Design And Analysis of Pile Foundation For Major Structures

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Abstract- *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. Piles made from these materials are driven, drilled or jacked into the ground and connected to pile caps.A pile is basically a long cylinder of a strong material such as concrete that is pushed into the ground to act as a steady support for structures built on top of it.Pile foundations are capable of taking higher loads than spread footings. There are two fundamental types of pile foundations (based on structural behaviour), each of which works in its own way.*

As pile foundations carry a lot of load, they must be designed very carefully. A good engineer will study the soil the piles are placed in to ensure that the soil is not overloaded beyond its bearing capacity. Every pile has a zone of influence on the soil around it. Care must be taken to space the piles far enough apart so that loads are distributed evenly over the entire bulb of soil that carries them, and not concentrated into a few areas.

Keywords- Pile foundations, zone of influence, steady support for structures.

I. INTRODUCTION

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. The purpose of a pile foundation 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. 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.

II. FOUNDATIONS

A foundation is a structure that transfers loads to the earth. Foundation is the element of a structure that serves to support the loads super imposed to it through the transmitting elements.

In addition foundation also serves some other function as:

- Prevent settlement of structure.
- Allow building over water ground.
- Resist uplifting or over turning forces due to wind.
- Resist lateral forces due to soil movement.
- Foundations are broadly classified into two categories:
  a) Shallow foundations
  b) Deep foundations

III. PILE FOUNDATIONS

Pile foundations consist of piles that are dug into the soil till a layer of stable soil is reached. These are used extensively for the support of buildings, bridges, and other structures to safely transfer structural loads to the ground and to avoid excess settlement or lateral movement.

Pile foundations are generally adopted in the following situations

- Low bearing capacity of soil.

- Non availability of proper bearing stratum at shallow depths.
- Heavy loads from the super structure for which shallow foundation may not be economical or feasible.

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. Commonly a pile has load or end bearing as well as skin friction to transfer the loads to the subsequent or surrounding soil.

The main types of materials used for the piles are wood, steel and concrete. Piles made from this material are driven, drilled or jacked into the ground and connected to the pile caps. Depending upon the type of soil, pile material and load transmitting characteristic piles are classified.

The design, performance and options of pile foundations depend on several factors such as:

- Depth of sound subsoil
- Constituents and nature of subsoil
- Physical environment of site
- Speed of work
- Loading condition of pile
- Efficacy of using a right kind of pile

IV. CLASSIFICATION OF PILES

Classifications based on function or action

- Friction piles
- Tension or uplift piles
- Compaction piles
- Anchor piles
- Fender piles
- Sheet piles
- Batter piles
- Laterally loaded piles
- End-bearing piles

Friction Piles:

Friction piles do not reach the hard stratum. These piles transfer the load through skin friction between the embedded surface of the pile and the surrounding soil. Friction piles are used when a hard stratum does not exist at a reasonable depth. The ultimate load (q_u) carried by the pile is equal to the load transferred by skin friction (q_s).

Load bearing Piles:

These are used to support retaining walls, bridges, dams, and wharves.

Compaction Piles:

These are used to compact loose granular soils in order to increase the bearing capacity. Since they are not required to carry any load, the material may not be required to be strong; in fact, sand may be used to form the pile. The pile tube, driven to compact the soil, is gradually taken out and sand is filled in its place thus forming a ‘sand pile’.

Tension Piles:

These are also called as uplift piles and are used to anchor structures subjected to uplift due to hydrostatic pressure or to overturning moment due to horizontal forces.

Sheet Piles:

Commonly used as bulkheads, or cut-offs to reduce seepage and uplift in hydraulic structures.

Fender Piles

These are used to protect water-front structures against impact from ships or other floating objects.

Anchor Piles:

These are used to provide anchorage against horizontal pull from sheet piling or water.

Batter Piles:

These are used to resist horizontal and inclined forces, especially in waterfront structures.

End-Bearing Piles:

End-bearing piles transmit the loads through their bottom tips. Such piles act as columns and transmit the loads through a weak material to a firm stratum below. If bed rock is located within a reasonable depth, piles can be extended to the rock. These are also known as point-bearing piles.

V. BORED PILING

5.1. BORED PILING

Bored Piling is one of the common and modern-day techniques for building a solid pile foundation for construction of various building types and structures.

