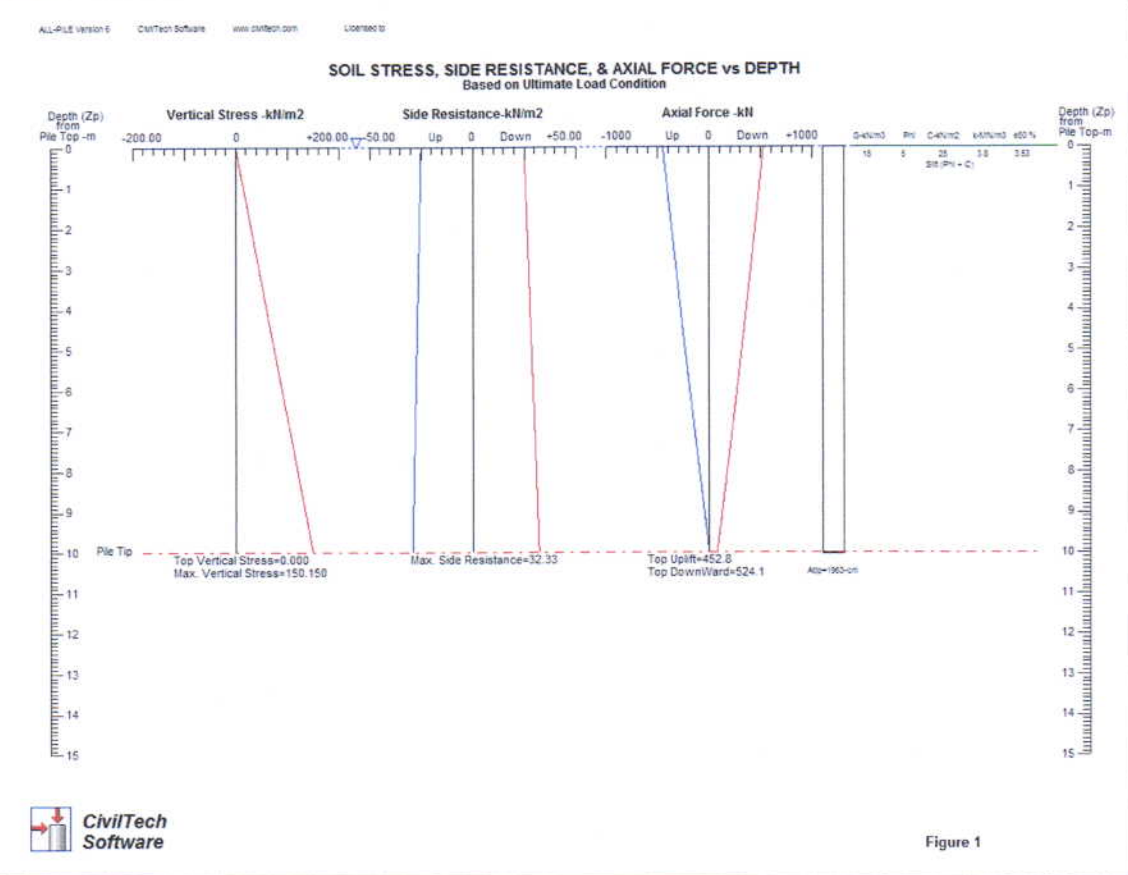
Vertical capacity:
Weight above Ground= 0.00 Total Weight= 27.06-kN *Soil Weight is not included
Side Resistance (Down)= 450.424-kN Side Resistance (Up)= 425.706-kN
Tip Resistance (Down)= 73.661-kN Tip Resistance (Up)= 0.000-kN
Total Ultimate Capacity (Down)= 524.084-kN Total Ultimate Capacity (Up)= 452.764-kN
Total Allowable Capacity (Down)= 337.113-kN Total Allowable Capacity (Up)= 239.911-kN
N/G! Qallow < Q

Settlement Calculation:
At Q= 1000.00-kN Settlement= 9999.00000-cm
At Xallow= 2.50-cm Qallow= 489.84616-kN

Note: If program can't find result or the result exceeds the up limits. The result shows 9999.

CivilTech Software

3- Soil stress



5-11 Table for Analysis several variables for bored pile using Allpile program:

No.	Dia. Cm	length	C	Ø	ɣ	load	Q allow. kN	Q all / Qall. Basic
1	50	10	25	5	15	1000	489.84616	1
2	50	10	25	5	15	1200	489.84616	1
3	50	10	25	5	15	2000	489.84616	1
4	50	10	25	5	17	1000	500.46936	1.021687
5	50	10	25	5	17	1200	500.46936	1.021687
6	50	10	25	5	17	2000	500.46936	1.021687
7	50	10	25	5	20	1000	517.77466	1.057015
8	50	10	25	5	20	1200	517.77466	1.057015
9	50	10	25	5	20	2000	517.77466	1.057015
10	50	10	25	10	15	1000	576.05548	1.175993
11	50	10	25	10	15	1200	576.05548	1.175993
12	50	10	25	10	15	2000	576.05548	1.175993
13	50	10	25	10	17	1000	599.23462	1.223312
14	50	10	25	10	17	1200	599.23462	1.223312
15	50	10	25	10	17	2000	599.23462	1.223312
16	50	10	25	10	20	1000	634.07507	1.294437
17	50	10	25	10	20	1200	634.07507	1.294437
18	50	10	25	10	20	2000	634.07507	1.294437
19	50	10	25	20	15	1000	754.71075	1.54071
20	50	10	25	20	15	1200	754.71075	1.54071
21	50	10	25	20	15	2000	754.71075	1.54071
22	50	10	25	20	17	1000	801.96753	1.637182
23	50	10	25	20	17	1200	801.96753	1.637182
24	50	10	25	20	17	2000	801.96753	1.637182
25	50	10	25	20	20	1000	872.92291	1.782035
26	50	10	25	20	20	1200	872.92291	1.782035
27	50	10	25	20	20	2000	872.92291	1.782035
28	50	10	50	5	15	1000	907.94086	1.853522
29	50	10	50	5	15	1200	907.94086	1.853522
30	50	10	50	5	15	2000	907.94086	1.853522
31	50	10	50	5	17	1000	919.13568	1.876376
32	50	10	50	5	17	1200	919.13568	1.876376
33	50	10	50	5	17	2000	919.13568	1.876376
34	50	10	50	5	20	1000	935.59235	1.909972
35	50	10	50	5	20	1200	935.59235	1.909972
36	50	10	50	5	20	2000	935.59235	1.909972

37	50	10	50	10	15	1000	989.77399	2.020581
38	50	10	50	10	15	1200	989.77399	2.020581
39	50	10	50	10	15	2000	989.77399	2.020581
40	50	10	50	10	17	1000	1010.74829	2.063399
41	50	10	50	10	17	1200	1010.74829	2.063399
42	50	10	50	10	17	2000	1010.74829	2.063399
43	50	10	50	10	20	1000	1042.66202	2.12855
44	50	10	50	10	20	1200	1042.66202	2.12855
45	50	10	50	10	20	2000	1042.66202	2.12855
46	50	10	50	20	15	1000	1157.47632	2.362938
47	50	10	50	20	15	1200	1157.47632	2.362938
48	50	10	50	20	15	2000	1157.47632	2.362938
49	50	10	50	20	17	1000	1204.67664	2.459296
50	50	10	50	20	17	1200	1204.67664	2.459296
51	50	10	50	20	17	2000	1204.67664	2.459296
52	50	10	50	20	20	1000	1275.57983	2.604042
53	50	10	50	20	20	1200	1275.57983	2.604042
54	50	10	50	20	20	2000	1275.57983	2.604042
55	50	10	75	5	15	1000	1322.78821	2.700416
56	50	10	75	5	15	1200	1322.78821	2.700416
57	50	10	75	5	15	2000	1322.78821	2.700416
58	50	10	75	5	17	1000	1333.92139	2.723144
59	50	10	75	5	17	1200	1333.92139	2.723144
60	50	10	75	5	17	2000	1333.92139	2.723144
61	50	10	75	5	20	1000	1350.74109	2.75748
62	50	10	75	5	20	1200	1350.74109	2.75748
63	50	10	75	5	20	2000	1350.74109	2.75748
64	50	10	75	10	15	1000	1407.71985	2.8738
65	50	10	75	10	15	1200	1407.71985	2.8738
66	50	10	75	10	15	2000	1407.71985	2.8738
67	50	10	75	10	17	1000	1430.2384	2.919771
68	50	10	75	10	17	1200	1430.2384	2.919771
69	50	10	75	10	17	2000	1430.2384	2.919771
70	50	10	75	10	20	1000	1464.00549	2.988705
71	50	10	75	10	20	1200	1464.00549	2.988705
72	50	10	75	10	20	2000	1464.00549	2.988705
73	50	10	75	20	15	1000	1580.27527	3.226064
74	50	10	75	20	15	1200	1580.27527	3.226064
75	50	10	75	20	15	2000	1580.27527	3.226064
76	50	10	75	20	17	1000	1625.64587	3.318687
77	50	10	75	20	17	1200	1625.64587	3.318687
78	50	10	75	20	17	2000	1625.64587	3.318687