Bored Piling is a process whereby steel circular casings are installed into the ground by the simultaneous process of drilling and soil removal. This is then followed by the concreting of the piles, which then forms a strong pile foundation for the structure. This process is usually required when soil replacement instead of soil displacement is required.

The considerations when forming bored piles includes three major factors:

- How to form the bore
- How to protect the soil from collapsing into the borehole during drilling
- How to take the soil out from borehole during drilling

INSTALLATION BY BORING

- Pile boring should be done depending upon the diameter of the piles
- The pile boring should be done by the given reference points
- First outer casing should be bored for 5minutes
- Second casing should be inserted into the first casing and later boring is done up to5m.After attaining hard soil change the bucket and bore until hard rock obtains

- When boring is done we will observe the changes in the color of soil like redsoil, clay etc.
- This boring is done until 1m and latter insert tremie pipes and pour concrete into the foundation.

VI. LOADS ON PILES

Objective: In the first part of this section, considering group of piles with limited number of piles subjected to vertical and lateral forces, forces acting centrally or eccentrically, we learn how these forces are distributed on individual piles.

In the second part, the comparison made between different methods used in pile design will enable students to appreciate the theoretical background of the methods while exercising pile designing.

In this project we consider the following items to calculation of load distribution.

- Calculate load distribution on group of piles consist of vertical piles subjected to eccentric vertical load.
- Calculate load distribution on vertically arranged piles subjected to lateral and vertical forces.
- Calculate load distribution on vertical and raking piles subjected to horizontal and eccentric vertical loads.
- Calculate load distribution on symmetrically arranged vertical and raking piles subjected to vertical and lateral forces

Pile arrangement

- Normally, pile foundations consist of pile cap and a group of piles. The pile cap distributes the applied load to the individual piles which, in turn,. transfer the load to the bearing ground. The individual piles are spaced and connected to the pile cap or tie beams and trimmed in order to connect the pile to the structure at ***cut-off level***, and depending on the type of structure and eccentricity of the load, they can be arranged in different patterns. Figure 6.1 bellow illustrates the three basic formation of pile groups.

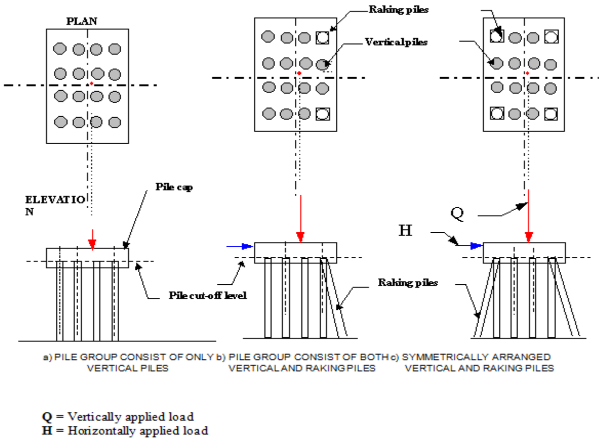


Figure 6.1 Basic formation of pile groups

LOAD DISTRIBUTION

To a great extent the design and calculation (load analysis) of pile foundations is carried out using computer software. For some special cases, calculations can be carried out using the following methods…For a simple understanding of the method, let us assume that the following conditions are satisfied: The pile is rigid The pile is pinned at the top and at the bottom.Each pile receives the load only vertically (i.e. axially applied);

Lateral Loads:

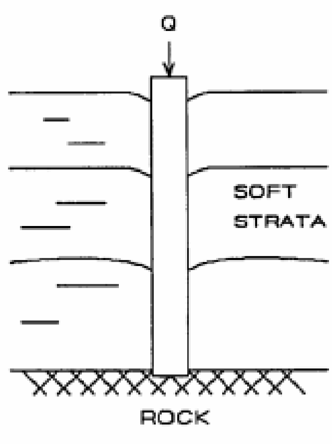
Lateral load capacity of a pile or drilled shaft is directly related to the diameter. Therefore, increasing the diameter, increases the load-carrying capacity.For a drilled shaft that sustains no axial load, the cost of construction may be optimized by the selection of rigid shafts without underreams and with length/diameter ratios less than 10. The selected shaft dimensions should minimize the volume of concrete required and maximize construction efficiency. The lateral load capacity of driven piles may be increased by increasing the number of piles and battering piles in a pile group.

Applications:

Driven pile groups are frequently used to support locks, dry docks, and other facilities constructed in river systems, lakes, lagoons, and other offshore applications. Drilled shafts typically support many permanent onshore structures such as administrative buildings, warehouses, and health care facilities. Drilled shafts are divided into two groups: displacement and non-displacement.

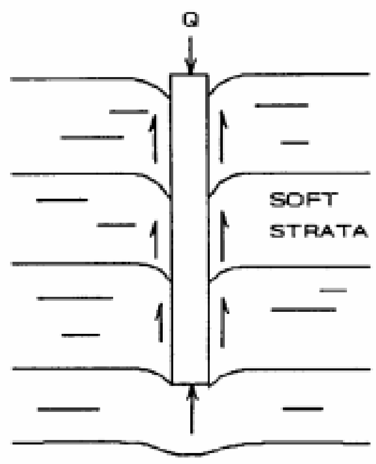
Displacement:

Driven pile foundations are usually preferable in loose, cohesionless and soft soils, especially where excavations cannot support fluid concrete and where the depth of the bearing stratum is uncertain. Groundwater conditions can be a deciding factor in the selection of driven piles rather than drilled shafts. Uncased shafts are generally excluded from consideration where artesian pressures are present. Often more than one type of driven pile may meet all requirements for a particular structure. Driven piles according to their application are presented in Figure a.



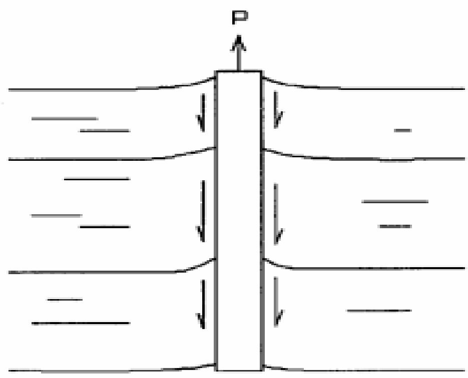
a. ENDBEARING PILE

Figures a and b illustrate piles classified according to their behavior as end bearing or friction piles. A pile embedded a significant length into stiff clays, silts and dense sands without significant end bearing resistance is usually a friction pile. A pile driven through relatively weak or compressible soil to an underlying stronger soil or rock is usually an end-bearing pile.



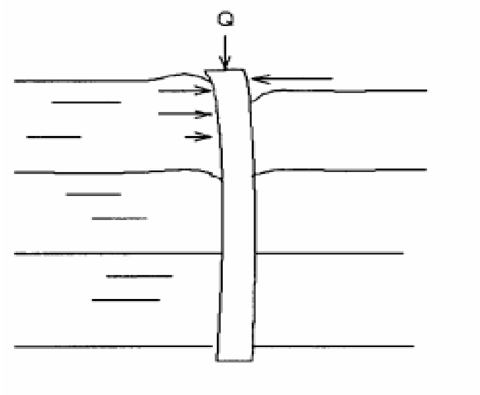
b. FRICTION PILE

Piles designed primarily to resist upward forces are uplift or tension piles (Figure c), and the resistance to the upward force is by a combination of side (skin) friction and self-weight of the pile.

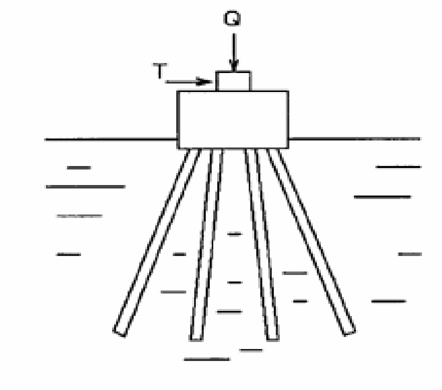


c. TENSION PILE

Lateral forces are resisted either by vertical piles in bending (Figure d) or by batter piles or groups of vertical and batter piles (Figure e).