79	50	10	75	20	20	1000	1694.27002	3.45878
80	50	10	75	20	20	1200	1694.27002	3.45878
81	50	10	75	20	20	2000	1694.27002	3.45878
82	50	15	25	5	15	1000	729.31177	1.488859
83	50	15	25	5	15	1200	729.31177	1.488859
84	50	15	25	5	15	2000	729.31177	1.488859
85	50	15	25	5	17	1000	747.41046	1.525807
86	50	15	25	5	17	1200	747.41046	1.525807
87	50	15	25	5	17	2000	747.41046	1.525807
88	50	15	25	5	20	1000	774.55902	1.581229
89	50	15	25	5	20	1200	774.55902	1.581229
90	50	15	25	5	20	2000	774.55902	1.581229
91	50	15	25	10	15	1000	865.1347	1.766136
92	50	15	25	10	15	1200	865.1347	1.766136
93	50	15	25	10	15	2000	865.1347	1.766136
94	50	15	25	10	17	1000	901.10968	1.839577
95	50	15	25	10	17	1200	901.10968	1.839577
96	50	15	25	10	17	2000	901.10968	1.839577
97	50	15	25	10	20	1000	955.53888	1.950692
98	50	15	25	10	20	1200	955.53888	1.950692
99	50	15	25	10	20	2000	955.53888	1.950692
100	50	15	25	20	15	1000	1149.27734	2.346201
101	50	15	25	20	15	1200	1149.27734	2.346201
102	50	15	25	20	15	2000	1149.27734	2.346201
103	50	15	25	20	17	1000	1225.24475	2.501285
104	50	15	25	20	17	1200	1225.24475	2.501285
105	50	15	25	20	17	2000	1225.24475	2.501285
106	50	15	25	20	20	1000	1339.96899	2.735489
107	50	15	25	20	20	1200	1339.96899	2.735489
108	50	15	25	20	20	2000	1339.96899	2.735489
109	50	15	50	5	15	1000	1332.84827	2.720953
110	50	15	50	5	15	1200	1332.84827	2.720953
111	50	15	50	5	15	2000	1332.84827	2.720953
112	50	15	50	5	17	1000	1350.65735	2.757309
113	50	15	50	5	17	1200	1350.65735	2.757309
114	50	15	50	5	17	2000	1350.65735	2.757309
115	50	15	50	5	20	1000	1377.51428	2.812137
116	50	15	50	5	20	1200	1377.51428	2.812137
117	50	15	50	5	20	2000	1377.51428	2.812137
118	50	15	50	10	15	1000	1469.62878	3.000184
119	50	15	50	10	15	1200	1469.62878	3.000184
120	50	15	50	10	15	2000	1469.62878	3.000184

121	50	15	50	10	17	1000	1506.52576	3.075508
122	50	15	50	10	17	1200	1506.52576	3.075508
123	50	15	50	10	17	2000	1506.52576	3.075508
124	50	15	50	10	20	1000	1562.09729	3.188955
125	50	15	50	10	20	1200	1562.09729	3.188955
126	50	15	50	10	20	2000	1562.09729	3.188955
127	50	15	50	20	15	1000	1757.91455	3.588707
128	50	15	50	20	15	1200	1757.91455	3.588707
129	50	15	50	20	15	2000	1757.91455	3.588707
130	50	15	50	20	17	1000	1834.32166	3.744689
131	50	15	50	20	17	1200	1834.32166	3.744689
132	50	15	50	20	17	2000	1834.32166	3.744689
133	50	15	50	20	20	1000	1949.36695	3.979549
134	50	15	50	20	20	1200	1949.36695	3.979549
135	50	15	50	20	20	2000	1949.36695	3.979549
136	50	15	75	5	15	1000	1953.86121	3.988724
137	50	15	75	5	15	1200	1953.86121	3.988724
138	50	15	75	5	15	2000	1953.86121	3.988724
139	50	15	75	5	17	1000	1971.46436	4.02466
140	50	15	75	5	17	1200	1971.46436	4.02466
141	50	15	75	5	17	2000	1971.46436	4.02466
142	50	15	75	5	20	1000	1998.02942	4.078892
143	50	15	75	5	20	1200	1998.02942	4.078892
144	50	15	75	5	20	2000	1998.02942	4.078892
145	50	15	75	10	15	1000	2089.41138	4.265444
146	50	15	75	10	15	1200	2089.41138	4.265444
147	50	15	75	10	15	2000	2089.41138	4.265444
148	50	15	75	10	17	1000	2126.12354	4.34039
149	50	15	75	10	17	1200	2126.12354	4.34039
150	50	15	75	10	17	2000	2126.12354	4.34039
151	50	15	75	10	20	1000	2181.5835	4.453609
152	50	15	75	10	20	1200	2181.5835	4.453609
153	50	15	75	10	20	2000	2181.5835	4.453609
154	50	15	75	20	15	1000	2378.87891	4.85638
155	50	15	75	20	15	1200	2378.87891	4.85638
156	50	15	75	20	15	2000	2378.87891	4.85638
157	50	15	75	20	17	1000	2456.2041	5.014236
158	50	15	75	20	17	1200	2456.2041	5.014236
159	50	15	75	20	17	2000	2456.2041	5.014236
160	50	15	75	20	20	1000	2573.02832	5.252727
161	50	15	75	20	20	1200	2573.02832	5.252727
162	50	15	75	20	20	2000	2573.02832	5.252727

163	50	20	25	5	15	1000	969.1109	1.978398
164	50	20	25	5	15	1200	969.1109	1.978398
165	50	20	25	5	15	2000	969.1109	1.978398
166	50	20	25	5	17	1000	994.30347	2.029828
167	50	20	25	5	17	1200	994.30347	2.029828
168	50	20	25	5	17	2000	994.30347	2.029828
169	50	20	25	5	20	1000	1032.25098	2.107296
170	50	20	25	5	20	1200	1032.25098	2.107296
171	50	20	25	5	20	2000	1032.25098	2.107296
172	50	20	25	10	15	1000	1161.48779	2.371128
173	50	20	25	10	15	1200	1161.48779	2.371128
174	50	20	25	10	15	2000	1161.48779	2.371128
175	50	20	25	10	17	1000	1213.11047	2.476513
176	50	20	25	10	17	1200	1213.11047	2.476513
177	50	20	25	10	17	2000	1213.11047	2.476513
178	50	20	25	10	20	1000	1290.85278	2.635221
179	50	20	25	10	20	1200	1290.85278	2.635221
180	50	20	25	10	20	2000	1290.85278	2.635221
181	50	20	25	20	15	1000	1566.07739	3.19708
182	50	20	25	20	15	1200	1566.07739	3.19708
183	50	20	25	20	15	2000	1566.07739	3.19708
184	50	20	25	20	17	1000	1673.73389	3.416856
185	50	20	25	20	17	1200	1673.73389	3.416856
186	50	20	25	20	17	2000	1673.73389	3.416856
187	50	20	25	20	20	1000	1836.43713	3.749008
188	50	20	25	20	20	1200	1836.43713	3.749008
189	50	20	25	20	20	2000	1836.43713	3.749008
190	50	20	50	5	15	1000	1790.11157	3.654436
191	50	20	50	5	15	1200	1790.11157	3.654436
192	50	20	50	5	15	2000	1790.11157	3.654436
193	50	20	50	5	17	1000	1815.31299	3.705884
194	50	20	50	5	17	1200	1815.31299	3.705884
195	50	20	50	5	17	2000	1815.31299	3.705884
196	50	20	50	5	20	1000	1853.39099	3.783618
197	50	20	50	5	20	1200	1853.39099	3.783618
198	50	20	50	5	20	2000	1853.39099	3.783618
199	50	20	50	10	15	1000	1984.16235	4.050583
200	50	20	50	10	15	1200	1984.16235	4.050583
201	50	20	50	10	15	2000	1984.16235	4.050583
202	50	20	50	10	17	1000	2036.74158	4.157921
203	50	20	50	10	17	1200	2036.74158	4.157921
204	50	20	50	10	17	2000	2036.74158	4.157921