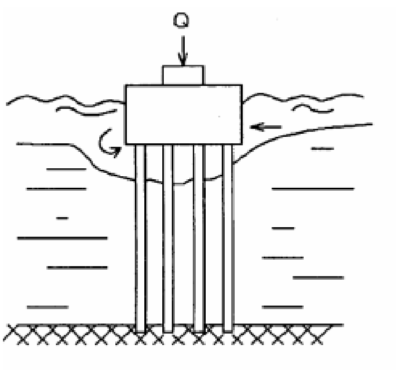


d. RESISTANCE TO BENDING

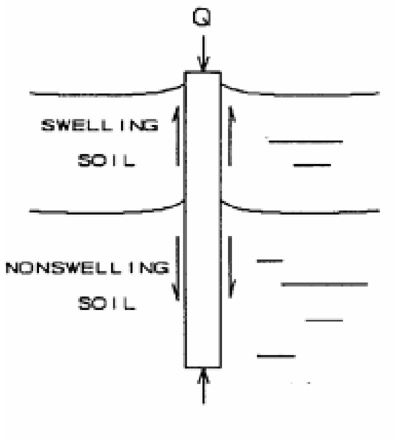


e. BATTERED GROUP

Piles are used to transfer loads from above water structures to below the scour depth (Figure f). Piles are also used to support structures that may be endangered by future adjacent excavations (Figureg). To prevent undesirable movements of structures on shrink/swell soils, a pile anchored as shown in Figure h can be used.



LOAD TRANSFER BELOW SCOUR DEPTH



h. PILE ANCHORED IN NONSWELLING SOIL

VII. TESTING OF PILES

7.1. TESTING OF PILES

The following tests are required to determine the performance of piles:

- Bearing capacity of pile
- The integrity of pile
- Settlement of pile under load

7.1.1. BEARING capacity of piles

Bearing capacity of pile depends on:

1) Size, shape and type of pile
2) Property of soil embedding the pile

At load greater than bearing capacity of pile, the soil embedding will show the shear failure making the pile penetrate into the ground until it finds a depth that equilibrium can be reached.

There is no perfect method to find bearing capacity of pile. Usually it is worked out using some empirical formula such as Hilary formula or static formula etc.

7.1.2. integrity test

This test is to find out the structural soundness of piles especially for those large diameters concrete piles.

Examples of structural soundness:

1) Whether there is any honeycomb in the pile

2) Compressive strength of concrete in pile

7.1.3. load test

This test is to determine settlement of pile under load. It is the most definitive method of determining load capacity of piles. Pile foundation can be constructed depending on the stiffness of subsurface soil and ground water conditions and using a variety of construction techniques.

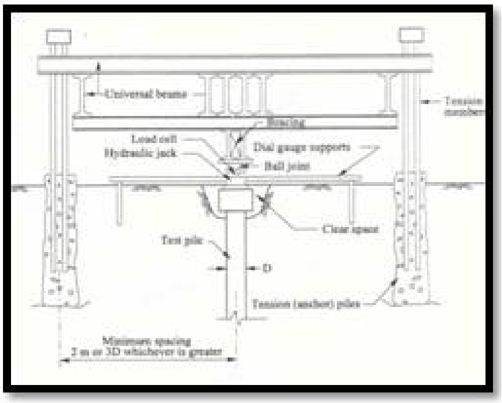


Fig.7.1.3. load test on pile

The most common techniques are in-situ casting and pre-auguring. Due to the extensive nature of the subsurface mass that it influences, the degree of uncertainty regarding the actual working capacity of a pile foundation is generally much higher than that of a shallow footing. The load test on piles can be done in two ways:

1) Static analysis
2) Dynamic analysis

The settlement analysis of pile foundations bears some similarity to the settlement analysis of shallow foundations, in that both are based on the same principles. There are, however, some distinct differences. These come, in part, from previously discussed disturbances of the adjacent soil and changes in its state of stress caused by the operation of pile placement in the ground. Because of these disturbances, the soil surrounding a pile, even if it was initially homogeneous, can exhibit sharp variations of stiffness in both vertical and horizontal directions at least in the highly stressed zones around the pile. If the pile is driven, it can retain large residual stresses which, in turn, significantly influence the pile response to load and its loadsettlement characteristics. The exact position of load transfer from the pile to the soil is unknown and usually varies with load intensity. As in the case of the. parent bearing capacity problem, the situation is further complicated by the effects of placing of adjacent piles and possible group action, making the rational formulation of this problem extremely difficult. Thus, at the present state of knowledge, only approximate solutions of this problem are available, and their limitations must be kept in mind in all applications.