205	50	20	50	10	20	1000	2116.29907	4.320334
206	50	20	50	10	20	1200	2116.29907	4.320334
207	50	20	50	10	20	2000	2116.29907	4.320334
208	50	20	50	20	15	1000	2401.69482	4.902957
209	50	20	50	20	15	1200	2401.69482	4.902957
210	50	20	50	20	15	2000	2401.69482	4.902957
211	50	20	50	20	17	1000	2513.70532	5.131622
212	50	20	50	20	17	1200	2513.70532	5.131622
213	50	20	50	20	17	2000	2513.70532	5.131622
214	50	20	50	20	20	1000	2683.18726	5.477612
215	50	20	50	20	20	1200	2683.18726	5.477612
216	50	20	50	20	20	2000	2683.18726	5.477612
217	50	20	75	5	15	1000	2640.12476	5.389702
218	50	20	75	5	15	1200	2640.12476	5.389702
219	50	20	75	5	15	2000	2640.12476	5.389702
220	50	20	75	5	17	1000	2666.32422	5.443187
221	50	20	75	5	17	1200	2666.32422	5.443187
222	50	20	75	5	17	2000	2666.32422	5.443187
223	50	20	75	5	20	1000	2705.802	5.523779
224	50	20	75	5	20	1200	2705.802	5.523779
225	50	20	75	5	20	2000	2705.802	5.523779
226	50	20	75	10	15	1000	2840.73438	5.799238
227	50	20	75	10	15	1200	2840.73438	5.799238
228	50	20	75	10	15	2000	2840.73438	5.799238
229	50	20	75	10	17	1000	2894.69165	5.909389
230	50	20	75	10	17	1200	2894.69165	5.909389
231	50	20	75	10	17	2000	2894.69165	5.909389
232	50	20	75	10	20	1000	2976.08423	6.075549
233	50	20	75	10	20	1200	2976.08423	6.075549
234	50	20	75	10	20	2000	2976.08423	6.075549
235	50	20	75	20	15	1000	3266.50464	6.66843
236	50	20	75	20	15	1200	3266.50464	6.66843
237	50	20	75	20	15	2000	3266.50464	6.66843
238	50	20	75	20	17	1000	3379.65723	6.899426
239	50	20	75	20	17	1200	3379.65723	6.899426
240	50	20	75	20	17	2000	3379.65723	6.899426
241	50	20	75	20	20	1000	3550.30396	7.247794
242	50	20	75	20	20	1200	3550.30396	7.247794
243	50	20	75	20	20	2000	3550.30396	7.247794
244	60	10	25	5	15	1000	620.50928	1.266743
245	60	10	25	5	15	1200	620.50928	1.266743
246	60	10	25	5	15	2000	620.50928	1.266743

247	60	10	25	5	17	1000	635.10553	1.296541
248	60	10	25	5	17	1200	635.10553	1.296541
249	60	10	25	5	17	2000	635.10553	1.296541
250	60	10	25	5	20	1000	657.11932	1.341481
251	60	10	25	5	20	1200	657.11932	1.341481
252	60	10	25	5	20	2000	657.11932	1.341481
253	60	10	25	10	15	1000	732.14355	1.49464
254	60	10	25	10	15	1200	732.14355	1.49464
255	60	10	25	10	15	2000	732.14355	1.49464
256	60	10	25	10	17	1000	762.17584	1.555949
257	60	10	25	10	17	1200	762.17584	1.555949
258	60	10	25	10	17	2000	762.17584	1.555949
259	60	10	25	10	20	1000	807.32593	1.648121
260	60	10	25	10	20	1200	807.32593	1.648121
261	60	10	25	10	20	2000	807.32593	1.648121
262	60	10	25	20	15	1000	962.50342	1.96491
263	60	10	25	20	15	1200	962.50342	1.96491
264	60	10	25	20	15	2000	962.50342	1.96491
265	60	10	25	20	17	1000	1023.24536	2.088912
266	60	10	25	20	17	1200	1023.24536	2.088912
267	60	10	25	20	17	2000	1023.24536	2.088912
268	60	10	25	20	20	1000	1114.47095	2.275145
269	60	10	25	20	20	1200	1114.47095	2.275145
270	60	10	25	20	20	2000	1114.47095	2.275145
271	60	10	50	5	15	1000	1138.31079	2.323813
272	60	10	50	5	15	1200	1138.31079	2.323813
273	60	10	50	5	15	2000	1138.31079	2.323813
274	60	10	50	5	17	1000	1152.08472	2.351932
275	60	10	50	5	17	1200	1152.08472	2.351932
276	60	10	50	5	17	2000	1152.08472	2.351932
277	60	10	50	5	20	1000	1172.90027	2.394426
278	60	10	50	5	20	1200	1172.90027	2.394426
279	60	10	50	5	20	2000	1172.90027	2.394426
280	60	10	50	10	15	1000	1244.8147	2.541236
281	60	10	50	10	15	1200	1244.8147	2.541236
282	60	10	50	10	15	2000	1244.8147	2.541236
283	60	10	50	10	17	1000	1273.94934	2.600713
284	60	10	50	10	17	1200	1273.94934	2.600713
285	60	10	50	10	17	2000	1273.94934	2.600713
286	60	10	50	10	20	1000	1317.99036	2.690621
287	60	10	50	10	20	1200	1317.99036	2.690621
288	60	10	50	10	20	2000	1317.99036	2.690621

289	60	10	50	20	15	1000	1471.74841	3.004511
290	60	10	50	20	15	1200	1471.74841	3.004511
291	60	10	50	20	15	2000	1471.74841	3.004511
292	60	10	50	20	17	1000	1532.37781	3.128284
293	60	10	50	20	17	1200	1532.37781	3.128284
294	60	10	50	20	17	2000	1532.37781	3.128284
295	60	10	50	20	20	1000	1623.58423	3.314478
296	60	10	50	20	20	1200	1623.58423	3.314478
297	60	10	50	20	20	2000	1623.58423	3.314478
298	60	10	75	5	15	1000	1662.46899	3.393859
299	60	10	75	5	15	1200	1662.46899	3.393859
300	60	10	75	5	15	2000	1662.46899	3.393859
301	60	10	75	5	17	1000	1675.99329	3.421469
302	60	10	75	5	17	1200	1675.99329	3.421469
303	60	10	75	5	17	2000	1675.99329	3.421469
304	60	10	75	5	20	1000	1696.39551	3.463119
305	60	10	75	5	20	1200	1696.39551	3.463119
306	60	10	75	5	20	2000	1696.39551	3.463119
307	60	10	75	10	15	1000	1766.1051	3.605428
308	60	10	75	10	15	1200	1766.1051	3.605428
309	60	10	75	10	15	2000	1766.1051	3.605428
310	60	10	75	10	17	1000	1794.40002	3.663191
311	60	10	75	10	17	1200	1794.40002	3.663191
312	60	10	75	10	17	2000	1794.40002	3.663191
313	60	10	75	10	20	1000	1837.13049	3.750423
314	60	10	75	10	20	1200	1837.13049	3.750423
315	60	10	75	10	20	2000	1837.13049	3.750423
316	60	10	75	20	15	1000	1987.80078	4.05801
317	60	10	75	20	15	1200	1987.80078	4.05801
318	60	10	75	20	15	2000	1987.80078	4.05801
319	60	10	75	20	17	1000	2047.45081	4.179783
320	60	10	75	20	17	1200	2047.45081	4.179783
321	60	10	75	20	17	2000	2047.45081	4.179783
322	60	10	75	20	20	1000	2137.41455	4.36344
323	60	10	75	20	20	1200	2137.41455	4.36344
324	60	10	75	20	20	2000	2137.41455	4.36344
325	60	15	25	5	15	1000	927.80481	1.894074
326	60	15	25	5	15	1200	927.80481	1.894074
327	60	15	25	5	15	2000	927.80481	1.894074
328	60	15	25	5	17	1000	952.98578	1.94548
329	60	15	25	5	17	1200	952.98578	1.94548
330	60	15	25	5	17	2000	952.98578	1.94548

331	60	15	25	5	20	1000	990.97333	2.02303
332	60	15	25	5	20	1200	990.97333	2.02303
333	60	15	25	5	20	2000	990.97333	2.02303
334	60	15	25	10	15	1000	1120.71667	2.287895
335	60	15	25	10	15	1200	1120.71667	2.287895
336	60	15	25	10	15	2000	1120.71667	2.287895
337	60	15	25	10	17	1000	1172.72205	2.394062
338	60	15	25	10	17	1200	1172.72205	2.394062
339	60	15	25	10	17	2000	1172.72205	2.394062
340	60	15	25	10	20	1000	1251.0199	2.553904
341	60	15	25	10	20	1200	1251.0199	2.553904
342	60	15	25	10	20	2000	1251.0199	2.553904
343	60	15	25	20	15	1000	1525.17944	3.113589
344	60	15	25	20	15	1200	1525.17944	3.113589
345	60	15	25	20	15	2000	1525.17944	3.113589
346	60	15	25	20	17	1000	1632.24207	3.332152
347	60	15	25	20	17	1200	1632.24207	3.332152
348	60	15	25	20	17	2000	1632.24207	3.332152
349	60	15	25	20	20	1000	1793.18555	3.660712
350	60	15	25	20	20	1200	1793.18555	3.660712
351	60	15	25	20	20	2000	1793.18555	3.660712
352	60	15	50	5	15	1000	1687.74731	3.445464
353	60	15	50	5	15	1200	1687.74731	3.445464
354	60	15	50	5	15	2000	1687.74731	3.445464
355	60	15	50	5	17	1000	1712.13928	3.495259
356	60	15	50	5	17	1200	1712.13928	3.495259
357	60	15	50	5	17	2000	1712.13928	3.495259
358	60	15	50	5	20	1000	1749.03955	3.570589
359	60	15	50	5	20	1200	1749.03955	3.570589
360	60	15	50	5	20	2000	1749.03955	3.570589
361	60	15	50	10	15	1000	1875.57458	3.828905
362	60	15	50	10	15	1200	1875.57458	3.828905
363	60	15	50	10	15	2000	1875.57458	3.828905
364	60	15	50	10	17	1000	1926.46704	3.9328
365	60	15	50	10	17	1200	1926.46704	3.9328
366	60	15	50	10	17	2000	1926.46704	3.9328
367	60	15	50	10	20	1000	2003.54822	4.090158
368	60	15	50	10	20	1200	2003.54822	4.090158
369	60	15	50	10	20	2000	2003.54822	4.090158
370	60	15	50	20	15	1000	2276.72876	4.647844
371	60	15	50	20	15	1200	2276.72876	4.647844
372	60	15	50	20	15	2000	2276.72876	4.647844

373	60	15	50	20	17	1000	2383.93168	4.866695
374	60	15	50	20	17	1200	2383.93168	4.866695
375	60	15	50	20	17	2000	2383.93168	4.866695
376	60	15	50	20	20	1000	2545.72119	5.196981
377	60	15	50	20	20	1200	2545.72119	5.196981
378	60	15	50	20	20	2000	2545.72119	5.196981
379	60	15	75	5	15	1000	2460.80981	5.023638
380	60	15	75	5	15	1200	2460.80981	5.023638
381	60	15	75	5	15	2000	2460.80981	5.023638
382	60	15	75	5	17	1000	2485.55444	5.074153
383	60	15	75	5	17	1200	2485.55444	5.074153
384	60	15	75	5	17	2000	2485.55444	5.074153
385	60	15	75	5	20	1000	2522.875	5.150341
386	60	15	75	5	20	1200	2522.875	5.150341
387	60	15	75	5	20	2000	2522.875	5.150341
388	60	15	75	10	15	1000	2650.19678	5.410263
389	60	15	75	10	15	1200	2650.19678	5.410263
390	60	15	75	10	15	2000	2650.19678	5.410263
391	60	15	75	10	17	1000	2701.26831	5.514524
392	60	15	75	10	17	1200	2701.26831	5.514524
393	60	15	75	10	17	2000	2701.26831	5.514524
394	60	15	75	10	20	1000	2778.4458	5.672078
395	60	15	75	10	20	1200	2778.4458	5.672078
396	60	15	75	10	20	2000	2778.4458	5.672078
397	60	15	75	20	15	1000	3052.5708	6.231693
398	60	15	75	20	15	1200	3052.5708	6.231693
399	60	15	75	20	15	2000	3052.5708	6.231693
400	60	15	75	20	17	1000	3160.25366	6.451523
401	60	15	75	20	17	1200	3160.25366	6.451523
402	60	15	75	20	17	2000	3160.25366	6.451523
403	60	15	75	20	20	1000	3323.02661	6.783817
404	60	15	75	20	20	1200	3323.02661	6.783817
405	60	15	75	20	20	2000	3323.02661	6.783817
406	60	20	25	5	15	1000	1241.6637	2.534803
407	60	20	25	5	15	1200	1241.6637	2.534803
408	60	20	25	5	15	2000	1241.6637	2.534803
409	60	20	25	5	17	1000	1276.95105	2.606841
410	60	20	25	5	17	1200	1276.95105	2.606841
411	60	20	25	5	17	2000	1276.95105	2.606841
412	60	20	25	5	20	1000	1330.25024	2.715649
413	60	20	25	5	20	1200	1330.25024	2.715649
414	60	20	25	5	20	2000	1330.25024	2.715649

415	60	20	25	10	15	1000	1512.95313	3.088629
416	60	20	25	10	15	1200	1512.95313	3.088629
417	60	20	25	10	15	2000	1512.95313	3.088629
418	60	20	25	10	17	1000	1586.19517	3.23815
419	60	20	25	10	17	1200	1586.19517	3.23815
420	60	20	25	10	17	2000	1586.19517	3.23815
421	60	20	25	10	20	1000	1697.00239	3.464358
422	60	20	25	10	20	1200	1697.00239	3.464358
423	60	20	25	10	20	2000	1697.00239	3.464358
424	60	20	25	20	15	1000	2090.38452	4.267431
425	60	20	25	20	15	1200	2090.38452	4.267431
426	60	20	25	20	15	2000	2090.38452	4.267431
427	60	20	25	20	17	1000	2244.43799	4.581924
428	60	20	25	20	17	1200	2244.43799	4.581924
429	60	20	25	20	17	2000	2244.43799	4.581924
430	60	20	25	20	20	1000	2477.46411	5.057637
431	60	20	25	20	20	1200	2477.46411	5.057637
432	60	20	25	20	20	2000	2477.46411	5.057637
433	60	20	50	5	15	1000	2256.78198	4.607124
434	60	20	50	5	15	1200	2256.78198	4.607124
435	60	20	50	5	15	2000	2256.78198	4.607124
436	60	20	50	5	17	1000	2292.77148	4.680595
437	60	20	50	5	17	1200	2292.77148	4.680595
438	60	20	50	5	17	2000	2292.77148	4.680595
439	60	20	50	5	20	1000	2347.03516	4.791372
440	60	20	50	5	20	1200	2347.03516	4.791372
441	60	20	50	5	20	2000	2347.03516	4.791372
442	60	20	50	10	15	1000	2532.50415	5.169999
443	60	20	50	10	15	1200	2532.50415	5.169999
444	60	20	50	10	15	2000	2532.50415	5.169999
445	60	20	50	10	17	1000	2606.86304	5.321799
446	60	20	50	10	17	1200	2606.86304	5.321799
447	60	20	50	10	17	2000	2606.86304	5.321799
448	60	20	50	10	20	1000	2719.14966	5.551028
449	60	20	50	10	20	1200	2719.14966	5.551028
450	60	20	50	10	20	2000	2719.14966	5.551028
451	60	20	50	20	15	1000	3118.98999	6.367285
452	60	20	50	20	15	1200	3118.98999	6.367285
453	60	20	50	20	15	2000	3118.98999	6.367285
454	60	20	50	20	17	1000	3275.40283	6.686595
455	60	20	50	20	17	1200	3275.40283	6.686595
456	60	20	50	20	17	2000	3275.40283	6.686595