For design purposes, it is convenient to separate the pilehead settlement (w_0) into its three components: settlement due to axial deformation of the pile shaft (w_e), settlement of pile point caused by load transmitted at the point (w_p), and settlement of pile point caused by load transmitted along the pile shaft (w_s)).

Thus, it can be written that, in general W_0= Wo + Wp+ Ws

DYNAMICS OF PILE DRIVING

Pile driving can be defined as the operation of forcing the pile into ground by dynamic means such as impact or vibration. In the most used impact method, the pile is driven by means of a hammer containing a ram (Fig. 49a), which falls along two parallel guides (leads) on the pile head. If the ram weight (Wr) and the falling distance (stroke) (h) are properly selected, the pile experiences on each blow a permanent downward displacement (set) (s). A sequence of such blows can bring the pile to a desired elevation as long as there is sufficient driving energy to overcome the dynamic resistance (R) of the pile and the pile is not damaged or broken by excessive driving stresses. The mechanics of operation of principal hammer types is shown in Figure 49. The ram of a drop-hammer is raised by a winch and allowed to drop freely from a prescribed height. The modern versions of this ancient method operate at approximately 10 blows per minute. In the case of single-acting hammers, the ram is lifted by steam or air pressure, increasing the frequency of blows to approximately 60 per minute. Free-fall still remains the principal source of driving energy. In the case of double- and differential-acting hammers, the steam or air pressure is used also to accelerate the ram downward. In this way, both the impact velocity and thedriving frequency are considerably increased. In diesel hammers ,the ram fall compresses the air inside an enclosed cylinder. A properly timed fuel injection during the ram-anvil impact causes an explosion of the fuel-air mixture, which is used to lift the ram and also to give the pile an additional dynamic impulse. In some models, the cylinder may be closed-ended, in which case a "bounce-chamber" of compressed air on the upper end of the cylinder provides a double-acting effect. Hydraulic hammers, which are still not used extensively, operate on a system similar to steam or air hammers. However, oil at a high pressure of 5,000 psi (34.5 MPa) replaces steam, which operates at usual pressures of slightly more than 100 psi (689 kPa). Finally vibratory drivers consist of a pair of counter-rotating eccentric weights whose horizontal impulses from centrifugal forces cancel, while vertical impulses add in producing a pulsating load of variable frequency. Principal characteristics of commonly used impact hammers and those of vibratory drivers. An up-to-date discussion of their relative merits can be found in Reference 195. To soften the impact and prevent pile and hammer damage, the pile head may be covered by a steel helmet (cap), with a renewable cushion (cap block) made of materials such as wood, fiber, or plastics. As shown in Figure, another cushion may be placed between the helmet and the pile head. The presence of the helmet with cushions.

ROUTINE VERTICAL LOAD TEST AS PER IS: 2911 (PART IV) 1985
DETAILS OF PILE

Name of the work : Provision of integrated Commander Coy Complex at Naval Dock Yard (V).

Name of the Client : Director General Naval Projects, Visakhapatnam. CA NO: DDG & CE (V) 04
Name of the Contractor: SVC PROJECTS Pvt. Ltd.,

a) Type of Test: Routine Vertical Load Test as per IS: 2911 (Part IV)-1988
b) Cut of Level (COL) : 2.35 m
c) Rock Touch Level (RTL) : 32.23
d) Founding Level (FL) : 33.32
e) Depth of Pile upto CL : 33.45
f) Grade of Concrete: RCC M 40 Design Mix RMC

Details of Reinforcement

i) Main Bars : 32# - 22 Nos
ii) Inner Ring : 16# - 1000 C/C
iii) Helical : 10# - 75 C/C
iv)X-Sec Area of Pile (IId2/4) : 3.14x (1.00) 2/4=0.785 Sqm

LOAD REEQUIREMENTS

a) Design Load : 300 MT
b) Test Load : 450 MT
c) Kentledge Load : 562.50MT
d) Load of each increment : 20% of Design Load i.e. 20% of 300MT=60.00 MT
e) No of Increments : Test Load
f) Load of each Increments: 450/60=7.5 Say 8