457	60	20	50	20	20	1000	3511.24609	7.168059
458	60	20	50	20	20	1200	3511.24609	7.168059
459	60	20	50	20	20	2000	3511.24609	7.168059
460	60	20	75	5	15	1000	3280.12476	6.696235
461	60	20	75	5	15	1200	3280.12476	6.696235
462	60	20	75	5	15	2000	3280.12476	6.696235
463	60	20	75	5	17	1000	3317.15796	6.771836
464	60	20	75	5	17	1200	3317.15796	6.771836
465	60	20	75	5	17	2000	3317.15796	6.771836
466	60	20	75	5	20	1000	3372.84717	6.885523
467	60	20	75	5	20	1200	3372.84717	6.885523
468	60	20	75	5	20	2000	3372.84717	6.885523
469	60	20	75	10	15	1000	3562.05933	7.271792
470	60	20	75	10	15	1200	3562.05933	7.271792
471	60	20	75	10	15	2000	3562.05933	7.271792
472	60	20	75	10	17	1000	3637.58276	7.42597
473	60	20	75	10	17	1200	3637.58276	7.42597
474	60	20	75	10	17	2000	3637.58276	7.42597
475	60	20	75	10	20	1000	3751.33154	7.658183
476	60	20	75	10	20	1200	3751.33154	7.658183
477	60	20	75	10	20	2000	3751.33154	7.658183
478	60	20	75	20	15	1000	4153.17334	8.478526
479	60	20	75	20	15	1200	4153.17334	8.478526
480	60	20	75	20	15	2000	4153.17334	8.478526
481	60	20	75	20	17	1000	4309.39551	8.797447
482	60	20	75	20	17	1200	4309.39551	8.797447
483	60	20	75	20	17	2000	4309.39551	8.797447
484	60	20	75	20	20	1000	4544.7666	9.277947
485	60	20	75	20	20	1200	4544.7666	9.277947
486	60	20	75	20	20	2000	4544.7666	9.277947
487	100	10	25	5	15	1000	1156.1521	2.360235
488	100	10	25	5	15	1200	1156.1521	2.360235
489	100	10	25	5	15	2000	1156.1521	2.360235
490	100	10	25	5	17	1000	1189.42444	2.428159
491	100	10	25	5	17	1200	1189.42444	2.428159
492	100	10	25	5	17	2000	1189.42444	2.428159
493	100	10	25	5	20	1000	1239.21936	2.529813
494	100	10	25	5	20	1200	1239.21936	2.529813
495	100	10	25	5	20	2000	1239.21936	2.529813
496	100	10	25	10	15	1000	1405.97913	2.870246
497	100	10	25	10	15	1200	1405.97913	2.870246
498	100	10	25	10	15	2000	1405.97913	2.870246

499	100	10	25	10	17	1000	1472.47925	3.006003
500	100	10	25	10	17	1200	1472.47925	3.006003
501	100	10	25	10	17	2000	1472.47925	3.006003
502	100	10	25	10	20	1000	1572.00781	3.209187
503	100	10	25	10	20	1200	1572.00781	3.209187
504	100	10	25	10	20	2000	1572.00781	3.209187
505	100	10	25	20	15	1000	1903.00208	3.884897
506	100	10	25	20	15	1200	1903.00208	3.884897
507	100	10	25	20	15	2000	1903.00208	3.884897
508	100	10	25	20	17	1000	2027.43555	4.138923
509	100	10	25	20	17	1200	2027.43555	4.138923
510	100	10	25	20	17	2000	2027.43555	4.138923
511	100	10	25	20	20	1000	2213.7793	4.519336
512	100	10	25	20	20	1200	2213.7793	4.519336
513	100	10	25	20	20	2000	2213.7793	4.519336
514	100	10	50	5	15	1000	2065.11646	4.215847
515	100	10	50	5	15	1200	2065.11646	4.215847
516	100	10	50	5	15	2000	2065.11646	4.215847
517	100	10	50	5	17	1000	2098.3457	4.283683
518	100	10	50	5	17	1200	2098.3457	4.283683
519	100	10	50	5	17	2000	2098.3457	4.283683
520	100	10	50	5	20	1000	2148.19263	4.385443
521	100	10	50	5	20	1200	2148.19263	4.385443
522	100	10	50	5	20	2000	2148.19263	4.385443
523	100	10	50	10	15	1000	2315.46851	4.72693
524	100	10	50	10	15	1200	2315.46851	4.72693
525	100	10	50	10	15	2000	2315.46851	4.72693
526	100	10	50	10	17	1000	2382.16748	4.863093
527	100	10	50	10	17	1200	2382.16748	4.863093
528	100	10	50	10	17	2000	2382.16748	4.863093
529	100	10	50	10	20	1000	2482.25488	5.067417
530	100	10	50	10	20	1200	2482.25488	5.067417
531	100	10	50	10	20	2000	2482.25488	5.067417
532	100	10	50	20	15	1000	2823.23022	5.763504
533	100	10	50	20	15	1200	2823.23022	5.763504
534	100	10	50	20	15	2000	2823.23022	5.763504
535	100	10	50	20	17	1000	2957.35229	6.037308
536	100	10	50	20	17	1200	2957.35229	6.037308
537	100	10	50	20	17	2000	2957.35229	6.037308
538	100	10	50	20	20	1000	3158.57617	6.448098
539	100	10	50	20	20	1200	3158.57617	6.448098
540	100	10	50	20	20	2000	3158.57617	6.448098

541	100	10	75	5	15	1000	2975.02588	6.073388
542	100	10	75	5	15	1200	2975.02588	6.073388
543	100	10	75	5	15	2000	2975.02588	6.073388
544	100	10	75	5	17	1000	3008.41162	6.141544
545	100	10	75	5	17	1200	3008.41162	6.141544
546	100	10	75	5	17	2000	3008.41162	6.141544
547	100	10	75	5	20	1000	3058.4978	6.243793
548	100	10	75	5	20	1200	3058.4978	6.243793
549	100	10	75	5	20	2000	3058.4978	6.243793
550	100	10	75	10	15	1000	3226.54443	6.586853
551	100	10	75	10	15	1200	3226.54443	6.586853
552	100	10	75	10	15	2000	3226.54443	6.586853
553	100	10	75	10	17	1000	3293.34473	6.723223
554	100	10	75	10	17	1200	3293.34473	6.723223
555	100	10	75	10	17	2000	3293.34473	6.723223
556	100	10	75	10	20	1000	3393.36914	6.927418
557	100	10	75	10	20	1200	3393.36914	6.927418
558	100	10	75	10	20	2000	3393.36914	6.927418
559	100	10	75	20	15	1000	3735.2168	7.625285
560	100	10	75	20	15	1200	3735.2168	7.625285
561	100	10	75	20	15	2000	3735.2168	7.625285
562	100	10	75	20	17	1000	3869.86304	7.90016
563	100	10	75	20	17	1200	3869.86304	7.90016
564	100	10	75	20	17	2000	3869.86304	7.90016
565	100	10	75	20	20	1000	4071.89111	8.312592
566	100	10	75	20	20	1200	4071.89111	8.312592
567	100	10	75	20	20	2000	4071.89111	8.312592
568	100	15	25	5	15	1000	1700.31628	3.471123
569	100	15	25	5	15	1200	1700.31628	3.471123
570	100	15	25	5	15	2000	1700.31628	3.471123
571	100	15	25	5	17	1000	1760.4381	3.593859
572	100	15	25	5	17	1200	1760.4381	3.593859
573	100	15	25	5	17	2000	1760.4381	3.593859
574	100	15	25	5	20	1000	1850.63782	3.777998
575	100	15	25	5	20	1200	1850.63782	3.777998
576	100	15	25	5	20	2000	1850.63782	3.777998
577	100	15	25	10	15	1000	2153.34521	4.395962
578	100	15	25	10	15	1200	2153.34521	4.395962
579	100	15	25	10	15	2000	2153.34521	4.395962
580	100	15	25	10	17	1000	2273.70288	4.641667
581	100	15	25	10	17	1200	2273.70288	4.641667
582	100	15	25	10	17	2000	2273.70288	4.641667

583	100	15	25	10	20	1000	2454.30664	5.010362
584	100	15	25	10	20	1200	2454.30664	5.010362
585	100	15	25	10	20	2000	2454.30664	5.010362
586	100	15	25	20	15	1000	3075.03906	6.277561
587	100	15	25	20	15	1200	3075.03906	6.277561
588	100	15	25	20	15	2000	3075.03906	6.277561
589	100	15	25	20	17	1000	3317.97729	6.773509
590	100	15	25	20	17	1200	3317.97729	6.773509
591	100	15	25	20	17	2000	3317.97729	6.773509
592	100	15	25	20	20	1000	3682.36084	7.517382
593	100	15	25	20	20	1200	3682.36084	7.517382
594	100	15	25	20	20	2000	3682.36084	7.517382
595	100	15	50	5	15	1000	2955.96289	6.034472
596	100	15	50	5	15	1200	2955.96289	6.034472
597	100	15	50	5	15	2000	2955.96289	6.034472
598	100	15	50	5	17	1000	3016.33618	6.157721
599	100	15	50	5	17	1200	3016.33618	6.157721
600	100	15	50	5	17	2000	3016.33618	6.157721
601	100	15	50	5	20	1000	3106.91675	6.342638
602	100	15	50	5	20	1200	3106.91675	6.342638
603	100	15	50	5	20	2000	3106.91675	6.342638
604	100	15	50	10	15	1000	3411.31494	6.964054
605	100	15	50	10	15	1200	3411.31494	6.964054
606	100	15	50	10	15	2000	3411.31494	6.964054
607	100	15	50	10	17	1000	3532.44531	7.211336
608	100	15	50	10	17	1200	3532.44531	7.211336
609	100	15	50	10	17	2000	3532.44531	7.211336
610	100	15	50	10	20	1000	3713.79541	7.581555
611	100	15	50	10	20	1200	3713.79541	7.581555
612	100	15	50	10	20	2000	3713.79541	7.581555
613	100	15	50	20	15	1000	4337.13965	8.854085
614	100	15	50	20	15	1200	4337.13965	8.854085
615	100	15	50	20	15	2000	4337.13965	8.854085
616	100	15	50	20	17	1000	4581.65234	9.353247
617	100	15	50	20	17	1200	4581.65234	9.353247
618	100	15	50	20	17	2000	4581.65234	9.353247
619	100	15	50	20	20	1000	4948.36475	10.10188
620	100	15	50	20	20	1200	4948.36475	10.10188
621	100	15	50	20	20	2000	4948.36475	10.10188
622	100	15	75	5	15	1000	4216.48535	8.607775
623	100	15	75	5	15	1200	4216.48535	8.607775
624	100	15	75	5	15	2000	4216.48535	8.607775

625	100	15	75	5	17	1000	4277.18311	8.731687
626	100	15	75	5	17	1200	4277.18311	8.731687
627	100	15	75	5	17	2000	4277.18311	8.731687
628	100	15	75	5	20	1000	4368.24854	8.917593
629	100	15	75	5	20	1200	4368.24854	8.917593
630	100	15	75	5	20	2000	4368.24854	8.917593
631	100	15	75	10	15	1000	4673.67578	9.541109
632	100	15	75	10	15	1200	4673.67578	9.541109
633	100	15	75	10	15	2000	4673.67578	9.541109
634	100	15	75	10	17	1000	4795.12744	9.789048
635	100	15	75	10	17	1200	4795.12744	9.789048
636	100	15	75	10	17	2000	4795.12744	9.789048
637	100	15	75	10	20	1000	4977.34473	10.16104
638	100	15	75	10	20	1200	4977.34473	10.16104
639	100	15	75	10	20	2000	4977.34473	10.16104
640	100	15	75	20	15	1000	5603.65576	11.43962
641	100	15	75	20	15	1200	5603.65576	11.43962
642	100	15	75	20	15	2000	5603.65576	11.43962
643	100	15	75	20	17	1000	5849.28906	11.94107
644	100	15	75	20	17	1200	5849.28906	11.94107
645	100	15	75	20	17	2000	5849.28906	11.94107
646	100	15	75	20	20	1000	6217.73242	12.69323
647	100	15	75	20	20	1200	6217.73242	12.69323
648	100	15	75	20	20	2000	6217.73242	12.69323
649	100	20	25	5	15	1000	2297.68652	4.690629
650	100	20	25	5	15	1200	2297.68652	4.690629
651	100	20	25	5	15	2000	2297.68652	4.690629
652	100	20	25	5	17	1000	2391.69116	4.882535
653	100	20	25	5	17	1200	2391.69116	4.882535
654	100	20	25	5	17	2000	2391.69116	4.882535
655	100	20	25	5	20	1000	2532.75737	5.170516
656	100	20	25	5	20	1200	2532.75737	5.170516
657	100	20	25	5	20	2000	2532.75737	5.170516
658	100	20	25	10	15	1000	3007.33105	6.139338
659	100	20	25	10	15	1200	3007.33105	6.139338
660	100	20	25	10	15	2000	3007.33105	6.139338
661	100	20	25	10	17	1000	3195.97607	6.524449
662	100	20	25	10	17	1200	3195.97607	6.524449
663	100	20	25	10	17	2000	3195.97607	6.524449
664	100	20	25	10	20	1000	3478.94092	7.102109
665	100	20	25	10	20	1200	3478.94092	7.102109
666	100	20	25	10	20	2000	3478.94092	7.102109

667	100	20	25	20	15	1000	4455.71191	9.096145
668	100	20	25	20	15	1200	4455.71191	9.096145
669	100	20	25	20	15	2000	4455.71191	9.096145
670	100	20	25	20	17	1000	4837.66016	9.875876
671	100	20	25	20	17	1200	4837.66016	9.875876
672	100	20	25	20	17	2000	4837.66016	9.875876
673	100	20	25	20	20	1000	5410.34619	11.04499
674	100	20	25	20	20	1200	5410.34619	11.04499
675	100	20	25	20	20	2000	5410.34619	11.04499
676	100	20	50	5	15	1000	3906.44824	7.974847
677	100	20	50	5	15	1200	3906.44824	7.974847
678	100	20	50	5	15	2000	3906.44824	7.974847
679	100	20	50	5	17	1000	4001.11865	8.168113
680	100	20	50	5	17	1200	4001.11865	8.168113
681	100	20	50	5	17	2000	4001.11865	8.168113
682	100	20	50	5	20	1000	4143.1748	8.458114
683	100	20	50	5	20	1200	4143.1748	8.458114
684	100	20	50	5	20	2000	4143.1748	8.458114
685	100	20	50	10	15	1000	4621.09619	9.43377
686	100	20	50	10	15	1200	4621.09619	9.43377
687	100	20	50	10	15	2000	4621.09619	9.43377
688	100	20	50	10	17	1000	4811.33105	9.822127
689	100	20	50	10	17	1200	4811.33105	9.822127
690	100	20	50	10	17	2000	4811.33105	9.822127
691	100	20	50	10	20	1000	5096.78271	10.40486
692	100	20	50	10	20	1200	5096.78271	10.40486
693	100	20	50	10	20	2000	5096.78271	10.40486
694	100	20	50	20	15	1000	6081.86377	12.41586
695	100	20	50	20	15	1200	6081.86377	12.41586
696	100	20	50	20	15	2000	6081.86377	12.41586
697	100	20	50	20	17	1000	6467.01074	13.20213
698	100	20	50	20	17	1200	6467.01074	13.20213
699	100	20	50	20	17	2000	6467.01074	13.20213
700	100	20	50	20	20	1000	7043.17285	14.37834
701	100	20	50	20	20	1200	7043.17285	14.37834
702	100	20	50	20	20	2000	7043.17285	14.37834
703	100	20	75	5	15	1000	5526.57324	11.28226
704	100	20	75	5	15	1200	5526.57324	11.28226
705	100	20	75	5	15	2000	5526.57324	11.28226
706	100	20	75	5	17	1000	5622.06641	11.47721
707	100	20	75	5	17	1200	5622.06641	11.47721
708	100	20	75	5	17	2000	5622.06641	11.47721

709	100	20	75	5	20	1000	5765.24707	11.76951
710	100	20	75	5	20	1200	5765.24707	11.76951
711	100	20	75	5	20	2000	5765.24707	11.76951
712	100	20	75	10	15	1000	6246.854	12.75269
713	100	20	75	10	15	1200	6246.854	12.75269
714	100	20	75	10	15	2000	6246.854	12.75269
715	100	20	75	10	17	1000	6438.52393	13.14397
716	100	20	75	10	17	1200	6438.52393	13.14397
717	100	20	75	10	17	2000	6438.52393	13.14397
718	100	20	75	10	20	1000	6726.08398	13.73101
719	100	20	75	10	20	1200	6726.08398	13.73101
720	100	20	75	10	20	2000	6726.08398	13.73101
721	100	20	75	20	15	1000	7716.57666	15.75306
722	100	20	75	20	15	1200	7716.57666	15.75306
723	100	20	75	20	15	2000	7716.57666	15.75306
724	100	20	75	20	17	1000	8108.08789	16.55231
725	100	20	75	20	17	1200	8108.08789	16.55231
726	100	20	75	20	17	2000	8108.08789	16.55231
727	100	20	75	20	20	1000	8704.68164	17.77024
728	100	20	75	20	20	1200	8704.68164	17.77024
729	100	20	75	20	20	2000	8704.68164	17.77024