DETAILS OF JACK

a) Capacity of Hydraulic Jack : 600 tons
b) Diameter of Ram : 27 Cm
c) X-Section Area of RAM : 3.14x(27)2/7=572.265 Sq.cm
d) Pressure of each increment : Load of each increment X 1000
e) X-Section area of Ram: 60.00x1000/572.265=104.85 say 105 Kg.cm2

DETAILS OF PRESSURE GAUGE

a) Capacity of Dial Gauge : 0-25 mm
b) Make of Gauge : WAAREE
c) Lease count of Gauge : 20 kg/cm2
d) Validity of Gauge : Calibrated

DETAILS OF DIAL GUAGES

a) Capacity of Dial Gauge : 0.25 mm
b) Make of DialGauge : BAKER
c) All four Gauge ABC&D : BAKER
d) Lease count of gauge : 0.01 mm
e) Validity of Gauge : Calibrated

DETAILS OF PRESSURE

a) Total Pressure to be applied : 450x1000/572.265=786.58 Say 790 kg/cm2
b) Pressure to be applied on each increments :105 kg/cm2
c) Active load to be applied on each increments :105x572.265/1000=60.08 MT

DETAILS OF LOAD APPLIED

a) Main Girders : ISMB-600=3.12.65=37.95RM@123.00 kg/RM = 4.66 MT
b) Secondary Girders : ISMB-300=12X11.50=138.00 RM@46.10 kg/RM = 6.36 MT
c) MS Plates 8 mm thick : 5x6.00x1.25+17x3.00x1.50+10x1.25x1.25 = 129.625 Sqm 129.625 Sqm@62.80 kg/Sqm = 8.14MT
d) PCC Blocks (Test Load Blocks) : 19.16
   i)45 No's of 4.50 Ton/each : 202.50
   ii) 18 No's of 3.50 Ton/each : 63.00
   iii)17 No's of 2.80 Ton/each : 47.60
   iv) 79 No's 2.75 Ton each : 217.25
   v) 5 No's of 2.70 Ton/each : 13.50
   Total: **563.01**

Total Kent ledge Load Applied: **563.01Mt**

VIII. CONCLUSION

The primary goal of this practical training program is to learn and understand the procedure and techniques involved for laying pile foundations, the process of keeping reinforcement in the pile and the load test on piles. Successfully we have achieved the goal and also seen the batching plant and its operation**.**

The net settlement in the vertical pile load test is 2.757mm which is less than the maximum allowable settlement (12mm), hence safe.

REFERENCES

[1] IS 456: Indian Standard Code Of Practice Forplain And Reinforced Concrete.
[2] IS 1786 : Indian Standard Code Of Practice For High Strength Deformed Steel Bars And Wires For Concrete Reinforcement
[3] IS 2911 Part (1): Indian Standard Code Of Practice For Design And Construction Of Foundations (Concrete Piles)
[4] IS 2911 Part (II) : Indian Standard Code Of Practice For Design And Construction Of Pile Foundations (Timber Piles).
[5] IS 2911 Part (IV) : Indian Standard Code Of Practice For Design And Construction Of Pile Foundations (Load Test On Piles).
[6] Soil Mechanics and Foundation by B.C.Punmia, Ashok Kumar Jain and Arun Kumar Jain, Laxmi, publications Pvt.Ltd., New Delhi-16th Edition, 2005.
[7] Soil Mechanics and Foundation Engg. By K.R. Arora, Standard Publishers and Distributors, Delhi-5th Edition, 2010.
[8] Geotechnical Engineering by C.Venkataramaiah, New Age International (P) Limited Publishers, New Delhi- 3rd Edition, 2006.
[9] VESI& A. S., "Bearing Capacity of Shallow Foundations." Handbook of Foundation Engineering, Winterkorn, H., and Fang, H. Y., eds., Van Nostrand, New York (1974) pp. 121-47.
[10] PERLOFF, W. H., "Pressure Distribution and Settlement." Handbook of Foundation Engineering, edited by H. Winterkorn and H. Y. Fang, Van Nostrand, New York (1974) pp. 148-96.