5-12 Conclusions and discussion:

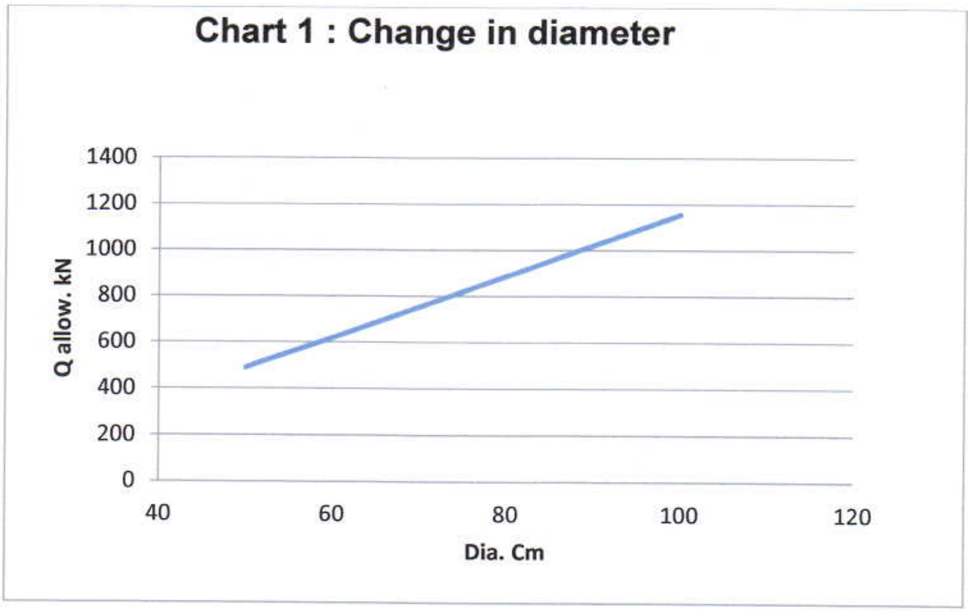
Allpile program is working to the detriment bearing capacity pile easily and quickly. When you enter any of the variable (diameter, length, c, **Ø, ɣ**, load) gives accurate results. When applying a 729 cases of this program concluded the following:

Case 1:

When you increase the diameter of pile , all variables are consistent, increase bearing capacity of pile as shown in (Chart 1)

kN

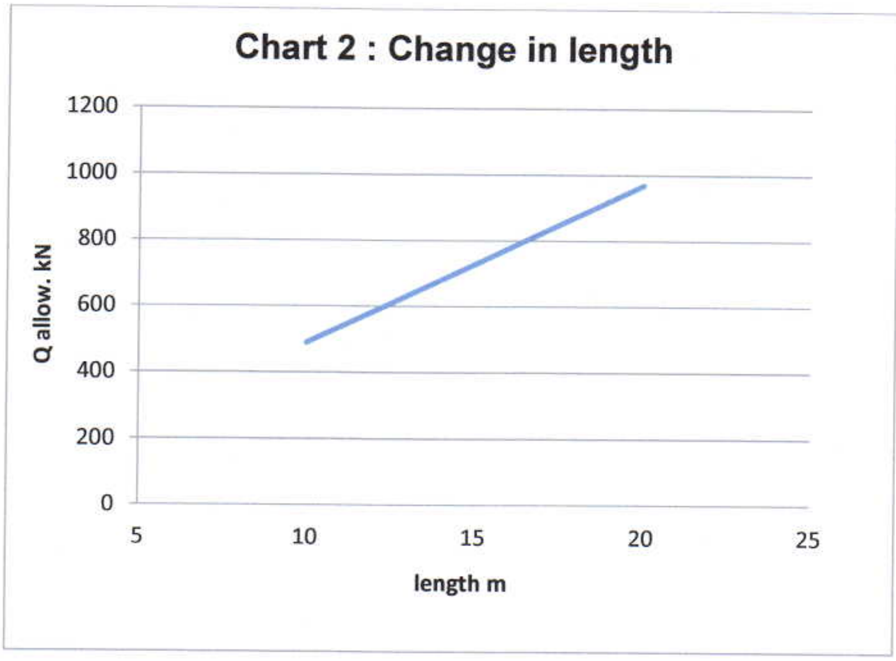
No.	Dia. Cm	length	C	Ø	ɣ	load	Q allow. kN
1	50	10	25	5	15	1000	489.8462
244	60	10	25	5	15	1000	620.5093
487	100	10	25	5	15	1000	1156.152



Case 2

When you increase the length of pile , all variables are consistent, increase bearing capacity of pile as shown in (Chart 2).

No.	Dia. Cm	length	C	Ø	ɣ	load	Q allow. kN
1	50	10	25	5	15	1000	489.8462
82	50	15	25	5	15	1000	729.3118
163	50	20	25	5	15	1000	969.1109



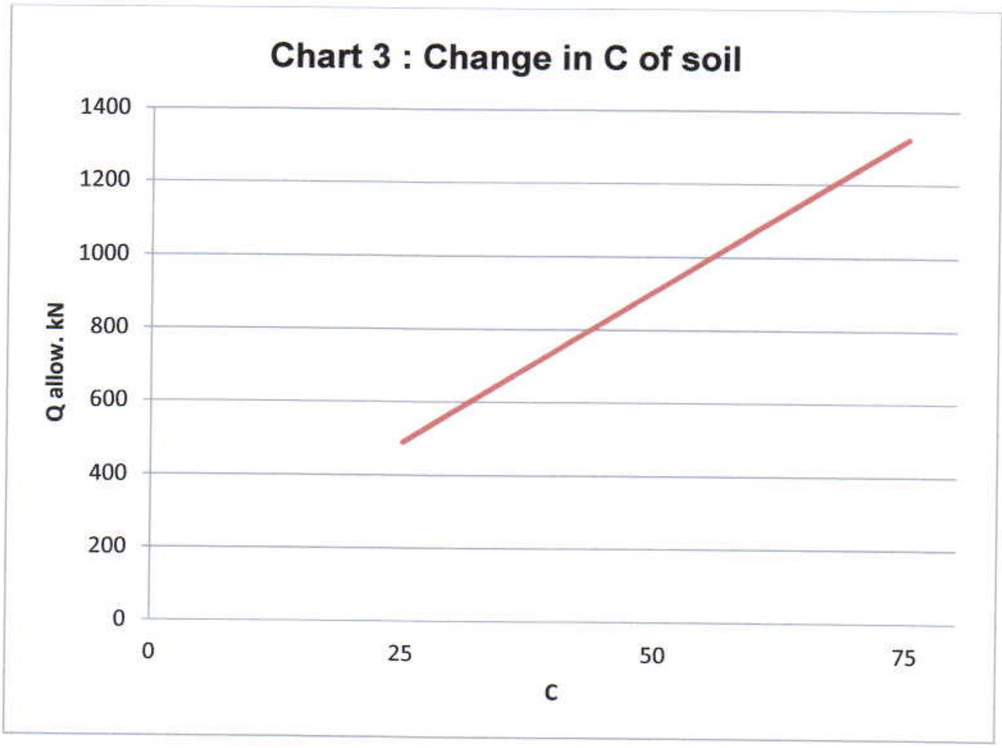
But the effect of pile diameter is greater than the effect of length, and the increase in diameter is not economic as shown by example:

No.	Dia. Cm	length	C	Ø	ɣ	Q allow. kN	Volume of pile m^3
163	50	20	25	5	15	969.1109	3.92
487	100	10	25	5	15	1156.152	7.853

Case 3

When you increase the **C** of soil , all variables are consistent, increase bearing capacity of pile as shown in (Chart 3)

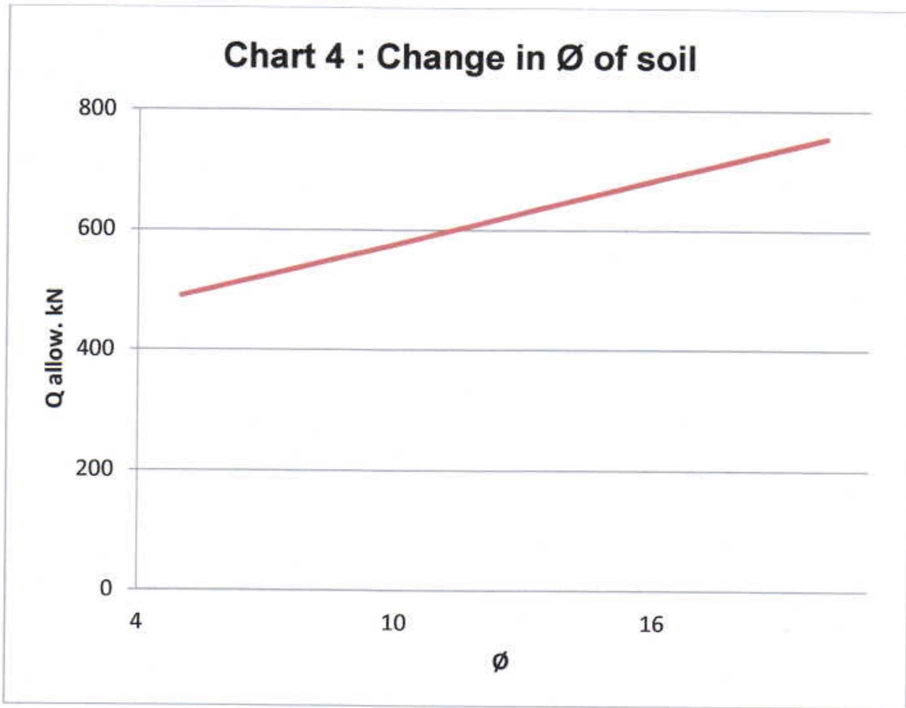
No.	Dia. Cm	length	C	Ø	ɣ	load	Q allow. kN
1	50	10	25	5	15	1000	489.8462
28	50	10	50	5	15	1000	907.9409
55	50	10	75	5	15	1000	1322.788



Case 4

When you increase the Ø of soil , all variables are consistent, increase bearing capacity of pile as shown in (Chart 4)

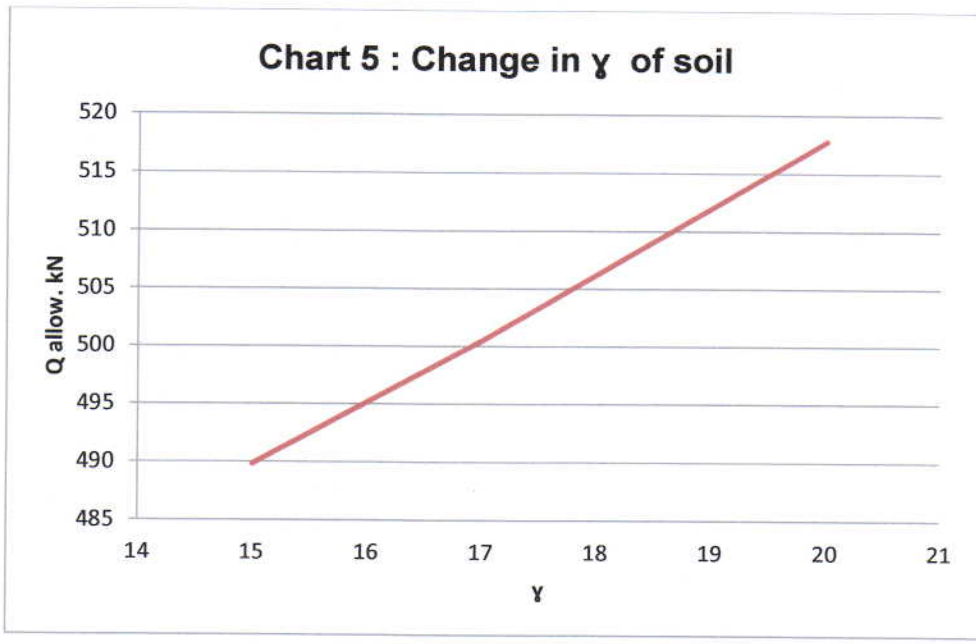
No.	Dia. Cm	length	C	Ø	ɣ	load	Q allow. kN
1	50	10	25	5	15	1000	489.8462
10	*50*	*10*	*25*	*10*	*15*	*1000*	*576.0555*
19	50	10	25	20	15	1000	754.7108



Case 5

When you increase the ɣ of soil, all variables are consistent, increase bearing capacity of pile as shown in (Chart 5)

No.	Dia. Cm	length	C	Ø	ɣ	load	Q allow. kN
1	50	10	25	5	15	1000	489.8462
4	50	10	25	5	17	1000	500.4694
7	50	10	25	5	20	1000	517.7747

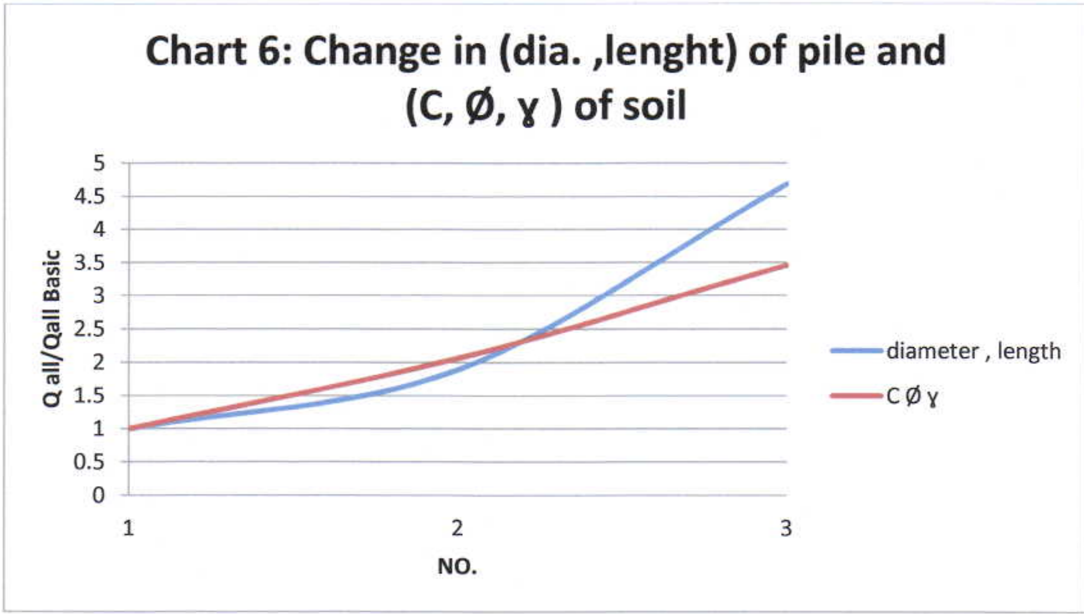


Case 6

Change soil properties difficult to achieve, as well as the changing dimensions of pile increases the bearing capacity much more, but have too much cost, as shown in (chart 6)

No.	Dia. Cm	length	C	Ø	γ	load	Q allow. kN	$\frac{Q\ all}{Qall.Basic}$
1	50	10	25	5	15	1000	489.8462	1
325	60	15	25	5	15	1000	927.8048	1.894074
649	100	20	25	5	15	1000	2297.687	4.690629

No.	Dia. Cm	length	C	Ø	γ	load	Q allow. kN	$\frac{Q\ all}{Qall.Basic}$
1	50	10	25	5	15	1000	489.8462	1
40	50	10	50	10	17	1000	1010.748	2.063399
79	50	10	75	20	20	1000	1694.27	3.45878



Reference:

1. Deep foundation, by Dr. Jie-Ru Chen Assistant Professor, National Chi Nan University.

2. http://www.piledrivers.org

3. www.roger-bullivant.co.uk company of pile testing Equipment

4. Allpile user's manual Published by **CivilTech Software** ,Bellevue, WA U.S.A. Web Site: http://www.civiltechsoftware.com

5. Bowels, J.E.(1982) foundation Analysis and Design (3rd ed.) McGraw-Hill Kogakisha .Pp (592-616)